A Directory of African Wetlands

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A DIRECTORY OF AFRICAN WETLANDS

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IUCN — THE WORLD CONSERVATION UNION

Founded in 1948, IUCN — The World Conservation Union — is a membership organisation comprising governments, non-governmental organisations (NGOs), research institutions and conservation agencies in over 100 countries. The Union's mission is to provide leadership and to promote a common approach for the world conservation movement in order to safeguard the integrity and diversity of the natural world, and to ensure that human use of natural resources is appropriate, sustainable and equitable.

Several thousand scientists and experts from all continents form part of a network supporting the work of its Commissions: threatened species, protected areas, ecology, environmental strategy and planning, environmental law, and education and communication. Its thematic programmes include forest conservation, wetlands, marine ecosystems, plants, the Sahel, Antarctica, population and natural resources, and Eastern Europe. The Union's work is also supported by 12 regional and country offices located principally in developing countries.

UNEP — THE UNITED NATIONS ENVIRONMENT PROGRAMME

Established as a result of the UN conference on the Human Environment in Stockholm 1972, UNEP is a unique body within the United Nations. It serves as a catalyst and coordinator — monitoring the global ecological situation and coordinating the environment activities of the UN agencies working to win the cooperation and participation of governments, the international scientific and professional communities and non-governmental organisations.

UNEP is the first and only UN agency to be based in a developing country, with its headquarters in Nairobi (Kenya). It also has regional or liason offices in Bangkok, Geneva, New York, Mexico City, Nairobi, Manama (Bahrain), Washington DC and Cairo. Covering a wide range of environmental problems, UNEP concentrates its activities on issues such as atmosphere and climate change, depletion of the ozone layer, fresh water resources, oceans and coastal areas, deforestation and desertification, biological diversity, biotechnology, health and chemical safety.

WCMC — THE WORLD CONSERVATION MONITORING CENTRE

The World Conservation Monitoring Centre (WCMC) is a joint venture between the three partners who developed the World Conservation Strategy: IUCN — The World Conservation Union, UNEP — United Nations Environment Programme, and WWF — World Wide Fund For Nature (formerly World Wildlife Fund). Its mission is to support conservation and sustainable development through the provision of information on the world's biological diversity.

WCMC has developed a global overview database that includes threatened plant and animal species, habitats of conservation concern, critical sites, protected areas of the world, and the utilisation and trade in wildlife species and products. Drawing on this database, WCMC provides an information service to the conservation and development communities, governments and United Nations agencies, scientific institutions, the business and commercial sector, and the media. WCMC produces a wide variety of specialist outputs and reports based on analyses of its data.

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A DIRECTORY OF AFRICAN WETLANDS

R. H. Hughes and J. S. Hughes

With a chapter on Madagascar by G. Bernacsek

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UNEP — The United Nations Environment Programme
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FOREWORD

Africa is an arid continent with the lowest river flow per unit area of any continental landmass. Most countries outside of the rainforest zone receive little rain for most of the year. Over large areas the soils are at best of low fertility and vulnerable to erosion. In launching Zimbabwe's *National Conservation Strategy* President R.G. Mugabe drew attention to these issues, noting "More than three million hectares of soil have been classified as severely eroded, resulting in the siltation of our major river systems, particularly the Save and Limpopo catchments. Permanent surface water supplies have disappeared and the levels of underground water tables have been measurably lowered... The time for complacency is long past." Under these conditions wetlands, with their abundant supply of fresh water, generally fertile soils, and high productivity, are therefore of special significance. They play a central role in the economy of all river basins and coastal zones.

Yet wetlands are also amongst the continent's most threatened ecosystems. As water resources come under increasing pressure from urban and industrial use, and the demand for agricultural land has increased, many floodplains and tidal wetlands have been reduced in size and their productivity declined. At the same time demographic change and drought have placed increased pressure upon rain-fed rangelands and agricultural land and, as a result, many floodplains and marshes once used only as dry season refugia have been subject to year round grazing and permanent cultivation.

As these pressures have grown so has wider awareness of the importance of Africa's wetlands and understanding of the consequences of wetland loss. In response national governments with the support of UNEP, IUCN, WWF, FAO, UNESCO, IWRB, ICBP, and other international partners have taken a rising interest in the conservation needs of these valuable ecosystems. Today 15 African countries are Contracting Parties to the Ramsar Convention, more than in tropical Asia and Latin America combined.

But as wetland conservation efforts have increased, so has awareness of the urgent need for better information on the distribution and values of these eco-systems. In response, the Directory of African Wetlands provides governments, NGOs, and international partners with a major tool to facilitate improved management of the wetlands of the region. In particular, by reviewing the wetland resources on the basis of hydrological units rather than focusing only upon sites of international importance, the Directory will serve both to identify sites for listing under the Ramsar Convention, and as a source book on wetlands of the continent which can guide governments and the development community in identifying both the potential for multiple-use and the need for care in utilising these ecosystems.

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The Directory will complement other recent efforts to bring together information on wetlands of the continent. In particular *African Wetlands and Shallow Water Bodies* which was published by ORSTOM in 1987, provides a more detailed insight into the limnology of some of the most important of Africa's wetlands. Similarly the Wetlands Directory published by the International Council for Game and Wildlife Conservation (CIC) in 1989 provides a more detailed review of wetlands which may be of importance for migratory waterbirds.

Production of the Directory is however but part of a continuing process to address the conservation needs of Africa's wetlands. It will serve as a major source of information for politicians, planners and managers, and serve to develop greater awareness of the importance of these resources. However, it needs to be followed by further national and international support for wetlands conservation in Africa. Only in this way can these resources be maintained and managed sustainably for the benefit of present and future generations.

Liberty Mhlanga
Vice-President - IUCN

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AUTHORS' PREFACE

A directory of Afrotropical wetlands of international importance was conceived in 1983. A draft manuscript, prepared by Erik Carp, was submitted for comment, to government and non-governmental bodies in many African countries in 1985. As a consequence of the comments received it was deemed necessary to change the format of the directory, and to broaden its scope to include all wetlands and water bodies in all forty seven African countries of continental Africa. In undertaking the preparation of this directory we have tried to provide a comprehensive inventory of all wetland systems, but it seems inevitable that a number of minor wetlands and water bodies will have been overlooked. Hitherto, a number of wetlands have been described in English only, or in French only, but this directory, published in both languages, provides an account of all African wetlands in each language.

We have researched the information for this directory very largely from maps, survey reports and the literature, but in an attempt to be as accurate and as up to date as possible we solicited information from individuals and authorities in every African country. However, the response to our requests for information was disappointingly uneven and in consequence we also sought information from individuals and organisations outside Africa. We gratefully acknowledge the help given to us Mr T. Alexander (Sir Murdoch MacDonald & Partners, Cambridge), Miss K. Amies (Map Room, University of Cambridge), Dr N.Arnold (British Museum, Natural History), Mr G. Begg (Chris Mulder Associates, Durban), Dr R. Bell (Kasungu National Park, Malawi), Dr G. Bernacsek (Fishery Biologist, Rome), Dr H. Berry (Etosha Ecological Institute, Okaukuejo, Namibia), Dr M. Burgis (City of London Polytechnic), Dr S. Cairncross (London School of Hygiene & Tropical Medicine), Dr P. Campredon (Banc d'Arguin National Park, Mauritania), Mr B. Clarke (British Museum, Natural History), Mr N. Cole (UNEC, Adis Abeba, Ethiopia), Dr P. Denny (Queen Mary College, University of London), Dr W. Dominey (Hawaiian Evolutionary Biology Program, Honolulu, Hawaii), Mr T. Evans (Sir Murdoch MacDonald & Partners, Cambridge), Mr R. Fairclough (Map Room, University of Cambridge), Mrs E. Forrest (Geographical Consultant, Cardigan, U.K.), Dr J. Gartlan (University of Wisconsin), Dr F. Getliffe Norris (University of Natal), Prof. J. Grindley (University of Cape Town), Ms M. Holness (ANGOP, London), Dr A. Jacob Guillarmod (Rhodes University, South Africa), Dr D. Lewis (Fisheries Dept., Monkey Bay, Malawi), Prof. J. Llandells (Adis Abeba University), Mr D. Mbuvi (Wildlife Conservation & Management, Nairobi, Kenya), Dr A. Montfort (Kigali, Rwanda), Dr N. Morgan (Sauxlures sur Moselotte, France), Dr P. Mundy (Dept. of National Parks and Wildlife Management, Zimbabwe), Dr F. Muthuri (University of Nairobi), Mr I. Ndunguru (College of African Wildlife Management, Mweka, Tanzania), Mr A. Peal (Forestry Development Authority,

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We have interpreted the term 'wetland' to include all areas of land that are permanently or periodically inundated, i.e. lakes, ponds, swamps, marshes, bogs, riverine and lacustrine floodplains, pans and wadis, coastal saltmarshes and mangrove swamps. Artificial impoundments are also included. The wetlands are described, country by country, within five major geographic regions; North West Africa, North East Africa, West Africa, Central Africa and Southern Africa. An introduction, indicating the climate, relief and principal drainage lines of each region, precedes the national accounts, which also begin with an introduction and a national map. Notes on the flora and fauna of the wetlands are included in the regional introduction where this is appropriate, but where marked variations occur within a region, e.g. Region 4, accounts of these things are given in the introduction to each country.

In giving accounts of individual wetlands we have not employed an identical format throughout the directory, since not all systems lend themselves equally well to precisely the same descriptive techniques. Further, limited space has precluded the inclusion of detailed accounts. The accounts of major wetlands are prefaced with geographic details; location, area, altitude and nearest towns. These are followed by brief descriptions, together with notes on human impact and exploitation, the current conservation status of the system, and special features of the flora and fauna if these merit separate mention. We have dealt with such things as geomorphology, hydrology and water quality, only where this is appropriate, and where reliable information is available.

We have treated other wetlands, or wetland complexes, entirely under a general heading because the literature dealing with them is so scant. Moreover, many accounts of wetlands deal only with the associated avifauna, and it has therefore proved impossible to provide similar information for all sites. However, to omit mention of small or poorly investigated sites would be to preclude the emergence

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of a comprehensive picture of the wetland situation in a country or a major physiographic region. Thus we have identified these small wetlands and given their coordinates, if nothing else. It has been out intention to produce a geographic overview of wetlands and water bodies, which may be useful in trying to understand biogeographic patterns, or the current status of a particular wetland species, and we hope that we shall have highlighted those systems that require further investigation. We have not attempted to give the definitive account of any wetland. However, more detailed accounts of some selected and better known wetlands are available in the 'Directory of African Wetlands and Shallow Water Bodies', Vol.1, edited by M.J. Burgis and J.J. Symoens, to be published in 1987 by ORSTOM, Paris.

When describing a major wetland we have given its location within extreme co-ordinates, i.e. the maximum extent of the wetland at high water. Since the perimeter of a wetland is never regular, all land within the co-ordinates is not necessarily wet. For small wetlands we have given only the co-ordinates for the centre of the wetland. In a few cases we have omitted the co-ordinates of some very minor wetlands at river mouths where the rivers are easy to locate. We have also tried to make the wetlands easy to locate by citing 'nearest towns' and have given the distance and direction of each town from the wetland concerned. However, in this context, the towns we have named are not necessarily the nearest, but the nearest major centres that will be certain to appear on almost any map.

The areas and dimensions given for individual wetlands and water bodies are ones we have calculated ourselves from the latest maps available, or in some cases, from satellite images. We have been concerned that the areas quoted for certain systems by different authorities are at wide variance with each other. Where authors have calculated areas significantly different from ours we have mentioned this and given a reference to the other author's work. We have expressed the areas of countries and drainage basins in square kilometres and the areas of wetlands in hectares.

We have also been concerned that certain named wetlands are shown at different locations on different maps, and in these cases we have preferred the locations shown on the most recent maps, or maps prepared from aerial photography. In carrying out the research for this directory it became apparent that some wetlands and water bodies have ceased to exist due to land reclamation, and consequently, although they still appear on some maps, we have omitted them. Other wetlands or water bodies which are marked on many modern maps do not exist, and have never existed. For example, Lake Bui, behind the Bui Dam, is marked on almost every map of Ghana published since the 1970s, yet it does not exist. An impoundment of the Black Volta River at Bui was projected in the early 1960s, but work on the Bui Dam has not yet (1987) commenced.

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We have not been able to provide detailed maps of each country, or of individual wetlands, and have written the directory on the assumption that readers will use it in conjunction with a good map or atlas. The maps we have provided with each national account are intended to permit only the approximate location of the wetlands in that country, and not all places mentioned in the text are marked on our maps.

The English spelling of place names in Africa, which is generally based upon the phonetic interpretation of the name as pronounced by native speakers of the area concerned, varies widely from source to source. We do not accept that in these cases there are correct English spellings and where conflicts arise we have usually adopted the spellings used in the 1985 edition of the Times Atlas.

We have not concerned ourselves with trying to decide which wetlands are of 'international importance', a matter presently excercising many ornithologists. All wetlands, large and small, are of some importance, and their importance varies depending upon the criteria applied. Collectively, small wetlands, like the 'dambos' of Zambia, are of enormous ecological consequence. To destroy one is of little import, but to whittle down the total wetland area provided by 'dambos' might prove disastrous in more than one context. To take the attitude that each individual site is unimportant, because it is small, might well lead to the attitude that 'dambos' *per se* are unimportant and do not therefore merit conservation.

We have not attempted to classify wetlands according to an artificial system, as has been customary with many authors. Whichever system is employed, every gradation between one class of wetland and the next becomes apparent when considering the large number of systems on the African continent. Short descriptions are therefore deemed more useful than classification codes.

We have not given authorities for every fact quoted, since this would have led to the compilation of a voluminous bibliography, specifically precluded by our brief. We have tried, wherever possible, to give references to sources which give 'overviews' or provide introductions to the literature.

R.H.Hughes
J.S.Hughes

April 1987

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REGION 1

NORTH WEST AFRICA

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Introduction

The region covers more than 5 896 000 km^2 and lies in major part, north of the Tropic of Cancer. It spans 42°18' of longitude and 22°35' of latitude, extending approximately 4540 km from west to east, between a headland on the Mauritanian coast (17°09'W) and a point on the Gulf of Salm (25°09'E) where Libya and Egypt meet, and 2480 km from north to south between the Senegal River (14°46'N) and Cape Blanc (37°20'N) on the Mediterranean Sea. Very large areas are uninhabited, and the mean population density over much of the interior is less than 1 person/km^2.

All constituent countries have extensive coastlines. Mauritania and Western Sahara adjoin the Atlantic Ocean, Morocco has both Atlantic and Mediterranean coasts, while Algeria, Tunisia and Libya border the south central Mediterranean Sea. The coastal plain is very wide in Senegal where the 100 m contour is generally more than 100 km inland and the 200 m contour up to 400 km inland, but it narrows in Western Sahara. Here the 100 m contour approaches to within 10 km of the coast in places and the 200 km contour to within 75 km. From Western Sahara, in passing northeast, the coast is locally of very high relief. The Anti-Atlas Range reaches the Atlantic Ocean south of Agadir (30°30'N/9°40'W) while the High Atlas reaches it to the north of this town. Thereafter a narrow coastal lowland is continuous from Essaouira (31°30'N/9°48'W) to the Mediterranean Sea, but along the Mediterranean coast between Tanger (35°48'N/5°50'W) and Tunis (36°50'N/10°13'E), where the Atlas Mountains lie parallel to the coast, the lowland plain is periodically interrupted by hills and rocky headlands. A broad coastal plain is once again manifest around the Gulf of Sirte, the head of which leads into a huge coastal basin lying below the 100 m contour. This, in the far east of the region, dips below sea level and then leads into the Qattara Depression (133 m below sea level) of Egypt.

The southern beaches, of Mauritania, Western Sahara and southern Morocco are sandy and influenced by a strong longshore drift. The Canary Current which flows southwestwards off the coasts of Morocco and Western Sahara is cold, discouraging the growth of corals and mangroves.

The interior of the region lies mostly between 500 and 1000 m asl with high points being reached in the A'Haggar (Hoggar) Massif of southern Algeria and in the Atlas Mountains. In the A'Haggar, Mt. Tahat (23°18'N/5°31'E) rises to an altitude of 2918 m asl and Mt. Ser Kaut (23°32'N/6°47'E) to 2906 m. However, the most lofty

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peaks are those of the complex of the Atlas Mountains, which reach 4165 m asl at Jbel Toubkal (31°03'N/7°55'W) and 4071 m asl at Irhil M'Goun (30°30'N/6°26'W) in Morocco. The Rif Atlas extends eastwards from Tanger to the Molouya River, on the far side of which it continues into Tunisia as the Tell Atlas. In places another distinct range, the Maritime Atlas, occurs between the Tell Atlas and the sea. The High Atlas extends from Agadir, ENE through Morocco to Algeria where it is sometimes called the Saharan Atlas. In Morocco the Middle Atlas diverges from the High Atlas, in a northeasterly direction, while the Anti-Atlas diverges WSW. This latter range is separated from the main range by the alluvial Sous Plain towards the coast and is joined to it by the volcanic formations of the Djebel Siroua (3304 m) in the east. The whole Atlas Complex is aligned roughly parallel to the coast for 2250 km from southern Morocco to western Tunisia.

Drainage from the Atlas complex is either to the coast or to the interior. Those rivers which reach the sea in southern Morocco, from outliers of the Atlas Mountains, are intermittent, but all the major streams north of Tan Tan (28°30'N/11°02'W), where the Oued Dra reaches the sea, are perennial, though extremely seasonal in their discharge rates. All the Atlas rivers may be torrential in the winter after rain, while in the summer many are reduced to the merest trickles. For example, flow in the Moulouya River, which enters the Mediterraneran Sea (35°08'N/2°22'W) east of Mellila, regularly peaks at over 991 m3/sec in the winter but falls to less than 5 m3/sec in the summer.

South of the Atlas Mountains numerous intermittent streams discharge into salt pans or disappear under the sands of the Erg Iguidi and the Grand Erg Occidental. The largest watercourse draining to the interior, the Oued Saoura, is perennial in its headwaters above Meridja (31°30'N/2°58'W), and below this place traverses a series of wadis and pans for 700 km, before terminating in vast pans in the desert south of Reggane (26°42'N/0°13'E). Water flows 500-600 km southwards in this watercourse every year, and it is in con- sequence one of the most important trans-Saharan caravan routes.

Drainage from the A'Haggar Massif is radial, with numerous wadis leading out into the desert. Most of these contain areas of moist sand, under which there is often subterranean water, but there is seldom any surface flow. The most spectacular wadis are on the south side of the massif, leading from the highest peaks, out of the region into Niger. Others lead southwestwards towards Mali. Yet others lead northwest to the great Tidikelt Depression (14 300 km^2) in southern Algeria, on the floor of which are huge salt pans known as the Sebkra Mekerrhane and Sebkra Azz el Matti.

There is ample evidence to indicate that the present extreme aridity of the Sahara has developed comparatively recently. The last pluvial phase ended some 5000-8000 years ago, prior to which the central Sahara was well watered and populated. Large lakes existed there and rivers flowed freely. Rock paintings and fossils tell of the widespread occurrence of the genus *Hippopotamus*, and harpoons and the skeletons of fish are common in some central regions. For further information on this subject see Monod (1963), Faure (1967, 1969), Hugot (1974) and Beadle (1981).

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Drainage of southern Mauritania is to the Senegal River which forms both the southern national border and the boundary of this region. However, drainage of central and northern Mauritania is dictated by a parallel series of sand dunes oriented NE-SW which reach from the interior to the sea. The inter-dune valleys carry feeble intermittent streams. These seldom flow over their full lengths at any one time, and most do not enter the sea directly but terminate in coastal marshes behind the dunes at the back of the sandy sea beaches.

Climate

This region is part of the largest arid area in the world. The interior, where it is not mountainous, is dominated by the stone and sand deserts of the Sahara, together with many large dry saline areas. Mean annual rainfall over 90% of the region is less than 100 mm. High pressure prevails over the interior during the northern winter at which time winds blow towards the southwest and northeast off the desert. They are hot, dry and dusty, but a stream of humid westerly air from the Atlantic penetrates along the northern coasts at this time, and brings rain to the coastal fringe. The highest falls are recorded in the Atlas Mountains, where very locally they may amount to 2000 mm/yr, but generally they are far less than this. The coastal strip receives between 100 and 1000 mm/yr.

Mean annual rainfall is 350 mm over the Senegal River Delta, but decreases progressively in passing northwards up the Mauritanian coast. At Tan Tan (28°30'N/11°02'W) in southern Morocco it is 97 mm, but from here on it begins to increase again. At first, what little rain there is, is received fairly evenly throughout the year, but as the Mediterranean is approached, the winter months become more distinctly wet and the summer months more distinctly dry. Proceeding up and around the coast from Tan Tan, Agadir (30°30'N/9°40'W) receives 224 mm, Safi (32°18'N/9°20'W) 327 mm, Casablanca (33°39'N/7°35'W) 406 mm, Tanger (35°48'N/5°50'W) 887 mm, Alger (36°50'N/3°00'E) 762 mm, Cape Bougaroun (37°01'N/6°30'E) 1038 mm, Bizerte (37°18'N/9°52'E) 625 mm, Jerba Island (33°49'N/10°52'E) 207 mm, and Tarabulus (32°54'N/13°11'E) 371 mm. At Tarabulus (Tripoli) mean monthly falls of 100 and 90 mm are recorded in December and January respectively, but July and August are rainless.

Inland, at an altitude of 470 m asl on the northwestern slopes of the High Atlas, Marrakech (31°38'N/8°00'W) has a mean annual rainfall of 253 mm. Here, some rain falls every month, but in no month does the mean exceed 50 mm. Precipitation is however, greatest in November and March and lowest in July. At greater altitude (830 m) and farther north, Khenifra (23°00'N/5°40'W) receives 627 mm of rain/yr and no month is totally rainless. By contrast, the southeastern side of the mountains is in a rainshadow and falls are much lower. Here, at 1117 m, Ouarzazate (30°57'N/6°50'W) has a mean annual receipt of 107 mm, and Midelt at 1501 m (32°41'N/4°43'W) receives only 229 mm/yr. Farther east, and still in the rainshadow, at an altitude of 767 m asl, Laghouat (33°49'N/2°55'E) has a mean annual rainfall of 167 mm.

During the northern summer the Azores anticyclone produces a northerly airstream over almost the entire North African region, but although this crosses the Mediterranean, it is a dry stream and brings virtually no rain. These northerly winds cross the Tropic of Cancer and penetrate southwards to the intertropical convergence zone which reaches a northerly limit of about 22°N in July.

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Potential evaporation is extremely high throughout the region. The dry winds from the interior, which are known as chergui when they reach the northern coasts, may raise daytime temperatures in the Atlas Mountains to 40°C. Temperature regimes are less extreme at the coast than in the mountains and desert, where frosts may occur at night and diurnal fluctuations of 45°C are not uncommon. Absolute maxima in excess of 50°C have been recorded at several interior stations. The High Atlas is snowcapped in the winter, above 1980 m, but the snow does not usually persist throughout the year.

Wetlands

Mangroves reach their northern limit on the West African coast north of Tidra Island in Mauritania (19°40'N/16°20'W). This is due both to the influence of the cold Canary Current which becomes manifest north of Nouadhibou (20°54'N/17°01'W), and to the lack of coastal alluvium occasioned by the great aridity of the hinterland. Mangroves do not grow where the inshore waters are cold throughout the year, and they are never well developed in the absence of abundant alluvium. Salt-marsh vegetation occurs behind the mangroves in Mauritania, and thereafter has localised distribution up the Atlantic coast of the region, and is well developed on the Mediterranean coasts, especially in Tunisia and Libya.

Brackish herb swamps and marshes are well developed behind the barrier beaches all the way northwards from the Senegal River Delta to Tarfaya (27°58'N/12°55'W) in southern Morocco. Many rivers draining the Atlas Mountains overflow their banks on the coastal plain during the winter, creating wetlands. The great plain of Rharb, at the foot of the Rif Mountains between Tanger and Khenitra, has been built from alluvium deposited by floods of the Oued Sebou. Other floodplains occur on the Sous and Tensift Rivers. There are numerous natural lakes and some impoundments in the Moroccan Atlas, and in Algeria and Tunisia, the extensive inland salt-marshes of the chotts.

In the Sahara strips of sandy soil along the thalwegs of some watercourses may remain moist for considerable periods after rain and there may be supplies of subterranean water. Such places support perennial vegetation. The river or stream which flows in such a water course is known as an oued, but the watercourse *per se* may also be referred to as an oued in the western Sahara, or a wadi in the eastern Sahara. Gueltas are semi-permanent pools which form on watercourses in canyons in massifs like the A'Haggar and Tibesti, and on the edges of escarpments like the Adrar. Springs occur at faults on the walls and floors of such gorges, or sometimes at the feet of dunes which have intruded into them. Any site of permanent water in the desert can be described as an oasis. Some oases, deriving their waters from subterranean aquifers, may be situated several hundreds of kilometres from their catchments.

Vegetation

The native forests of Mediterranean North Africa have largely been destroyed, but vestiges of them persist in the mountains. Elsewhere scrub prevails in uncultivated parts of the coastal strip. On the southern slopes of the Atlas Mountains, montane vegetation gives way sequentially to steppe, xerophytic scrub and finally to desert. The several types of wetland vegetation are rather uniform across the region and each is described here,

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although complementary notes are given in the national accounts where the situation merits it. Some of the inland sites, wadis, chotts and oases have plants with maritime affinities, or support species which also grow in coastal salt-marshes, and presumably these, like the inland fauna with marine affinities, are relict populations which have survived from the last great marine transgression.

Wetland Vegetation

Within the region, mangroves are confined to Mauritania and are dominated by *Avicennia africana*. Both *Conocarpus erectus* and *Laguncularia racemosa* occur in the region, but *Rhizophora* species are absent from the coast north of the Senegal River Delta. In most places, salt-marsh vegetation backs the mangrove, and *Fimbristylis obtusifolia, Paspalum distichum (= P. vaginatum), Philoxerus vermicularis, Sesuvium portulacastrum* and *Sporobolus virginicus* are often found in these places.

There is little tidal amplitude on the Mediterranean Coast of North Africa. Maximum ranges approach 90 cm on the Tunisian coast, while normal ranges are seldom more than 20 cm. Thus tidal salt-marshes are not extensive. However, herbaceous halophytic vegetation is well developed in the region, but principally on non-tidal coastal plains and around pans in the interior. In the east of the region, narrow tidal salt-marshes often grade inland into salt deserts.

On wide sandy Mediterranean coasts the pioneer community is dominated by *Halocnemon strobilaceum*. This species collects sand and tends to form hummocks, and is usually joined by species such as *Bassia muricata, Cutandra memphitica* and *Traganum nudatum*. This community may be succeeded inland by some or all of *Limoniastrum guyonianum, Nitraria retusa, Suaeda vermiculata* and *Zygophyllum album*. Farther inland, and out of tidal influence, yet still on moist saline soils, the pioneer is usually a species of *Arthrocnemum*, either *glaucum* or *macrostachyum*. On the Algerian coasts, which are often of high relief, salt-marshes are less extensive, and here *Salicornia arabica* and *S. europaea* are usually the pioneers. They are succeeded by, among other species, *Limonium sebkarum* and *L. sinuatum*, with *L. spathulatum* becoming more important towards the east. On the landward boundaries of the salt-marshes, adjacent to non-tidal salt flats, *Sarcocornia fruticosa* often becomes dominant, or sometimes *S. perennis*, with *Centaurium spicatum* as principal associate in zones subject to inundation, and *Monerma cylindrica* in unflooded zones. At the mouths of perennial rivers and streams the aforementioned species give way to swards of *Spartina maritima* containing *Cyperus aculeata, Puccinellia distans* and *P. palustris*. *Ruppia spiralis* is common in estuaries, penetrating to where salinity falls as low as 10‰. *Cymodocea* sp., *Ruppia maritima* and *Zostera noltii* are common on submerged banks in lagoons.

Other important species on the North African coasts are *Halopeplis amplexicaulis*, which becomes dominant on waterlogged soils subject only to minimal accretion, and *Juncus acutus*, which occurs on saline soils of the landward fringes, if they are regularly flushed by soil water. The latter species is frequently associated with *Aeluropus littoralis* and *Inula crithmoides*. Where the landward transitions of the salt-marshes are not to salt deserts, and in consequence the soil water is only brackish, and where the soil is sandy, bushes of *Tamarix africana* are frequently in evidence.

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Marshy depressions in the Mediterranean coastal lowlands were once forested, and in them isolated trees or clumps of trees may still be encountered. *Fraxinus angustifolia, Laurus nobilis, Populus alba, Salix alba, Tamarix* spp. and *Ulmus campestris* are the most widespread species in this situation. However, most marshy depressions are now often covered by herbs. Many are covered by an almost monospecific sward of *Juncus acutus*, but some have a more heterogeneous flora, with bushes or small trees of *Laurus nobilis* and *Tamarix* spp. on the margins, and elsewhere a cover of *Juncus acutus, J. maritimus, Plantago coronopus, Scirpus holoschoenus, Spergularia maritima* and *Statice* spp.

Ponds and lakes, on the coastal strip are often fringed by *Phragmites australis, Scirpus lacustris* and *Typha capensis (= T.latifolia)*, with *Ceratophyllum demersum*, and *Potamogeton* spp. dominant in deep water. Some areas behind the beaches, where the free discharge of water to the sea is impeded by dunes, also support extensive reedbeds. In parts of Algeria, small stands of *Alnus glutinosa, Juncus* spp., *Scirpus holoschoenus* and *S. littoralis* are also common in these latter places, and on sandy soils the reedbeds may be backed by thickets of *Tamarix* spp. *Phragmites australis* and *Typha capensis* also cover substantial areas on the margins of lakes in the mountains, up to altitudes of about 1500 m asl.

The chotts which lie along the northern border of the Sahara, in the Sahara/Mediterranean transition zone, are large salt flats. Some are flooded every winter, others seldom carry surface water. Some are extremely saline and on these the dominant plant is *Halocnemum strobilaceum*, often providing 50-70% cover. The largest and least saline chotts are covered by *Salsola sieberi* and *Zygophyllum cornutum* with variable proportions of *Limoniastrum guyonianum, Limonium pruinosum, Nitraria retusa, Salsola tetragona* and *Suaeda mollis*. This vegetation provides 30-60% cover. In some more southerly situations, e.g. in some wadis, saline soils carry *Traganum nudatum* and *Zygophyllum album*. The salt pans of the central and southern parts of the Sahara are largely unvegetated and in any case cannot be considered as wetlands.

Montane bog communities may be dominated by *Sphagnum subsecundum*, but usually this occurs in mosaics with other bog communities. These occur on permanently or semi-permanently waterlogged soils and contain species such as *Anagallis crassipes, Asphodelus microcarpus, Eleocharis multicaulis, Erica scoparia, Hypericum afrum, Isoetes hystrix, Montia fontana* and *Phragmites australis*.

In the desert, *Acacia nilotica, A. tortilis, Ficus sycomorus, Hyphaene thebaica* and *Tamarix senegalensis* grow around gueltas, and on wadi floors where the water table is sufficiently close to the surface. The trees may be arranged in two parallel lines on either side of the bed occupied by running water when the stream flows.

Along the Senegal River and its affluents in Mauritania, there is a broad seasonal floodplain dominated by grasses at the lowest levels. Here the annual grass *Oryza barthii* is the dominant species where inundation is deepest, with *Echinochloa pyramidalis* perhaps the species covering the greatest area, occupying places flooded to intermediate depths, say 1-2 m. *Oryza longistaminata* also occurs in this latter zone, while *Andropogon gayanus, Hyparrhenia rufa, Panicum* spp., *Paspalum orbiculare* and *Vetiveria nigritana* are common species on the fringes. Riparian and levée forests occur along the river, with *Acacia nilotica* the commonest species in sites subject to seasonal inundation,

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but with *Cola laurifolia, Cynometra vogellii* and *Diospyros elliotii* in permanently swampy sites. *Borassus aethiopum* and *Raphia sudanica* occur on the higher levées and the former also on the margins of the floodplain. *Phragmites mauritianus* and *Typha domingensis* fringe lakes and lagoons on the floodplain.

Wetland Fauna

Some of the inland sites are of special interest because they harbour invertebrates of marine affinity and their faunas are dealt with in the national accounts.

Fishes: The fish faunas of the coastal wetlands are typical of either the Mediterranean or the central western Atlantic Ocean, and are outside the scope of this account. Very few European fishes have penetrated the Maghreb or the Sahara. Of those that have, *Aphanius fasciatus* is found in hot springs and saline waters, *Barbus biscarensis* reaches the A'Haggar, *Gasterosteus aculeatus* occurs in coastal pools and streams, while *Salmo trutta* occurs in some rocky streams of the Algerian Atlas. *Tellia apoda* is isolated in some high Atlas ponds and there are several minnows (*Phoxinella* spp.), of Eurasian affinity, in the Mahgreb. Similarly, few tropical African fishes have penetrated the region, and those that have are are also dealt with at appropriate places in the text. No tropical species are found north of the Atlas Mountains.

Amphibians: The amphibian fauna is small. Two European species have been recorded from the A'Haggar Massif, *Bufo viridis* and *Rana esculenta*, and are found in the Mahgreb. *Bufo regularis* and *Prychadena mascariensis* have been recorded from eastern Chad. The occurrences of other amphibians is dealt with in the text.

Reptiles: Four species of turtles, all endangered, breed on the Atlantic beaches. *Caretta caretta* is found as far north as Menasra (34°36'N) in Morocco, but the other species, *Chelonia mydas, Dermochelys coriacea* and *Eretmochelys imbricata* have a more southerly occurrence and, within the region, principally frequent Mauritanian beaches. *Natrix anoscopus* is found in the Mahgreb, but otherwise snakes are comparatively rare in the wetlands.

Birds: Almost all the wetlands of the region provide important habitats for birds. Among the important species of the coastal zone, including the salt-marshes, estuaries, and brackish or freshwater lakes, are *Acrocephalus arundinaceus, A. melanopogon, A. paludicola, A. schoenobaenus, A. scirpaceus, Anas acuta, A. angustirostris, A. crecca, A. clypeata, A. fuligula, A. penelope, A. platyrhynchos, A. querquedula, A. strepera, Anser anser, Anthus pratensis, Ardea cinerea, A. purpurea, Ardeola ralloides, Athytha ferina, A. fuligula, A. nyroca, Burhinus oedicnemus* (E only), *Calandrella brachydactyla, Calidris alba, C. alpina, C. canuta, C. minuta, Charadrius alexandrinus, C. hiaticula, Chlidonias hybridus, C. leucopterus, C. niger, Ciconia nigra, Egretta alba, E. garzetta, Fulica atra, F. cristata, Gallinago gallinago, G. media* (E only), *Gelochilidion niloticus, Glareola pratincola, Grus grus, Haematopus ostralegus, Himantopus himantopus, Hirundo rustica, Hydroprogne tschegrava, Ixobrychus minutus, Larus andouinii, L. fuscus, L. genei, Limosa lapponica, L. limosa, Locustella luscinioides, Luscinia svecica, Lymnocryptes minimus* (E only), *Merops apiaster, Moticilla alba, M. flava, Muscicapa striata, Numenius arquata, N. phaeopus, N. tenuirostris, Nycticorax nycticorax, Oxyura leucocephala, Phalacrocorax carbo, Philomachus pugnax, Phoenicopterus ruber, Pla-*

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talea leucorodia, Plegadis falcinellus, Pluvialis apricaria, P. squatarola, Podiceps cristatus, P. nigricollis, Porphyrio porphyrio, Porzana parva, P. porzana, P. pusilla, Recurvirostra avosetta, Riparia riparia, Sterna albifrons, S. sandvicensis, S. hirundo, Streptopelia turtur, Tachybaptus ruficollis, Tadorna ferruginea, T. tadorna, Tringa erythropus (E only), *T. glareola, T. nebularia, T. totanus* and *Vanellus vanellus.*

Birds of prey widely recorded in Mediterranean wetlands include *Buteo rufinus, Circus aeruginosus, C. macrourus* (E only), *C. pygargus* (E only), *Falco naumanni, Hieraaetus fasciatus* and *Pandion haliaeetus.* Two vultures, *Gyps fulvus* and *Neophron percnopterus* have been regularly recorded in Algerian and Tunisian coastal wetlands. Many of the species listed above, such as *Phoenicopterus ruber*, which thrive on shallow muddy salt flats, are found on the chotts, but some species, e.g. *Charadrius morinellus* and *Chlamydotis undulata* are more characteristic of the chotts and wet steppes than other wetlands.

Most of the species listed above also occur on inland lakes and marshes, some up to considerable altitudes. *Grus grus, Tadorna ferruginea* and several ducks are regularly reported on wetlands up to 1000 m asl. Others which are far more common in inland, on freshwater wetlands, include *Locustella naevia* and *Sturnus vulgaris.* In the far east of the region *Coracias garrulus* and *Jynx torquilla* are encountered on pans, oases and irrigated areas. Species which regularly collect in the Tanger Peninsula, en route to Europe, include *Accipiter nissus, Apus apus, A. melba, A. pallidus, Buteo buteo, Ciconia ciconia, C. nigra, Circaetus gallicus, Circus cyaneus, Falco columbarius, F. normanni, F. peregrinus, F. tinnunculus, Lanius senator, Merops apiaster* and *Upupo epops.*

Mammals: Large native mammals are virtually unknown in North African wetlands, except for *Panthera pardus*, which is still present in the Atlas Mountains where it has been recorded around lakes and along rivers, and *Sus scofer.* The latter species is widespread in the Mediterranean part of the region, extending into the Atlas Mountains, but it is hunted intensively near centres of population. *Cervus elaphus* was introduced to the Rif region of Morocco and has been recorded in reed swamps both there and farther east, while *Bubalus bubalis*, which is dependent upon swamps, was introduced to Tunisia in Roman times, but is no longer known in the feral state (although still present, semi-wild, in protected areas).

However, small mammals, especially rodents, are abundant in the wetlands, in numbers, if not in numbers of species. Apart from water rats, voles and mice, *Lutra lutra* is widely distributed across the Mediterranean part of the region, in the estuaries, lakes, reed swamps and rivers, ascending to 2500 m in the Atlas Mountains. Several small cats have been recorded in the wetlands. *Felis caracal* occurs in the Atlas Mountains and has been recorded in wetlands there, as well as on the chotts of the high plateaux. *Leptailurus serval* also occurs in Atlas wetlands. The so called swamp cat, *Felis chaus*, occurs in the wadis of the Tassili N'Ajjer and A'Haggar, and a desert cat, *Felis margarita*, has been recorded on the chotts and at several oases. *Felis lybica* (often now referred to *F. sylvestris*) is quite widespread in coastal wetlands from Morocco to Libya. Other carnivores widespread in the Mediterranean region include *Genetta genetta* and *Herpestes ichneumon*, while *Mustela putorius* occurs in the Rif region of Morocco. *Vulpes vulpes* is increasing in numbers throughout the Mediterranean coastal strip and frequently hunts on the fringes of

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reed swamps and along rivers, while *Canis aureus* has been recorded from the chotts. *Paraechinus aethiopicus* is widely distributed in the region and is known from the margins of the chotts. *Hystrix cristata* often frequents or lives in thickets along rivers, and *Macaca sylvana* is locally not uncommon in riverine woodland in the Atlas Mountains.

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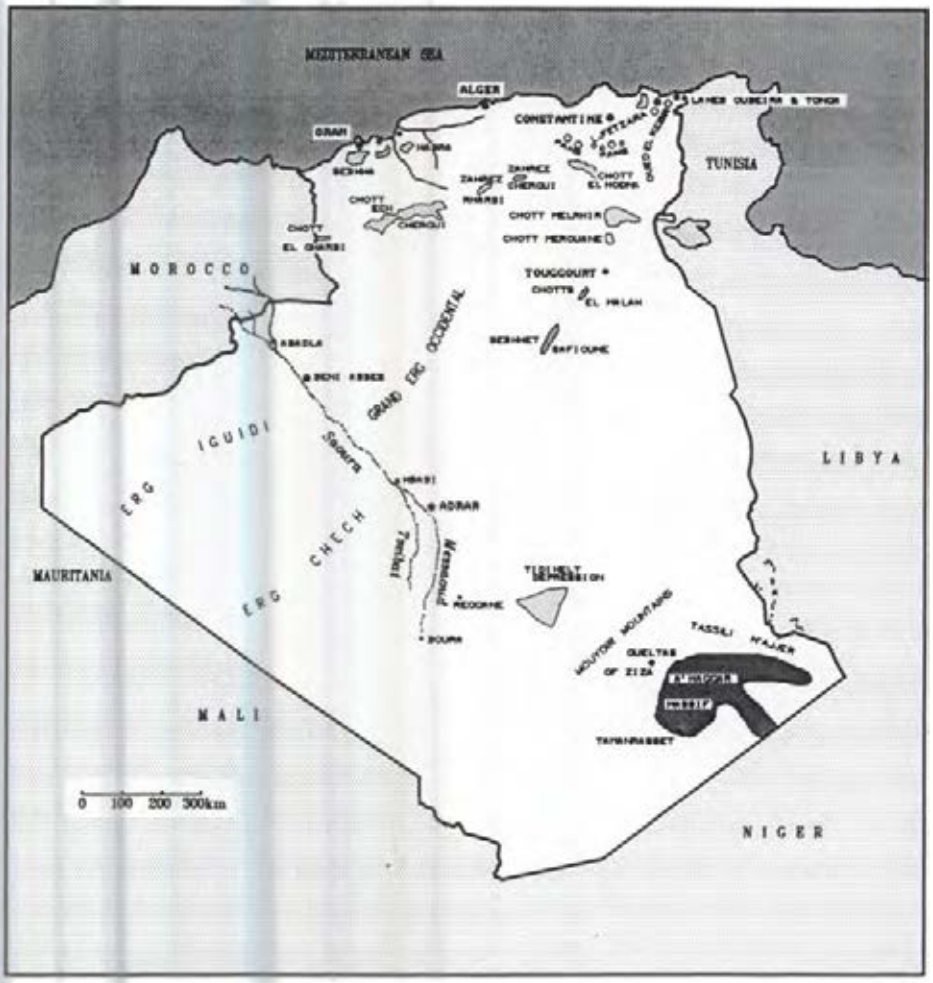

Map of Algeria

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1.1 ALGERIA

Introduction

With an area of 2 381 745 km^2 Algeria is the second largest country in Africa. It has a population of 20 500 000 (1983) and thus a mean population density of 8.6 persons/km^2. It is bounded by Mali and Niger in the south, by Libya and Tunisia in the east, by the Mediterranean Sea in the north, and by Morocco, Western Sahara and Mauritania in the west. It extends approximately 1985 km from north to south, between latitudes 18°57' and 37°08'N, and 2080 km from east to west between longitudes 12°00'E and 8°39'W, and has a coastline of 1355 km.

The Mediterranean fringe of Algeria is mountainous. The coastal strip is narrow, and only in the vicinity of Oran (35°43'N/0°43'W) are there significant lowland area less than 100 m above sea level. These comprise two blocks, one just inland behind the heights of Oran, and the other close by at the head of the Bay of Arzew. Along the rest of the coast the Tell Atlas rises steeply and crosses the country from west to east. This range is separated from the Saharan Atlas which lies inland along the fringe of the desert, by the High Plateau. The plateau is really a great basin set between the parallel mountain ranges. It is 940 km long and extends into Algeria from Morocco (700 km in Algeria), attaining a width of 190 km and ending west of Biskra (34°50'N/5°41'E). Its floor is mostly close to 1000 m asl, but it rises to 1200-1400 m as it approaches the mountains, and descends into a number of depressions along its central axis. These get progessively deeper from west to east and provide vast wetland areas known generically as *chotts*. The floor of the westernmost, the Chott Ech Chergui, has a low point of 984 m, but is mostly over 993 m. The floor of the Zahrez Rharbi is lower, 827 m, while that of the Zahrez Chergui is 756 m, and that of the Chott el Hodna, at the eastern end of the plateau, is only 391 m asl. While the Chott Ech Chergui can be said to 'lie on the plateau', the middle two pans are contained in a SW-NE oriented depression in the middle of the plateau. Here parallel scarps, several hundred metres high, descend from the plateau to the floor of the trench in which the pans lie. The Chott el Hodna occupies the lowest part of a great bowl-shaped depression at the eastern end of the plateau.

The peaks of both the Tell and Saharan Atlas Ranges rise to between 1800 and 2000 m, with high points of 2321 m at Djebel Mahmel (35°21'N/6°15'E) in the Tell Atlas and 2187 m at Djbel Mzi (32°29'N/1°08'E) in the Saharan Atlas, but the highest points in the country are far to the south in the A'Haggar Massif in the Sahara Desert. Here Mt. Tahat rises to 2981 m (23°19'N/5°34'E), Mt. Asseksem rises to 2728 m (23°18'N/5°41'E), and several other peaks exceed 2300 m.

The interior of Algeria is desert. The southwestern extremity of Algeria is occupied by the very dry, stony Hamada du Draâ, a shelf of high land extending into the country from Morocco. The central southeastern flanks of the Saharan Atlas slope down for some 250 km to a central depression 200-500 m asl, which, like most major physiographical features in North West Africa, is oriented SW-NE. The depression is filled by sand desert, by the Erg Iguidi, which enters Algeria from Mauritania in the SW, by the Grand Erg Occidental in the centre, and by the Grand Erg Oriental in the east. Plateaux of higher land emerge above the sand desert in places, e.g. in the southwest the circular Mcherrah

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Aftout, which reaches 1200 m, separates the Erg Iguidi from the Erg Chech which stretches into central Algeria from northern Mali. The land rises again, south of the sand deserts, up to the stony Plateau of Tademait. From here one may proceed southwestwards, down into the Tidikelt Depression, less than 200 m asl, or southeastwards, up through various minor ranges to the long NW-SE ridge of the Tassili N'Ajjer. From there one may pass to the massifs of the Adrar (Mt. Afao - 2158 m) and A'Haggar, the latter reaching south to within 230 km of the border with Niger.

Drainage from the coastal ranges is by numerous short streams which flow directly to the Mediterranean Sea, or by others which discharge onto the High Plateau, where their flood waters accumulate in the chotts. Drainage from the Saharan Atlas is either northwards to the plateau or southeastwards into the desert. Along the southeastern flank many intermittent streams flow in parallel, often in very deep gullies or canyons, to the Ergs Iguidi and Occidental where they lose themselves under the sand. In the western central region some streams rise in the Moroccan Atlas, where rainfall is comparatively high, and some, e.g. the Oueds Rheris and Guir are perennial in their upper courses. These flow southeastwards into Algeria, and the Oued Saoura, the continuation of the Oued Guir system, carries water each year for distances of 500-700 km into the desert, terminating in a series of pans between Adrar (27°51'N/0°19'W) and Reggane (26°42'N/0°13'W). At the far eastern end of the Saharan Atlas range other intermittent watercourses drain eastwards to the great depression of the Chott Melrhir, part of which is below sea level. In the far west of Algeria, rainfall is so scant over the Hamada du Draâ that there are few fixed watercourses, and any run-off from occasional storms is dissipated by ephemeral streams.

Climate

During the northern summer the Azores anticyclone produces a northerly airstream over almost the entire North African region, but although this crosses the Mediterranean, it is a dry stream and brings virtually no rain. These dry winds blow right across Algeria to the Tropic of Cancer. High pressure prevails over the Sahara during the northern winter and winds then blow off the desert towards the southwest and northeast. They are hot, dry and dusty, but a stream of humid westerly air from the Atlantic penetrates along the northern coasts at this time, and brings rain to the coastal fringe. Consequently, northern Algeria has a Mediterranean type of climate with cool wet winters and hot dry summers.

Rainfall is reliable only along the Mediterranean fringe where falls of 600-1100 mm may be received at the coast, with a summer drought of 3-4 months. However, some coastal stations are in rain-shadows and are extremely arid, with mean annual falls of 150 mm or less. Generally, falls increase on the seaward slopes of the coastal mountains, but rainfall decreases quickly in moving inland across the High Plateau to the Saharan Atlas. South of this latter range rainfall is unreliable and most of the interior receives less than 100 mm/yr, with stations in the central south receiving less than 20 mm/yr. Stations in the desert may be completely rainless for several years on end.

Along the coast mean annual precipitation is 384 mm at Oran (35°43'N/0°43'W), increasing to 762 mm at Alger (36°42'N/3°08'E) and to 1038 mm at Cape Bougaroun (37°10'N/6°30'E). Some 60 km inland from Oran, at Mascara (35°20'N/0°09'E), 590 m up on the seaward slopes of the Tell Atlas, mean annual rainfall is 511 mm. At Le Kreider

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(34°06'N/0°02'E) on the shores of the Chott Ech Chergui on the High Plateau, it is 155 mm, while towards the eastern end, 1160 m asl, at Djelfa (34°30'N/3°20'E), it is 308 mm. Over the mountains on the fringe of the desert at Laghouat (33°50'N/2°59'E), at an altitude of 767 m asl, it is 167 mm. In the central desert Timimoun (29°15'N/0°14'E), 293 m asl, has a mean annual rainfall of 10 mm; Ouallene Bordj (24°37'N/1°13'E), at an altitude of 346 m asl receives 36 mm/yr, while Bordj Omar Driss (28°04'N/6°39'E) at 375 m, receives a mean total of 28 mm/yr.

Mean annual temperatures are 18.3°C at Alger and 18.0°C at Cape Bougaroun, falling to 17.0°C at Mascara, on the seaward side of the mountains, and to 17.3°C at Laghouat, on the landward side of the mountains. On the High Plateau at Djelfa the mean temperature is only 13.4°C. Mean temperatures in the desert increase southwards away from the Atlas Mountains, thus at both Timimoun and Bordj Omar Driss it is 23.9°C, but 27.7°C at Ouallene Bordj. The mean monthly temperature of the warmest month (July) is 34°C at Adrar, and that of the coolest month (January) 13°C, with absolute maxima and minima of above 50°C and below -4°C, having been recorded at this centre. Diurnal temperature ranges are greater in the mountains and in the desert than at the coast. Daily amplitudes of 35-40°C are not uncommon in the latter places. Absolute minima of -10°C are known from the Atlas Mountains, and -20°C has been recorded in the A'Haggar.

Wetlands

Some coastal wetlands exist in both the west and extreme east of Algeria. The northern rivers of the Atlas are all short, and subject to great seasonal variation in flow rates. Some may flood their banks locally but they support no wetlands of significance. Among the southern rivers, only the Oued Saoura is important. This carries water into the desert each year, producing a series of semi-permanent pools and patches of humid sand. The major wetlands are the chotts, vast shallow temporary lakes of saline character. There are numerous oases in the interior.

List of Wetlands Described

1. Coastal Wetlands
    (a) The Sebkha d'Oran
    (b) The Salines d'Arzew
    (c) Marshes of the Plain of Habra
    (d) Marshes of the Plain of Guerbes
    (e) Lake Fetzara
    (f) Floodplain of the Oued el Kebir
    (g) Melah Lagoon
    (h) Lake Oubeira
    (i) Lake Tonga
    (j) Garaet el Mekhada
2. The Oued Saoura

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3. The Chotts
    (a) Chott Ech Chergui
    (b) Zahrez Rharbi
    (c) Zahrez Chergui
    (d) Chott el Hodna
    (e) Chotts of the Sétif & Constantine Region
    (f) The Chott Melrhir & Merouane Complex
    (g) The Chotts of el Malah
    (h) Sebkhet Safioune
4. Oases
    (a) The Gueltas of Ziza
    (b) The Gueltas of the Tassili N'Ajjer
    (c) The Gueltas of the A'Haggar Massif
    (d) The Gueltas of the Mouydir Mountains & Tidikelt Depression
5. Artificial Impoundments
    (a) The Barrage of Cheffia
    (b) Lake Boughzoul

1. Coastal Wetlands

(A) THE SEBKHA D'ORAN

Location: 35°27'-35°37'N/0°34'-1°01'W
Area: 40 000 ha
Altitude: 90-102 m asl
Nearest Towns: Oran (15 km N); Mostaganem (68 km WNW)

General: This is a saline endorheic system. The principal basin, subject to fluctuating levels of inundation after winter rains, is shown on all reliable maps as 43 km long with a mean width of 8.6 km, giving it an area close to 40 000 ha, though various authors, e.g. Carp (1980) and Scott (1980) state that its area varies from 50 000-150 000 ha. The basin slopes from west to east, having an altitude of 102 m asl at the western end adjacent to the railway. Thus flooding is deepest at the eastern end and spreads westwards with heavy rains. The eastern end of the basin is just below 90 m asl.

Flora & Fauna: The shores and some affluent streams are fringed by *Phragmites australis*, with *Arthrocnemum glaucum*, *Juncus acutus*, *Scirpus* sp., and *Suaeda fruticosa* dominant on the seasonally inundated salt flats. The fauna is as described in the regional introduction. *Phoenicopterus ruber* and *Recurvirostra avosetta* have been recorded.

Human Impact & Utilisation: The area is a popular hunting area and hunting pressure on birds is high.

Conservation Status: Unprotected.

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(B) THE SALINES D'ARZEW

Location: 35°39'-35°46'N/0°15'-0°23'W
Area: c. 6500 ha
Altitude: near sea level
Nearest Towns: Arzew (15 km N); Oran (25 km WNW)

General: These comprise two saline marshy areas south of the coastal town of Arzew. The largest and most eastern marsh is 15 km long and 4 km wide, and contains a permanent lake. Both salinas are fed by small streams but derive much of their water from direct precipitation. Both have typical halophilic coastal floras and both are important habitats for birds.

Human Impact & Utilisation: Grazing occurs on the peripheral marshes and there is some hunting.

Conservation Status: Unprotected.

(C) MARSHES OF THE PLAIN OF HABRA

Location: 35°36'-35°46'N/0°02'-0°12'W
Area: 3000-12 000 ha variable
Altitude: 1-13 m asl
Nearest Towns: Mostaganem (30 km NNE); Oran (55 km WNW)

General: This is a marshland system on the Plain of Habra, immediately south of the coastal town of La Macta, and otherwise known as the Marais de la Macta. The system comprises three permanent marshes, with large areas of open water, and intervening areas subject to temporary inundation following winter rains. Water depths are never very great, and the area was subject to an unsuccessful drainage operation in the early 1960s, but it became re-flooded by the 1970s. The marshland extends almost to the sea from which it is cut off by dunes, and reaches an elevation of 13 m at its southern extremity. The seaward area is saline. The marshes and lakes are fed by direct precipitation and by a small stream which enters the southern end.

Flora & Fauna: Typical halophyte flora near the dunes, with *Sarcocornia fruticosa* and *Juncus acutus*, and with bushes of *Arthrocnemum glaucum* and *Tamarix gallica*. Fauna as described in the regional introduction. An important site for waterfowl.

Human Impact & Utilisation: No further attempts at drainage are in progress, but irrigation agriculture takes place on nearby land. Some cattle are grazed on the fringes and there is still some hunting.

Conservation Status: The semi-permanently flooded area has been proclaimed as a nature reserve.

(D) MARSHES OF THE PLAIN OF GUERBES

Location: 36°52'N/7°15'E
Area: 0-10 m
Altitude: c. 50 000 ha
Nearest Towns: Annaba (45 km E); Alger (372 km W)

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General: An extensive system of marshes is situated on the alluvial coastal plain of the Oued el Kebir. Coastal dunes impede the free drainage of the area and the marshes extend upstream from the mouth for over 30 km and at one point reach nearly 20 km in width. The plain is hemmed in by hills all round, but is open to the Mediterranean Sea at the northwest. During the winter, maximum water depths of 2 m are attained.

Flora & Fauna: The marshes comprise vast tracts of dense vegetation, brackish in the lower reaches, dominated upstream by *Phragmites australis* with much *Typha capensis* and several species of *Carex, Cladium, Juncus* and *Scirpus*. Some sizeable stands of *Alnus glutinosa*, rich in ferns, are subject to semi-permanent inundation, both along the river and in depressions. Lake Freitis is a shallow (4 m) lake along the Oued el Kebir. The area is an important wintering ground for *Anser anser, Gallinago gallinago* and *Vanellus vanellus* amongst other birds. Most of the small mammals recorded in North African Wetlands occur here; *Genetta genetta* is locally common, and *Mungos mungo widringtonii* has been recorded.

Human Impact & Utilisation: The area has been little disturbed and the interiors of the marshes are relatively inaccessible. There is very little hunting.

Conservation Status: Unprotected.

(E) LAKE FETZARA

General: This once great freshwater lake was drained, but remains a wintering site for many wildfowl and still appears on maps as a lake, for which reason it is included. It is situated some 20 km southwest of Annaba and 390 km east of Alger.

(F) FLOODPLAIN OF THE OUED EL KEBIR

Location: 36°45'-36°52'N/7°55'-8°13'E
Area: 8000-12 000 ha variable
Altitude: 0-3 m asl
Nearest Towns: Annaba (20 km NW); Alger (435 km W)

General: This wetland, sometimes referred to as the Garaet el Mkhada, comprises the coastal floodplain of the Oueds Bounamoussa, el Kebir (not to be confused with another river of the same name flowing to the sea on the Plain of Guerbes west of Annaba) and Mafrag, and their tributaries. Water backs up behind the coastal dune system, producing a large marshy area with several shallow lagoons in continuity with the river and one small isolated and permanent lake, the Lac des Oiseaux.

Hydrology & Water Quality: The total wetland area varies with the amount of winter rain, but the mean depth seldom exceeds 30 cm. Direct precipitation amounts to some 750 mm/yr, while evapotranspiration is closer to 1000 mm/yr. The marsh therefore depends upon the floodwaters of the affluent streams and annual variations in the area flooded can be quite dramatic. The waters are oligohaline and generally well oxygenated.

Flora & Fauna: Typical of the habitat and region. Emergent macrophytes cover more than 90% of the area, with *Juncus maritimus, Phragmites australis, Scirpus lacustris, S. litoralis, S. maritimus* and *Typha capensis* covering large areas, and occluding many shallow lagoons. Submerged vegetation includes *Chara* and *Ruppia spiralis* near the sea, with *Callitriche* and *Ranunculus* spp., and *Zannichellia palustris* farther inland. There

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are small stands of *Alnus*, *Salix* and *Tamarix*, some of which are subject to inundation. Fish, including *Mugil cephalus*, and eels are caught near the river mouth. The avifauna is rich and includes *Anser anser* and *Oxyura leucocephala*, many birds of prey and the vultures *Gyps fulvus* and *Neophron percnopterus*. Mammals include *Cervus elaphus*, *Felis caracal*, *F. sylvestris*, *Genetta genetta*, *Lutra lutra* and *Sus scrofer*.

Human Impact & Utilisation: Some hunting pressure, but the system is largely undisturbed.

Conservation Status: Unprotected.

(G) MELAH LAGOON

Location: 36°53'N/8°17'E
Area: 880 ha
Altitude: sea level
Nearest Towns: Annaba (40 km W); Alger (460 km W)

General: A complex of wetlands including this lagoon, Lakes Oubeira and Tonga, and the Garaet (Marsh) of el Mekhada, is situated on the coastal plain near the town of El Kala (36°53'N/8°29'E). The lagoon is a small salt water body with an outlet to the sea at the northern end, having a maximum depth of 6 m. It is 4 km long and 2 km wide and is fed by the Oueds Aroug and Melah which both enter at the southern end. There are broad peripheral strips of salt-marsh, but fresh water influence extends some 200 m into the lake from the mouths of the two affluent streams which flow in winter.

Flora & Fauna: The submerged mudbanks are dominated by *Ruppia spiralis*, but with *Zostera noltii* present on the emergent ones. The margins carry typical tidal salt-marsh vegetation as described in the regional introduction, with an extensive sward of *Juncus maritimus* at the southern end. Fish present include *Dicentrarchus labrax*, *Sparus aurata* and *Solea* sp. *Gambusia holbrookii* has been introduced. The lagoon is an important habitat for wildfowl, and the mammal fauna of the periphery includes *Sus scrofer*.

Human Impact & Utilisation: The lagoon is fished commercially, using fish traps, and the mouth is maintained by dredging. Some hunting occurs but the use of boats on the water is restricted.

Conservation Status: Presently unprotected but will possibly be included in El Kala National Park which was formally established in 1983.

(H) LAKE OUBEIRA

Location: 36°49'-36°51'N/8°22'-8°25'E
Area: 2100 ha
Altitude: c. 2 m asl
Nearest Towns: Annaba (55 km WNW); Alger (470 km W)

General: This is a freshwater lake, 2-3 m deep, which is subject to seasonal variations of up to 2.5 m. The lake is some 7 km long and 3 km wide, and is situated 10 km from Melah Lagoon and 5 km from the sea at the nearest point. A channel from the Oued Kebir feeds the lake at the southeastern end when the floods rise. When the river water begins to recede gates are closed to prevent the return of water from the lake to the river. The water in the lake usually has a pH of 7.2-7.6 and is generally well aerated.

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Flora & Fauna: The lake is fringed by *Phragmites australis* and some rushes and sedges and is filled with dense beds of *Ceratophyllum demersum, Myriophyllum spicatum, Potamogeton* spp and *Trapa natans*. It contains a rich invertebrate fauna, including leeches, e.g. *Hirudo medicinalis*, and a variety of fresh water fish including *Anguilla anguilla, Atherina* sp., and *Alosa* sp. *Gambusia affinis* has been introduced. It is an important habitat for aquatic birds, among which *Plegadis falcinellus* is an occasional visitor.

Human Impact & Utilisation: Hunting and commercial fishing occur on the lake.

Conservation Status: Included in El Kala National Park and designated as a Wetland of International Importance under the Ramsar Convention.

(I) LAKE TONGA

Location: 36°49'-36°52'N/8°29'-8°33'E
Area: 2000 ha (mostly marshland)
Altitude: 0-1 m asl
Nearest Towns: Annaba (65 km WNW); Alger (485 km W)

General: The 'lake' proper is some 7 km long and just over 3 km wide at maximum. It is surrounded by a zone of temporary inundation and there is little open water (perhaps 3%) as the lake is densely covered by emergent macrophytes. Maximum depths recorded after heavy rain are close to 2 m, but the mean depth is near 70 cm. The lake is fed by direct precipitation, peripheral run-off and water from intermittent streams. It is situated some 5 km from the sea at the nearest point. It is separated from Lake Oubeira to the west by a ridge 5 km wide which carries both a road and a railway.

Flora & Fauna: Much of the 'lake' is occluded by emergent vegetation, principally *Blisma plantago aquatica, Glyceria maxima, Iris pseudacorus, Phragmites australis, Schoenoplectus* sp., *Sparganium erectum* and *Typha capensis*, and it could perhaps be more correctly called a reed swamp. There are waterlilies in channels and open patches, and under the open water there are beds of *Ceratophyllum* and *Potamogeton*. Zooplankton is dominated by *Ceriodaphnia megops* with *Metacyclops minutus* and *Myxodiaptus incressatus*, while benthic invertebrates include *Hirudo medicinalis* and *Asellus* sp. It supports many species of fish, including *Anguilla anguilla*, a rich avifauna, and a wide spectrum of terrestrial vertebrates including *Sus scrofer*.

Human Impact & Utilisation: Attempts to drain the 'lake' to the sea by a canal in 1860-1863 were abandoned because the bottom of the lake is so close to mean sea level. However, although this failed, water was pumped out for various purposes until 1935. Since then the area has been relatively undisturbed, but has become subject to intense hunting pressure and there is some fishing.

Conservation Status: Included in El Kala National Park and designated as a Wetland of International Importance under the Ramsar Convention.

(J) GARAET EL MEKHADA

Location: 36°29'N/7°51'E (centre of wetland)
Area: 8900 ha
Altitude: 5-10 m asl
Nearest Towns: Annaba (20 km NNW); El Kala (40 km ENE)

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General: This is a freshwater marsh situated along the Oued Chourka above its confluence with the Oued el Kebir. Its flat marshy expanse is isolated from the sea by the coastal dunes west of Cape Rosa. In winter, water enters the marsh from the two streams mentioned, but the Oued Bounamoussa also contributes some water to the lower, northern, end of the marsh. In summer the marsh dries completely. The marsh is largely covered by emergent macrophytes, dominated by *Phragmites australis* and *Scirpus lacustris* and the fauna includes the small mammals indicated in the regional introduction, as well as *Sus scrofer*.

2. The Oued Saoura

General: The Oued Saoura is the most extensive intermittent river in the Sahara. It has several sources at the eastern end of the High Atlas in Morocco, the principal ones being at 32°20'N/4°05'W where the Oued Guir rises, and at 33°03'N/2°52'W where its major affluent rises. The Oued Guir is a perennial river in its upper course and carries surface water across the Algerian border to a point south of Meridja each year. Here it enters a pan system (31°12'N/2°54'W) above Abadla and on emerging from this it is joined by the Oued Zousfana at Igli (30°27'N/2°17'W). This latter stream rises to the northeast (32°02'N/1°09'W), in Morocco, in the Mountains of Ksour, a ridge extending from the High Atlas. From Igli, the watercourse becomes known as the Oued Saoura and runs southwestwards into the desert, flowing on the surface to the vicinity of El Ouata, a village just south of the town of Beni Abbès. Thereafter it is an intermittent stream and crosses the stony lands of the Hamada du Guir and then penetrates the sand desert. It runs between the dunes of the Ergs Iguidi and Chech to the west, and those of the Grand Erg Occidental to the east. The sands of these systems encroach upon the river valley, and indeed upon the river bed, which provides a string of moist sands, pans and pools (gueltas) for a distance of 650 km.

A large area subject to surface flooding, 40 km long and 10 km wide, used to occur (30°46'-31°08'N/2°39'-2°54'W) near Adabla, and another smaller pan occurs at Marhouma (29°58'N/2°00'W). At a point below Ksabi (29°05'N/1°00'W) the Oued Saoura bifurcates and continues in parallel, the westerly course being known as the Oued Tsebat and the easterly one as the Oued Messaoud. Farther south, surface water used to appear regularly on both the Oueds Tsebat and Messaoud, at 28°05'N/0°39'W and 28°05'N/0°33'W respectively. Other pans, or sebkhets, up to 180 km long and 12 km wide occur between Adrar (27°51'N/0°19'W) and Reggane (26°42'N/0°13'W), but these are very much drier than the northern pans. Between them, the Oueds Tsebat and Messaoud carry subterranean water as far south as the well of Boura (26°13'N/0°15'W) to where there is little doubt that surface floods penetrated at least once during the 18th Century.

Hydrology & Water Quality: Mean annual precipitation over the system is minimal, 50 mm at Beni Abbès, 18 mm at Adrar and 10 mm at Reggane, and has virtually no effect on surface flooding. However, there are strong annual variations in rainfall, and while Adrar may receive 0 mm for several successive years, it has recorded falls of 65 mm/yr. Floods in the river are chiefly due to heavy rainfall in the Atlas Mountains, and they may occur several times a year. Occasionally floods arise because of storms over the lower reaches of the Oueds Guir and Zousfana. Surface waters used periodically to reach far

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into the desert. According to Dubief & Cornet (1958), the river flooded south for 800 km from the source of the Oued Guir in 1959, and since 1900 has sent surface water 500 km downstream 5 times, 400 km 6 times, 300 km 13 times and 200 km 33 times. Floods are reputed to have reached Reggane in 1915, 975 km from the source of the Oued Guir, but while this is not substantiated, it is recorded in historical documents that slaves were sent north from Reggane by boat in the 16th Century. However, since the Oued Guir has been impounded at Djorf Torba, these floods no longer occur. The Oued Guir usually carries water of low conductivity, but downstream, with progressive evaporation, this increases and eventually a crust of salts may be left on the stream bed.

Flora & Fauna: Since water levels are very variable, emergent macrophytes are generally absent from the stream bed, although they are not entirely absent and they occur along irrigation channels at oases. Here *Phragmites australis* is usually dominant, with *Typha capensis* and species such as *Cynodon dactylon, Juncus maritimus, Scirpus holoschoenus, Sonchus maritimus*, all salt tolerant species. There are some *Hyphaene* palms and occasional stunted figs (*Ficus sycomorus*) along the oued, and locally thickets of *Nerium oleander* and *Tamarix* spp., but *Phoenix dactylifera* has been extensively planted in the valley and is by far the most common tree. Pools and semi-permanent pools contain a dense, if not rich, invertebrate fauna. Among fishes, the typical Atlas species occur in the upper, freshwater reaches, extending downstream with the flood, and moving back again as it dissipates. Downstream only euryhaline species persist, including *Aphanius fasciatus* and *A. iberus*. Among amphibia, *Bufo mauritanicus, Discoglossus pictus* and *Rana ridibunda* have been recorded in the middle valley, and are abundant at oases. Among mammals there are desert rodents, and carnivores such as *Felis margarita*.

Human Impact & Utilisation: The Oued Saoura has been a major caravan route across the Sahara from time immemorial and the centres of Beni Abbès, Marhouma, Aguedal, Guerzim, Kerzaz, Timoudi, Ksabi and El Kseïbat have developed at points in its bed where water is freely available. The waters are used for various purposes, including irrigation, at centres along most of its upper course. However, a consequence of the damming of the Oued Guir is that the subterranean waters of the Oued Saoura are becoming more saline. The valley of the Oued Saoura is comparatively densely populated, and has probably been a centre of population since Neolithic, and indeed Palaeolithic times. Fossil evidence suggests that a cattle farming society existed here during a Neolithic period. Tourism in the valley is increasing as there is now a good sealed road, but pollution is becoming a problem at some centres where sewage, either treated or untreated, is discharged directly into the oued, e.g. at Beni Abbès.

Conservation Status: Unprotected.

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3. The Chotts

(A) CHOTT ECH CHERGUI

Location: 34°03'-34°36'N/0°24'W-1°11'E
Area: c. 150 000 ha
Altitude: 982 m asl
Nearest Towns: Oran (180 km NNW); Alger (290 km NE)

General: The Chott Ech Chergui is the largest, highest and most western of the temporary shallow water bodies on the High Plateau. It is oriented WSW-ENE and is 160 km long, with a maximum width of 26 km near the eastern end. It is endorheic and occupies a shallow depression on the plateau into which some 25 intermittent streams discharge. The seasonal flood waters lie at about 982 m and throughout the chott areas above 984 m are permanently dry. There are several of these dry areas, the highest reaching 1017 m, and in the central part of the chott they occupy more land than the zone subject to inundation. In a wet year as much as 150 000 ha can be flooded. The water is saline, increasing in salt content as the season progresses. Water depths vary from 1 m to a few centimetres.

Flora & Fauna: Essentially as described in the regional introduction. Due to great variations in the water level there are few reeds, but low growing halophytes abound along the shores where *Sarcocornia fruticosa* is dominant over large areas. All the chotts are of importance to wintering and migrating waterfowl, and the Chott Ech Chergui supports large numbers of ducks, including *Anas acuta, A. penelope, Tadorna tadorna*, together with *Charadrius morinellus, Grus grus, Phoenicopterus ruber* and *Recurvirostra avosetta*.

Human Impact & Utilisation: The chotts provide excellent shooting, and hunting pressure on the avifauna is severe. Some salt is extracted, cattle are grazed on the periphery, and locally, salt-tolerant strains of cereals are grown on adjacent land.

Conservation Status: Unprotected.

(B) ZAHREZ RHARBI

Location: 34°51'-34°58'N/2°36'-2°58'W
Area: 22 000 ha
Altitude: 826 m asl
Nearest Towns: Oran (310 km NW); Alger (200 km N)

General: The inundated zone of the Zahrez Rharbi is 25 km long and up to 10 km wide, fringed on the south and east by expanses of humid sand. The system is endorheic and saline. The depression lies at the western end of a trough 30 km wide, running WSW-ENE for 140 km along the High Plateau. The sides of the trough rise steeply from the floor, to altitudes of 1200-1370 m asl on the north, and to 1550 m on the south side. The flora and fauna are similar to that of the Chott Ech Chergui, as is human impact on the site.

Conservation Status: Unprotected.

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(C) ZAHREZ CHERGUI

Location: 35°08'-35°19'N/3°24'-3°43'E
Area: 19 500 ha
Altitude: 755 m asl
Nearest Towns: Alger (170 km NNW); Laghouat (150 km SSW)

General: This chott occupies the eastern and lowest end of the trough holding the Zahrez Rharbi. The depression is fed by 11 oueds and the area subject to inundation, 34 km long and up to 9 km wide, is bounded by humid sands along the southern shore. An area of permanent swamp occurs at the western end, and the land rises from the eastern end to a high ridge separating this endorheic system from the Chott el Hodna farther east. Conditions on the chott are similar to those described above for the Chott Ech Chergui.

Conservation Status: Unprotected.

(D) CHOTT EL HODNA

Location: 35°18'-35°32'N/4°15'-5°06'E
Area: c. 85 000 ha
Altitude: 390 m asl (lowest point in basin)
Nearest Towns: Alger (200 km NW); Biskra (80 km SE)

General: This chott occupies the lowest, almost central, part of a basin at the eastern end of the High Plateau. The basin is oriented WNW-ESE and is 220 km long, and 90 km wide at maximum, set between mountains reaching altitudes of 1800-1900 m asl on the north side and 900-1600 m on the south side. Some of the affluent streams, such as the Oueds Djenane and Sbisseb, are perennial in their upper courses and the Oued M'Sila tends to flow throughout its length for much of the year. At least 22 major streams discharge into the chott and in addition it is fed by several freshwater springs around its southern periphery. The area flooded each year varies but is usually in excess of 80 000 ha and is some 77 km long and up to 19 km wide. The chott holds water only in the winter and is saline, with salts encrusting the muddy periphery in summer. Some authors (e.g. Carp 1980) state that the pan extends at least 90 km from east to west in wet years and that the inundation zone can reach 400 000 ha. However, while the flood may exceed 77 km in length, an area of 400 000 ha implies a water body with a mean width in excess of 45 km reaching from M'Sila (472 m asl) in the north to the feet of the Djebel Meharga in the south, with maximum water depths approaching 80 m. It seems unlikely that such a water body has ever developed this century as a lake 80 m deep would be perennial.

Flora & Fauna: The flora of the shore is halophytic, and includes a number of coastal species such as *Juncus acutus* and *Sarcornia fruticosa*, but reeds, rushes and sedges, and some palms, grow around springs and along water courses leading to the chott. The area is very important to wintering and migrating waterfowl.

Human Impact & Utilisation: The area is not densely populated. Cattle are grazed on the periphery and some crops, including dates and cereals, are grown locally. Although the chott is ringed by roads, approaching to within 15 km of the northern shore, hunting pressure is said to be light.

Conservation Status: Unprotected.

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(E) CHOTTS OF THE SETIF & CONSTANTINE REGION

General: A discontinuous band of wetlands extends for 175 km from a point south of Sétif (36°09'N/5°26'E) to one southeast of Constantine (36°25'N/6°43'E). This comprises a series of pans, located from west to east, as follows: un-named pan (36°00'N/5°20'E); Sebkhet el Amiet (35°54'-35°56'N/5°31'-5°35'E); Chott el Fran (35°53'-35°59'N/5°37'-5°42'E); Sebkhet Bazer (36°02'-36°04'N/5°37'-5°45'E); Chott Beïda (35°53'-36°00'N/5°45'-5°53'E); un-named pan (35°49'N/6°11'E); Chott Gadaïne (35°45'-35°53'N/6°12'-6°23'E); Sebkhet Zemoul (35°51'-35°54'N/6°31'-6°36'E); Sebkhet Djendli (35°42'-35°45'N/6°31'-6°36'E); Garaet et Mahrsel (35°49'-35°51'N/6°44'-6°48'E); Garaet Ank Djeme (35°44'-35°49'N/6°47'-6°54'E); Garaet Guellif (35°44'-35°49'N/6°55'-7°01'E); and Garaet et Tarf (35°33'-35°45'N/6°56'-7°13'E).

These pans are situated on a high plain, 30 km wide at the western end, but broadening along an E-W axis to 80 km at the eastern end. The plain is hemmed in by mountains to both north and south, rising to 2321 m at Djebel Mahmel and 2326 m at Djebel Chélia due south of Constantine. The plain is crossed by many watercourses, both intermittent and perennial, especially towards its western end. In the main it lies 950-1000 m asl and is studded with hills, rising in places more than 400 m above this. However, Chott Gadaïne, in a central southerly position, is less than 900 m asl. The largest pan, Garaet et Tarf, occupies some 25 000 ha when fully inundated and measures 28 km in length with a maximum width of 17 km. It has a belt of humid sand around much of its periphery. The pans are flooded to variable depths and extents each year, and there are numerous marshy areas in the vicinity of springs around the edges of the plain.

Flora & Fauna: Essentially as described in the regional introduction for chotts of the high plateaux. Reeds, rushes, sedges and trees grow along some of the watercourses, and in permanent marshy areas around springs. The pans are endorheic and saline, and have typical low growing halophyte floras on their muddy salt encrusted margins, where species of *Salicornia, Sarcocornia* and *Sueda* are abundant. All pans and freshwater marshes are important sites for wintering and migrating waterfowl, especially *Anas acuta, A. penelope, Charadrius morinellus, Grus grus, Phoenicopterus ruber, Recurvirostra avosetta* and *Tadorna tadorna*.

Human Impact & Utilisation: A number of roads cross the plain including that between Batna and Constantine. The eastern pans are more accessible than the western ones and are subject to greater hunting pressure during the winter. Some agriculture occurs on the plain, but apart from hunting and some salt gathering, the pans, *per se*, are little interfered with.

Conservation Status: Unprotected.

(F) THE CHOTTS MELRHIR & MEROUANE COMPLEX

Location: 33°50'-34°29'N/5°57'-7°25'E
Area: c. 275 000 ha
Altitude: below sea level
Nearest Towns: Biskra (60 km NE); Touggourt (85 km S)

General: Chott Melrhir is 65 km long and has a mean width of 29 km. It contains extensive areas of humid sand and its land surface descends to 36 m below sea level. It

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is separated from Chott Merouane to the south, by a narrow corridor of permanently dry land, only 4 km wide in places. The northern part of Chott Merouane lies 40 m below sea level. A series of small seasonally flooded wetlands extends eastwards, almost continuously from the southeastern extremity of Chott Melrhir into Tunisia. These are, from west to east, the Chotts es Setal, el Aquila, Djerabaa, Zebabir, Zhilhif, Aslaudi and Khalla. The last named chott crosses the national border and lies in the same depression as the Chott el Rharsa in Tunisia. The lowest parts of the depressions are permanently flooded, and the system is saline and endorheic, since although the depression continues eastwards, it tends to drain back into Chott Melrhir.

Flora & Fauna: The inundated zones are fringed by low growing halophytes, including species of *Arthrocnemum, Limonium, Juncus, Salicornia, Sarcocornia, Scirpus* and *Suaeda*. The fauna is as described in the regional introduction for chotts. There is a rich avifauna including several species of *Anas, Chlamydotis undulata* and *Phoenicopterus ruber*.

Human Impact & Utilisation: The area is comparatively inaccessible and hunting is more or less confined to the zones along the road which runs between the two major chotts.

Conservation Status: Unprotected.

(G) THE CHOTTS OF EL MALAH

Location: 32°41'-33°01'N/5°29'-5°40'W
Area: 23 000 ha
Altitude: 90-98 m asl
Nearest Towns: Biskra (205 km N); Touggourt (50 km NE)

General: This is a system of three separate chotts (or sebkas) which are very irregularly flooded. The southernmost pan measures some 11x8 km and is 90 m asl. The central pan, 24x8 km, is about 95 m asl, while the northernmost pan is 98 m asl. The chotts lie just north of the collection of mesas at El Hadjira, with tops at 165 m asl, and there are palm plantations between the scarps and the chotts. The flora and fauna of the system is as described in the regional introduction. Some hunting takes place on the chotts which are unprotected.

(H) SEBKHET SAFIOUNE

Location: 32°14'-32°24'N/5°17'-5°25'E
Area: c. 11 000 ha
Altitude: 101 m asl
Nearest Towns: Touggourt (105 km NE); Biskra (275 km N)

General: This is a large saline and endorheic pan at the end of the Oued en Nsa, an intermittent watercourse 195 km long. This stream rises at an altitude of over 600 m asl, as the Oued el Ferch, and runs SE, receiving several tributaries. At first it runs along the foot of a broken escarpment on the south side, but becomes deeply entrenched and then, as the Oued en Nsa, flows eastwards for 70 km through a narrow and ever deepening gorge in a plateau set between 265-270 m asl. Finally, its waters, when in flood, spill onto a plain some 110 m asl at the eastern edge of the plateau, and spread southwards to

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collect in the sebkhet. Inselbergs rise nearly 100 m from the floor of the pan at its southeastern end and the escarpment of the plateau lies 5-12 km to the west. There are date palm plantations to the south, between the sebkhet and the escarpment of the plateau. Some hunting occurs on the sebkhet when it is flooded and attracts waterfowl. The system is not protected.

4. Oases

(A) THE GUELTAS OF ZIZA

Location: 23°32'N/2°34'E
Area: a few m^2
Altitude: c. 515 m asl
Nearest Towns: Tamanrasset (310 km ESE); Oran (1360 km N)

General: This is one of the most isolated occurrences of free surface water in the Sahara. It is situated near the southwestern extremity of the plateau, Adrar Nahalet, which extends westwards from the massif of the A'Haggar. The permanent guelta (pool), 13 m wide when full and 6 m deep, is inside a volcanic crater which partly encloses a valley. It collects water from two oueds which drain Ziza Mountain, to the south, and is reputed to have no underground input. Several small temporary pools also occur in the bed of the main oued draining Mt. Ziza. The water of the guelta is fresh. There are no macrophytes or vertebrates in the guelta, and life forms are restricted to blue-green algae, some zooplankton, and a few insects. The water of the guelta supports a dozen people and their domestic animals. The guelta is unprotected.

(B) THE GUELTAS OF THE TASSILI N'AJJER

General: Over 300 permanent gueltas (ponds) are known to occur in the Tassili N'Ajjer which is a high sandstone plateau extending northeastwards from the A'Haggar Massif. It descends to a lower plateau along a scarp line running in a gentle arc from southeast to northwest, while a mountainous ridge surmounts the plateau, running roughly parallel to the escarpment, but some 30-50 km back from it. The highest point on the ridge, at 2158 m, is Mt. Afao (25°09'N/8°12'E). Maximum temperatures on the high plateau are seldom in excess of 32°C, while winter minima are usually 1-2°C, although frosts occur on the peaks and snow has been recorded several times. The slopes of this Mt. Afao are drained by a dendritic system of oueds, culminating in the Oued Imirhou. This watercourse, and its principal affluents, the Oueds Iherir and Torset, all traverse deep gorges running NE to the lower plain where they swing NW to lose themselves under the sands of the Erg Issaounane west of Illizi (26°32'N/8°33'E), 535 m asl. The Oued Imirhou drains a basin larger than 12 500 km^2 and rises about 1800 m asl in innumerable gullies on the Mt. Afao Massif. Permanent and temporary ponds occur on all three oueds in an area 25°10'-25°36'N/8°00'-9°20'E, the Oued Iherir alone contains 45 permanent gueltas, has been known to carry flowing surface water for distances of up to 20 km. The gueltas occur between altitudes of 1100-1200 m asl, vary in depth from 4-15 m, and may be connected by streams or waterfalls after rain. A hot spring (45°C) is situated at the junction of the Oueds Imirhou and Torset, which supplies a guelta known as Tihoutar ti-n-Afella.

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Other gueltas occur to the west along the Oued Tadjeradjeri and its upper tributaries, in an area 25°10'-25°50'N/7°50'-8°00'E. The most important of these lie along the bed of an affluent, the Oued Aharhar. There is a small lake, 500 m long and about 4 m deep, at about 26°N in the main valley at an altitude of 1120 m asl. It is situated in a flat open area and supports dense *Typha* beds, which extend well out into the lake. Springs occur in some of the higher valleys. Farther west there is a fossil floodplain, some 1160 m asl (25°12'-25°26'N/7°36'-7°45'E) at the confluence of three gorges. Of these, the Oued Tin Bawendi contains a series of gueltas over a stretch of several kilometres, the gueltas being separated by *Typha* beds along the watercourse. On the mountainous ridge to the east of Mt. Afao, at altitudes close to 1600 m asl (25°12'N/8°28'E), there are gueltas in a number of short gorges at Assar.

Hydrology & Water Quality: Rain over the Tassili N'Ajjer is scant and annually very variable. The mean annual receipt is probably close to 25 mm, but in some years as much as 150 mm may be received locally. This usually falls as a consequence of storms arising from temporary and very turbulent projections of the intertropical front, which push northwards to the A'Haggar region. The maximum recorded flood on the Oued Imerhou extended 270 km below the source, and flowing surface water has persisted in the Oued Iherir for up to 6 months of the year. Floods in this latter watercourse regularly extend 20 km downstream. The gueltas quickly become stagnant after floods, but are well oxygenated immediately after them. Salinity varies considerably from guelta to guelta. The upper ones tend to be fresh after rain, and salinity in the lower gueltas declines with the frequency of flushing, but high salinities occur in the lowest ones. Magnesium and sulphate concentrations are high in some gueltas and these tend to be the principal ions throughout the system.

Flora & Fauna: Filamentous green algae occur around the rims of rocky gueltas, and *Volvox* spp. are common in the phytoplankton of some. However, the margins of most are fringed by stands of *Typha capensis*, in belts up to 10 m wide, but *Phragmites australis* is less important, and is absent from many gueltas. *Polygonum* sp. occurs on the margins of a few. Submerged species include *Ceratophyllum demersum, Myriophyllum spicatum, Potamogeton* spp., and *Utricularia* spp. and Characeae. *Nerium oleander* and *Tamarix gallica* are abundant along the oued beds in most valleys, with *Acacia nilotica* and *Hyphaene thebaica* on the banks of many. Occasional trees of *Olea laperrinii* grow along the Oued Iherir. *Phoenix dactylifera* has been planted in great numbers in suitable sites in all valleys.

Among animals the poriferan *Spongilla carteri* has been recorded in some gueltas, together with the bryozoan *Fredericella sultana*. There is in fact, a remarkably diverse invertebrate fauna, including several relict species, and with representatives of both the Afrotropical and Palaearctic realms. This includes the vectors of bilharzia and malaria. Among the fishes are *Barbus biscarensis* (Palaearctic), *Barbus deserti* (Afrotropical), *Clarias anguillaris, C. gariepinus* and *Tilapia zillii*. These species do not necessarily occur together. *Bufo viridis, Prychadena occipitalis* and *P. mascareniensis* are the principal amphibians. *Crocodylus niloticus* is now extinct, but survived here at least until 1924. Among notable mammals, *Felis chaus*, a true wetland species, occurs here (other occurrences in the A'Haggar and Nile Delta), together with *F. margarita*.

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Human Impact & Utilisation: The area has certainly been continuously inhabited since Neolithic times. Cereals (wheat), dates, figs, grapes, and root crops are produced in the valleys, where the resident population has fluctuated this century but has generally been several thousand, continuously more than 1000 along the Oued Iherir alone. Fish are taken from the gueltas and camels, cattle and goats are grazed. *Typha* is used for thatching and making mats, and part of the stem is eaten as a vegetable. There is some tourism, people coming to visit the frescoes found on the plateau, but very little interference. A number of wells have been dug in the Oued Tadjeradjeri system, together with irrigation canals to lead the water to the village of Arharhar, but these have fallen into disuse since the development of oil fields at In Amenas. This development has probably reduced the population throughout the region in recent years.

Conservation Status: The valley of Iherir is protected as a nature park, administered by the Ministry of Fine Arts, but protection does not extend to the flora and fauna, only to the frescoes.

(C) THE GUELTAS OF THE A'HAGGAR MASSIF

General: The dramatically dissected A'Haggar Mountains, rising to 2918 m at Mt. Tahat, drain principally to the south and west. The massif comprises Precambrian granite, but the highest parts, over 1900 m, are covered by Tertiary and Quarternary lavas. The climate of the massif is more temperate than that of the surrounding lowlands. Rainfall increases with altitude, from less than 20 mm/yr on the Plain of Tanzerouft, to 50 mm/yr at Tamanrasset (22°50'N/5°28'E) situated 1400 m asl on the SW slopes, and to 125 mm/yr at Asselerem Peak (2728 m). Annual variations are marked, as is general in deserts, and while annual falls of less than 10 mm have been recorded at Tamanrasset, 160 mm fell in 1933. Similarly, Mt. Asselerem, which has had total annual receipts less than 35 mm, recorded 260 mm in 1957. The mean annual temperature of the warmest month (July) at Tamanrasset is 29°C, and that of the coolest month (January) 12°C. The mean annual temperature is 21°C, significantly lower than on the Tanzerouft Plain, and frost occurs at Tamanrasset on an average of 29 days each year, with an absolute minimum reading of -6°C. Snow is common on the high peaks, where temperatures of -12°C have been recorded.

The most important of the western drainage systems is the Oued Tamanrasset, which once bore its waters to the Atlantic before being captured by the Niger. Today it carries occasional floods onto the Tanzerouft Plain, but gueltas, which freeze in winter, occur in its upper reaches, in a system of deep gorges. The most gueltas are those of Imaoulaouene, which occur in a tributary gorge near the city of Tamanrasset. A fault across the river bed, at an altitude of 1540 m asl, causes a current of subterranean water to surface and cascade in several steps through a series of ponds, before once again disappearing underground at 1500 m.

Many gueltas occur around the edge of the Atakor, i.e. around the rim of volcanic lavas that top the massif between 1800-2100 m. Many are situated in fairly open river beds, as strings of pools among rocks and boulders, and these are connected by flowing surface water for a good part of the year, since rainfall, though scant, is more or less aseasonal. Other gueltas are plunge pools beneath ledges over which waterfalls descend periodically, yet others are in kettleholes (marmites de géant) worn into the granite.

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Innumerable gueltas, of similar nature to those described above, occur in the deep ravines leading south out of the central massif, in particular those of the Oueds Azrou, Afrahoukhine, Sersouf, Tin Tarabine, Afara and Takalous, between longitudes 6° and 7°30'E. Ultimately these watercourses all join the Oued Tin Tarabine which passes to the east of a long N-S oriented inselberg at a point 22°08'N/6°39'E. Near here there is a permanent pool, and from here the Oued Tin Tarabine trends SE. Floods in very wet years have extended far past the inselberg. Another long and deeply entrenched valley, that of the Oued Tagrira, begins 40 km south of the inselberg and runs towards the SW. This latter system has a bed of humid sand, floods occasionally, and carries arborescent vegetation at points.

Hydrology & Water Quality: The gueltas and cascades of Imaoulaouene are permanent and there may be several floods on the system in a single year, but virtually all of the upper oueds in the massif flow for several days each year. Heavy floods, leading to surface water in the lower oueds, are uncommon, but the Oued Tamanrasset has carried water to the Tanzerouft Plain half a dozen times this century, and to its centre in 1950 and 1951. The upper pools vary in depth from 2-5 m. Salinity of the water in the gueltas varies, as might be expected, with the degree and frequency of flushing which they receive. Salts crystallise around some gueltas, and remarkably, on the stems of *Typha capensis*. Conductivities generally range from 150-1500 µSiemens/cm.

Flora & Fauna: *Nerium oleander* and *Tamarix gallica* is common in the beds of oueds where the water table is close to the surface. *Acacia nilotica* and *Hyphaene thebaica* also occur near gueltas, but have largely been replaced by *Phoenix dactylifera*. There are occasional trees of *Ficus sycomorus* and *Olea laperinii* in inaccessible side gullies. Stands of *Typha capensis* are commonplace, sometimes in association with *Phragmites australis*. This latter species occurs in some sites which become temporarily dry. Other emergent macrophytes include *Juncus buffonius*, *Scirpus holoschoenus* and the grass, *Polypogon monspelliensis*. Submerged macrophytes include *Ceratophyllum demersum*, *Myriophyllum spicatum* and *Potamogeton* spp. Algae include species of *Chara*, *Cladophora*, *Closterium*, *Cosmarium*, *Dictyosphaerium*, *Microcystis*, *Oedogonium*, *Scenedesmus*, *Ulothrix*, *Volvox* and *Zygnema*.

Among fishes, *Tilapia zillii* is the most widespread, being found in a great many of the upper, permanent, ponds, but it is excluded from the highest ones by low winter temperatures. *Barbus biscarensis* is abundant in some systems and *B. deserti* has also been recorded from the massif. *Bufo viridis* and *Rana ridibunda* are widespread amphibians.

Human Impact & Utilisation: The upper gueltas of the Atakor are little disturbed and little visited, except by tourists who can visit a number using 4 wheel drive vehicles. Picknicking beside and swimming in the gueltas then occurs but has no significant influence upon the ecosystem at present. There are no permanent human habitations at the upper gueltas. The lower gueltas of the Oued Tamanrasset system no longer supply water for human habitation directly, but camels, cattle and goats drink from them and are grazed nearby. Some agriculture and horticulture is carried out along the lower oueds and there are *Phoenix dactylifera* plantations.

Conservation Status: Unprotected.

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(D) THE GUELTAS OF THE MOUYDIR MOUNTAINS & TIDIKELT DEPRESSION

General: The granitic Mouydir Mountains comprise a chain oriented SSW-NNE, rising to heights of 1100-1680 m, and lying 100-150 km northwest of the A'Haggar Massif. Geologically they are related to the Precambrian core of this massif. The principal drainage lines from the Mouydir Mountains are NW, to the Tidikelt Depression. A number of gueltas occur in gorges leading out the mountains, e.g. that in the Gorge of Arak (25°17'N/3°41'E). Here several permanent and semi-permanent gueltas occur in the upper canyon beginning about 700 m asl, while in the lower and wider gorge, at an altitude of 560 m asl, there is a second series of shallow semi-permanent pools, created where groundwater reaches the surface. At still lower altitudes, and farther west, along the borders of the Tidikelt Depression, but still on oueds, there are numerous pools, notably those of Aït Elkra (24°31'N/2°32'E), Talohak (24°45'N/2°20'E), Aguelman Tadjelet (24°52'N/1°45'E), Bou Rhanet (25°12'N/1°18'E), Tikkindine (25°31'N/1°25'E), I-n-Rellal (25°41'N/2°03'E) and Ti-n-Atanan (25°52'N/1°38'E). Ultimately the water from the eastern highlands seeps into the ground beneath the great saline pans of the depression, the Sebkras Azz el Matti and Mekerrhane.

Hydrology & Water Quality: The water of the Arak gueltas is generally fresh, as is that of the pools bordering the Tidikelt Depression, but the pans, and subsurface water of the depression is saline. Rain over the Mouydir Mountains is generally light, c. 10-50 mm/yr, and unreliable.

Flora & Fauna: The pools of the Arak Gorge are fringed by *Phragmites australis*, *Typha capensis* and *Scirpus holoschoenus*, while submerged species include *Ceratophyllum demersum*, *Myriophyllum spicatum* and *Ruppia spiralis*, the last a species with strong coastal affinity. The humid soils of the oueds throughout the region support *Nerium oleander* and *Tamarix gallica*, with occasional stands of *Acacia nilotica* and *Hyphaene thebaica*. There are no fish in the lower pools but *Tilapia zillii* occurs in the permanent high gueltas of the Arak Gorge. *Bufo mauretanicus* and *B. viridis* occur in the district. The usual desert mammals are present, as referred to in the regional introduction.

5. Artificial Impoundments

(A) THE BARRAGE DE CHEFFIA

Location: 36°45'N/8°05'N
Area: c. 3000 ha (at capacity)
Altitude: 170 m asl
Nearest Towns: Annaba (35 km NW); Alger (448 km W)

General: This barrage is on the Oued Bounamoussa well above its entry to the marshy alluvial plain (Garaet el Mekheda) which it shares on the coastal plain with the Oued el Kebir. The open water area is set round by hills and has a maximum depth of 20 m. The reservoir provides a refuge for birds when shooting is in progress on the lower wetlands of the coastal plain. Hunting is not permitted.

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(B) LAKE BOUGHZOUL

Location: 35°39'-35°45'N/2°50'E
Area: 5000 ha total wetland (1100 ha open water)
Altitude: 635 m asl
Nearest Towns: Alger (120 km N); Djelfa (120 km S)

General: The Oued Touil crosses the High Plateau from the south side, with a wide wet sandy bed, flowing almost due north for 125 km before it joins the perennial Oued Nahr Quassel on its right bank. This latter stream flows down from the northern mountains, and just below the confluence mentioned, is joined by the Oued ech Chemara, another intermittent stream. The Oued Nahr Quassel then traverses a permanent marsh some 10 km long before expanding into Lake Boughzoul which has an open water surface in excess of 1000 ha. This is the largest artificial lake on the High Plateau and is situated close to the Djelfa-Media road. The vegetation of the permanent marsh is lush and includes *Phragmites* and *Typha*. The entire wetland provides an important habitat for waterfowl including wintering *Charadrius alexandrinus, Gelochelidion nilatica, Himantopus himantopus* and *Podiceps cristatus*. The lake is unprotected.

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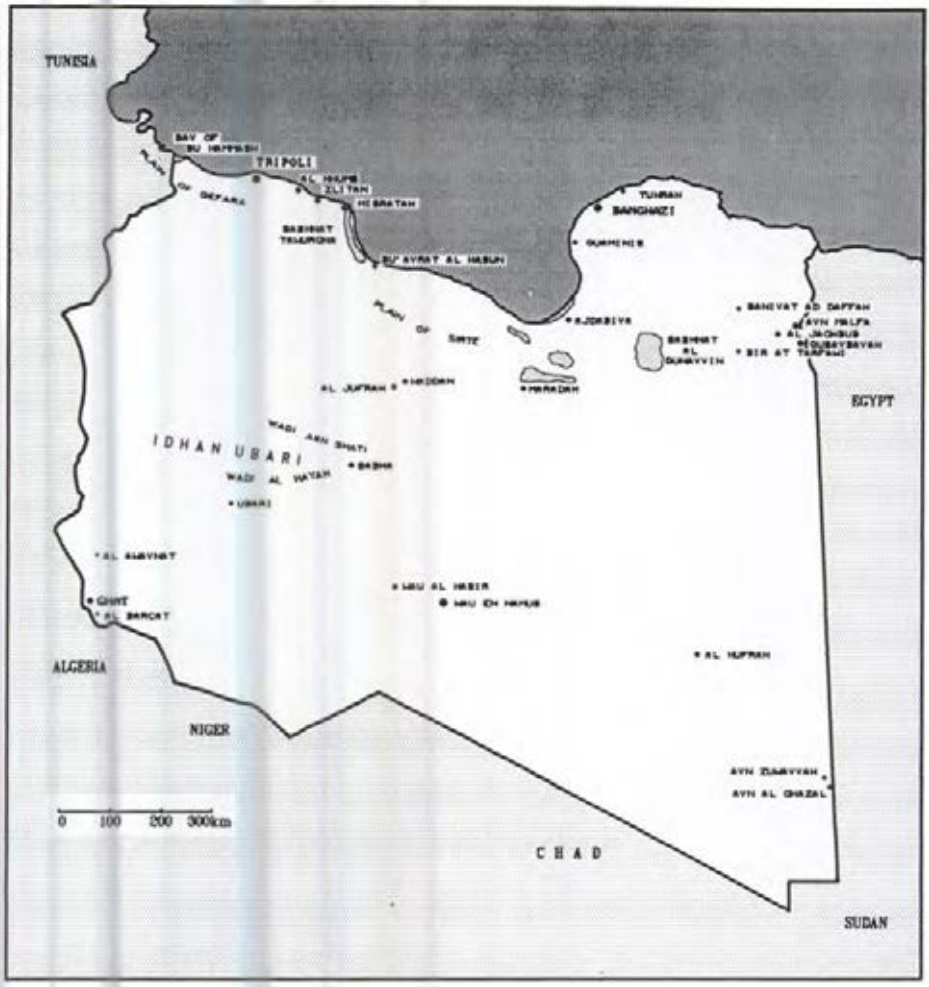

Map of Libya

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1.2 LIBYA

Introduction

Libya is bounded by Egypt in the east, by Sudan, Chad and Niger in the south, by Algeria in the west, and by the Mediterranean Sea in the north. It has an area of 1 759 540 km^2, a population of 3 224 000, and thus has a mean population density of 1.8 persons/km^2. It extends approximately 1460 km from south to north between latitudes 19°33' and 33°13'N, and 1550 km from west to east between longitudes 9°21' and 25°09'E.

The coastline is over 1500 km long, and apart from an area in the east, between Banghazi (32°07'N/20°04'E) and Damah (32°46'N/22°39'E), this rises gently on passing inland. In the west, the Gefara Plain, which lies along the coast, tends to be saline and rises gently in the south to the Jabal Tarabulus (Jabal Nafusa), a Cretaceous limestone formation 300-600 m high. This in turn leads southwards to the great rocky plateau of the Al Hammadah al Hamrah covering some 49 000 km^2. In the central region, along the Gulf of Sirte, the coastal plain is at first 50-70 km wide but opens inland, from the southeastern gulf, to a vast lowland area between the coastal highlands of the east and the high desert lands along the southern borders. Here some 200 000 km^2 of land lies below the 100 m contour, and a peripheral zone of equivalent area lies below the 200 m contour. East of the Gulf of Sirte, the coastal plain is narrow, 10-15 km wide, and rises by the north-facing terraces of the Al Jabal al Akhdar to a highland block 400-600 m high. This hilly region is 200 km long, parallel with the coast, and 70 km wide. On the south side it slopes down to the interior plain. To the east of these highlands, the coast is flat and backed by undulating land on which a belt of sparse vegetation extends some 20 km inland. The highest land in Libya is found in the far central south where a promontory of the Tibesti Mountains, over 1500 m asl, reaches northwards into the country from Chad. A sand desert covers most of interior lowland Libya, occupying much of the eastern, southeastern, central and southwestern sectors.

There are no perennial rivers in Libya, but numerous dry watercourses (wadis or ouadis) are filled by flash floods after local rain. They dry quickly, but pools and trickling streams may persist for a time. There are large artesian water resources, and there are plans, already partially implemented, to pump water from the interior to the coast for irrigation. It is planned that eventually a total of 578 wells will produce 3 000 000 m^3 water/day.

Climate

The climate of Libya is jointly influenced by the desert to the south and the Mediterranean Sea to the north, there being no natural barriers between. In winter the coastal areas and the Tibesti Mountains are quite cold, the latter subject to frosts, while in summer the whole country is hot. Tarabulus (Tripoli) has a mean annual temperature of 19.8°C. That at Banghazi is very similar but the annual range and daily fluctuations are greater at Tarabulus. A hot dust laden wind, known locally as the ghibli, may reach the coast from the Sahara at any time, but chiefly during the spring and autumn. This raises temperatures dramatically, and an absolute maximum of 58°C has been recorded on the Gefara Plain.

Precipitation at first declines on passing eastwards along the coast, but rises briefly over the Al Jabal al Akhdar. Mean annual rainfall at Tarabulus is 371 mm, 247 mm at Misratah

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and 113 mm at Bu Ayat al Hasun (31°26'N/15°44'E), but this increases again to 260 mm at Banghazi and may reach 500 mm on the seaward heights of the Al Jabal al Akdhar. Annual variations are marked and the coastal regions are prone to periods of drought. The interior is very dry. Rainfall decreases rapidly away from the coast and 95% of the country receives less than 100 mm/yr, and much receives less than 40 mm. Most of the southwest, including the Tibesti Massif, has a mean annual rainfall of less than 20 mm. Insolation in the interior is extreme and potential evaporation reaches or exceeds 4500 mm/yr.

Vegetation

In years of good rainfall the coastal plains are covered by annual grasses and other herbaceous vegetation, including species of *Asphodelus*, while the highlands of the Al Jabal al Akhdar support tall (3-4 m) sclerophyllous scrubland, known locally as macchia. Floristically this is quite diverse but usually contains an abundance of *Juniperus phoenicea* and *Pistacia lentiscus*. Several grasses and the low shrub, *Poterium spinosum*, occur as an under-storey in more open stands, and becomes dominant where grazing pressure is intense. Macchia is a form of degraded woodland, probably once dominated by species of *Cupressus*, *Juniperus*, *Olea* and *Quercus*. In the west the Jabal Tarabulas is less densely vegetated, and the natural vegetation is of low grasslands between barren hills. There are several important oases in the interior, where vegetation is comparatively lush.

Wetlands

Salt pans (sabkhas) and salt-marshes occur along the coastal strip, formed by the ponding and subsequent evaporation of water behind the coastal dunes. These arise where run-off collects, but the capillary rise of groundwater from a shallow water table has also contributed to the development of these features. Just west of the Tunisian border, in the bay of Bu Kammash (32°03'N/11°43'E), there is slight tidal movement and small tidal salt-marshes occur there. Semi-permanent and temporary pools occur in some wadis and there are several important oases in the interior.

List of Wetlands Described

1. Coastal Wetlands
   - (a) The West Coast
   - (b) The Gulf of Sirte
2. Oases
   - (a) Oases of the Ghat Region
   - (b) Oases of the Sabha District
   - (c) The Lakes of Wau en Namus
   - (d) The Oases of Kufrah
   - (e) Other Oases

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1. Coastal Wetlands

(A) THE WEST COAST

General: Some slight tidal rise and fall (maximum 40 cm) occurs along the coast west of Tarabulus and some mudflats in the Bay of Bu Kammash (37°03'N/11°43'E) carry salt-marsh vegetation. In addition there are saline pans and marshes on the Plain of Gefara inland. These sites carry halophytic vegetation as described in the regional introduction.

Between Az Zawiyah (32°45'N/12°44'E) and Misratah (32°23'N/15°06'E) run-off from the Jabal Tarabulus is, in places, impounded in depressions behind the coastal dunes, and some water bodies so formed may persist from year to year. The most important of these are in the Wadi Kiam between Al Khums (32°39'N/14°16'E) and Zlitan (32°28'N/14°34'E), and in the Wadi Turhat some 50 km east of Tarabulus. These water bodies are brackish and fringed by reeds, rushes and sedges. All these sites are important to wintering and migrating waders and are unprotected.

(B) THE GULF OF SIRTE

General: Drainage from the eastern end of the Jabal Tarabulus is by several wadis to the great sabkhat of Tawurgha which extends along shore behind the sand beach for 100 km between Misratah and Bu'ayrat al Hasun. This area of salt-marsh and salt pan is up to 25 km wide and covers 230 000 ha, with fresh water springs at several places on the landward side, e.g. at the village of Tawurgha (32°03'N/15°06'E). The flora and fauna are as described in the regional introduction and the area is unprotected.

Other salt pans, some of considerable extent, occur inland on the Plain of Sirte. One of the largest, parts of which may be temporarily, and very shallowly inundated, is immediately north of Maradah, and at its western end, wells yield potable water. Another, brackish pan, 90 m asl, the Sabkhat al Qunayyin (29°59'-30°26'N/20°50'-21°10'E), covers 120 000 ha and extends N-S for 45 km with a maximum width of 30 km. It lies 100 km northwest of the northern end of the Calanscio Sand Sea, and a chain of small oases stretches between the sand sea and the pan. However, the most important wetland in this region is the great marsh (30°22'-30°55'N/19°50'-20°11'E) behind the coastal dunes at Ajdabiya. This is 70 km long and 12 km wide in places, and carries typical salt-marsh/swamp vegetation. There are clusters of salt pans at its southern and northern ends, but the marsh itself is virtually at sea level, and is permanently wet and brackish. Again, this is an important site for wintering and migrating birds, and also for other elements of the wetland fauna.

North of this, continuing up the eastern side of the Gulf of Sirte towards Banghazi, there is a series of salt pans subject to temporary inundation behind the barrier beach. These begin at Qaminis (31°40'N/20°01'E) and continue as far as Tukrah (32°32'N/20°35'E). Immediately north of Qaminis, a system of pans reaches 40 km inland from the sea. Many carry halophytic vegetation including species of *Juncus*, *Limonium*, *Salicornia*, *Sarcocornia* and *Suaeda*, with *Phragmites* and and some sedges along watercourses which frequently carry water. Others north of Banghazi have freshwater pools, but these particular sites are very much disturbed and threatened by the encroachment of urban

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development. All these sites are important for wintering and migrating birds including *Phoenicopterus ruber*, and all support populations of amphibians and grass snakes.

2. Oases

(A) OASES OF THE GHAT REGION

General: The city of Ghat (24°58'N/10°11'E) is situated 640 m asl, close to the Algerian border, under the western slopes of a high promontory (Jabal Arakus) which reaches north from the Tassili N'Ajjer into Libya. There are some 20 natural springs in the city itself, which water gardens and plantations of *Phoenix dactylifera*, and there are numerous wells. Another 15 springs and more wells occur at Tounin, 1 km west of Ghatel, where again, there are extensive date palm plantations. Close by there are 3 permanent spring fed lakes at Tin Djeraben, another at Habschat, and at Feuet, just east of Ghat, three more spring fed pools. At Al Barcat, 12 km south of Ghat, there are numerous pools and areas of natural swampland. There is also a large pan, the Sabkha of Ghat, which holds water temporarily after rainstorms. Water from the springs and wells is fresh, that of the sabkha is saline.

Flora & Fauna: The shallow pools and the swamps of Al Barcat support macrophytes, both emergent species, e.g. *Juncus* spp., *Phragmites australis*, *Scirpus holoschoenus* and *Typha capensis*, and submerged species such as *Ceratophyllum demersum*, *Potamogeton* spp., and *Utricularia* spp. Species of *Chara* abound in most of the pools, and there is an abundant plankton. Mosquitoes are present, as well as three molluscs, *Biomphalaria pfeifferi*, *Bulinus truncatus* and *Melanoides tuberculata*; thus both bilharzia and malaria occur here. Four fishes are known from the area. *Barbus deserti* occurs in the pools and swamps of Al Barcat (the type locality) and *Clarias lazera* in most wadis. *Hemichromis bimaculatus* is also present in the ponds of Al Barcat, while *Gambusia affinis* has been introduced to almost all the local ponds, frequently at the expense of the other species. *Bufo regularis*, *B. viridis*, *Rana ridibunda* and *Tomopterna cryptotis* are common. Several small mammals are found here, including cats and rodents.

Human Impact & Utilisation: The area has long been inhabited and has supported agriculture for centuries. The city of Ghat is growing and encroaching upon the oasis. There are extensive *Phoenix dactylifera* plantations.

Conservation Status: Unprotected.

(B) OASES OF THE SABHA DISTRICT

General: The greatest concentration of oases in Libya, comprising many seguias, springs and pools, is set within a great rectangle of desert, 263 km long and 175 km wide, defined by the 4 co-ordinates 25°54'N/12°56'E; 27°29'N/12°56'E; 27°29'N/15°26'E; and 25°54'N/15°26'E. Within this area the great Idhan (erg) of Ubari extends eastwards from Algeria into Libya, narrowing and terminating in a point, known as the Ramlat az Zallaf, northeast of the city of Sabha (27°03'N/14°26'E). This extension of the erg lies between two valleys, both oriented roughly E-W. These are the Wadi ash Shati on the northern side and the Wadi al Hayah on the southern side. Along the northern side of the erg, 50 km north of Sabha, sands have intruded into the Wadi ash Shati, over a distance of

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about 160 km between Idri (27°44'N/13°10'E) in the west and Ashkidar (27°32'N/14°30'E) in the east. A large number of springs occur along both sides of this wadi giving rise to settlements at Idri, Qattah, Al Qardah and Ashkidhar, and *Phoenix dactylifera* plantations occur almost throughout the valley.

Other springs and saltwater lakes occur in depressions between the dunes of the erg proper, in the area between Ubari (26°35'N/12°46'E) to the SW and Sabha to the NE. The lakes occur where the water table reaches the surface, and in some places it appears that the water emerges under pressure. The most important are at Al Emba (26°52'N/13°01'E), Mandara (26°47'N/13°19'E), Umm al Hasan (26°55'N/13°22'E), Fredga (26°59'N/13°22'E), Bahar et Truna (26°58'N/13°36'E), Nesc'huscia (27°00'N/13°41'E), Umm al Ma (26°52'N/13°41'E), Bahar ed Dud (26°46'N/13°45'E) and Tadecma (26°52'N/13°54'E). While some of these lakes are marked at different co-ordinates on different maps we believe the positions given here to be accurate.

On the southern side of the erg extension (Ramlat az Zallaf) there are springs and plantations at Ubari, and passing eastwards, others along the Wadi al Hayah in the vicinity of Al Fjayj (26°33'N/13°19'E), and yet others at Sabha and Samnu (27°17'N/14°56'E).

An elevated rocky strip of land some 60-70 km wide, separates the Idhan Ubari (Ramlat az Zallaf) in the north from another great erg, the Idhan Murzuq to the south. Wadis fringe the northern margins of this latter erg, and oases again occur in their beds. There are several springs between the towns of Tsawah (25°59'N/13°29'E) and Murzuq (25°56'N/13°58'E) on the Wadi Atabah, surrounded by extensive date palm plantations. Further east a long and narrow extension of the erg carries many more springs along its northern flank, from Umm al Aranib (26°09'N/14°48'E) eastwards for 53 km towards Tmissah (26°19'N/15°45'E), and again this strip of desert is heavily planted with *Phoenix dactylifera*.

In this region, which has few recording stations, June is the hottest month, with a mean temperature of 32.3°C at Sabha, and January the coldest month, with a mean temperature of 11.2°C. Absolute minimum temperatures at ground level are extremely close to 0°C, though no frost has been recorded at Sabha, and absolute maxima in the area probably approach 50°C, e.g. 49°C was recorded at Murzuq in July 1932. Clouds are uncommon in the sky and mean annual rainfall probably does not exceed 10 mm throughout the region. Totally rainless years are not uncommon.

Hydrology & Water Quality: The spring waters are generally fresh, but those of the pools and swamps between dunes are often highly saline with conductivities approaching 2750 µSiemens/cm.

Flora & Fauna: Algae occur in the pools, where *Chara* spp. are common and often abundant. *Phragmites* and *Scirpus* grow around some pools, but most natural trees have been cleared and replaced with *Phoenix dactylifera*. The fauna is not well known but *Bulinus truncatus* is widespread and bilharzia occurs in the area. No fish are recorded from the area. However, the pools on the erg (Ramlat az Zallaf) are famous because the brine shrimp, *Artemia oudneyi*, occurs in them. Species of *Bufo* and *Rana* occur at oases in the wadis. The typical spectrum of desert mammals is present.

Human Impact & Utilisation: The pools of the erg are little disturbed and support small communities of negroid people, who have clearly been isolated for a great length of time. The valley oases are the sites of settlements, large and small. Herding and the culture of

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dates and other crops occurs at most of them. The natural vegetation of the oases has largely been destroyed. Sabha has a population in excess of 300 000 and water is piped in from other oases.

Conservation Status: Unprotected.

(C) THE LAKES OF WAU EN NAMUS

General: In southern central Libya, on an isolated and elevated stony plain, is the volcanic crater of Wau en Namus (24°54'N/17°47'E). It is a young volcano, formed about 5000 years ago, and part of a sporadic chain of volcanoes leading away to the northwest. The crater is 4 km in diameter with a central cone 120 m high, about the foot of which are 5 small lakes, 434 m asl, totalling 32 ha in extent. The lakes are saline although fed by freshwater springs, some of which are hot. Their salinity is presumably due to the fact that over the long period of their existence, c. 5000 yrs, they have concentrated salts with rates of evaporation which could be as high as 5000 mm/yr. Over most of the crater floor the water table is barely 1 m deep. Three lakes are thought to be permanent, while the two smallest ones are known to dry up periodically.

Flora & Fauna: The lakes are fringed by *Phragmites australis* and there is a grove of *Hyphaene thebaica* and *Tamarix nilotica*. We have no information regarding the fauna except that it is a stopping off point for migrating waterfowl.

Human Impact & Utilisation: The oasis is visited by travellers along the caravan route between the large oases at Sabha (27°03'N/14°26'E) and Al Kufrah (24°10'N/23°15'E). However, traffic along this route has declined in recent years. The oasis is not inhabited and is virtually undisturbed.

Conservation Status: Unprotected.

(D) THE OASES OF KUFRAH

General: The town of Al Kufrah with its several oases is situated in an elliptical trough, measuring 100 km from E-W and 60 km from N-S, in the southeastern desert. The basin has a flat sandstone floor at an altitude of 465 m asl, and is surrounded by scarps and low hills reaching 600 m asl on the north, east and south, with a sand desert, the Ramlat Rabyanah on the west. The water table is close to the surface throughout the trough and lakelets occur in depressions between dunes adjacent to the trough in the Ramlat Rabyanah, e.g. at Rabyanah (24°14'N/21°59'E), 'Ayn (24°26'N/22°26'E) and Buzaymah (24°44'N/22°03'E). In the Al Kufrah trough the principal oases are at Bir al Ikwan (24°30'N/23°26'E), 'A 'ilat al Judayyid (24°22'N/23°30'E), Buwaymah (24°14'N/23°24'E), At Taj (24°13'N/23°17'E), Al Kufrah (24°08'N/23°18'E) and At Tallah (24°08'N/23°11'E).

There is a series of small saline (natron) lakes in the Al Kufrah trough, some of which are hypersaline with crystalline sodium sulphate on their beds. Nevertheless, it appears that all the lakes derive their water from the underlying groundwater, and not from the evaporation of rainwater which is virtually nil. Mean annual precipitation at Al Kufrah is less than 2 mm and one year in every 2.6 is completely rainless. The maximum annual precipitation recorded was 12.5 mm. The mean monthly temperatures of the hottest month, August, are around 31°C and those of the coolest month, January, 12°C. Absolute

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maxima are in excess of 45°C throughout the trough while absolute minima are about -2°C. Potential evaporation is said to approach 6000 mm/yr.

Flora & Fauna: A species of *Ruppia* occurs in some lakelets between dunes in the erg, and these are fringed by *Cyperus laevigatus* with stands of *Phragmites australis*, all backed to landward by *Juncus maritimus*, and this in turn by *Tamarix* bushes and palms, originally *Hyphaene* but now largely *Phoenix dactylifera*. Many of the springs and ponds of the trough are also reed fringed and contain abundant algae, chiefly *Chara vulgaris*. There are extensive *Phoenix* plantations in the trough. We have no reliable information regarding the fauna.

Human Impact & Utilisation: Dates are grown and water from the oases supports a substantial human population in several small towns. Major irrigation schemes were inaugurated in the 1960s and it is planned to pump water supplies from the underground basin to the coast via the Sarir Water Wells Field (27°35'N/21°26'E).

(E) OTHER OASES

General: Vast water supplies lie beneath the Ramlat Rabyanah, and natural oases occur on the northern fringes of the erg at Zighao (25°28'N/22°04'E), 245 m asl, and at Tazirbu (25°43'N/21°06'E), 184 m asl. Water is extracted from the artesian basin south of Tazirbu and pumped from the water wells there to the Sarir field en route to the coast.

Other oases occur at Wau al Kabir (25°20'N/16°43'E) 415 m asl, in the central south, and at Al Awaynat (25°52'N/10°36'E) 105 km north of Ghat. In the north central district, south of the Plain of Sirte, there are oases at Waddan (29°12'N/15°56'E), Al Fuqha (27°52'N/16°22'E), Zallah (28°33'N/17°34'E) and Maradah (29°15'N/19°11'E).

The most easterly group of oases is situated near the Egyptian border in the vicinity of Al Jaghbub (29°42'N/24°38'E). The most northerly is at Saniyat ad Daffah (30°07'N/24°08'E), and the most southerly is in the Great Sand Sea at Bir at Tarfawi (29°34'N/24°03'E). Two others, Ayn Malfa (29°49'N/24°50'E) and Ayn al Qusaybayah (29°35'N/24°48'E), are right on the border, the latter below sea level. This group is of biological interest because the oasis at Al Jaghbub contains molluscs of marine origin, including a population the relict cockle, *Cardium edule* ssp. *rectidens*.

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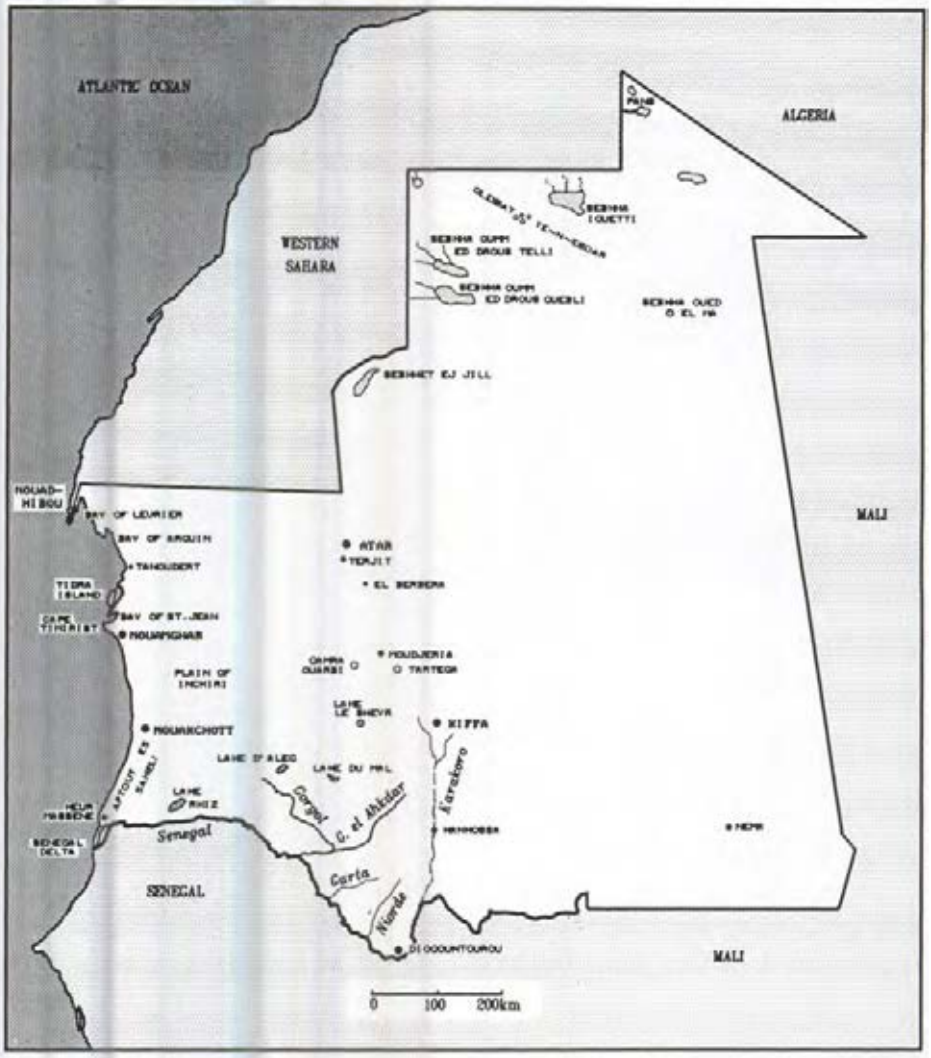

Map of Mauritania

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1.3 MAURITANIA

Introduction

Mauritania has an area of 1 030 700 km^2, a population of 1 781 000, and therefore a mean population density of 1.7 persons/km^2. The country extends 1430 km from north to south between latitudes 14°46'N and 27°23'N, and 1275 km from east to west between longitudes 4°44'W and 17°04'W. It is bounded by Senegal and Mali in the south, by Mali in the east, by Algeria and Western Sahara in the north, and by Western Sahara and the Atlantic Ocean in the west. It has an Atlantic coastline of 815 km and a broad coastal plain below the 100 m contour. This extends inland for over 300 km in the south and 70 km in the north. East of this a tortuous scarp line rises abruptly to a flat interior peneplain lying 180-230 m asl. There are many inselbergs in the lowlands immediately to the west of the gullied and dissected scarp line. Other inselbergs are situated on the interior peneplain. The highest point in the country, 915 m asl, is reached at Kediet ej Jill (22°38'N/12°33'W) on the western central part of the interior peneplain. This comprises a number of plateaux separated by broad fossil wadis, e.g. the plateau of Adrar in the central region, and that of the Tagant to the southeast.

Most of the country is covered by skeletal soils with at least 50% being covered by sand dunes. The major dune fields cross the central region in parallel lines oriented SW-NE, and extend from the coast to the northeastern border with Mali. The western edges of the paleozoic sandstone plateaux of the Adrar and Tagant are deeply dissected and the many steep-sided gorges form dendritic systems leading to wide wadis. More often than not the wadi beds are partly choked by sand dunes.

Regular drainage occurs only in the south, where rains occur each summer, and is to the Senegal River which flows along the southern border. Rainfall over the rest of the country is extremely unreliable and falls in the north are often so light as to produce little run-off. However, occasional storms produce ephemeral floods in wadis, and these are either dissipated in large pans (sebkhets) in the interior, some of which hold large temporary ponds, or reach the coastal marshes via the depressions between lines of dunes. In some of the higher and more sheltered gorges, semi-permanent surface waters collect in pools (gueltas) or there may be springs.

Climate

Mauritania is hot and extremely arid. North of the Tropic of Cancer, NE Trade Winds blow constantly from the Sahara, and for 8-10 months they prevail over the southern parts of the country as well. Their influence wanes in the south only as the intertropical convergence moves north in summer, bringing humid air to southern and central districts. The humid air mass persists over the southernmost regions for up to three months, but may reach the central districts only for a week or two. At Sélibabi (15°10'N/12°11'W) where the mean annual rainfall exceeds 550 mm, the rains may begin as early as June and persist until October. At Kiffa

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(16°37'N/11°42'W), where rain falls in the July-September period the mean annual receipt is 350 mm. However, slightly farther north and to the west, Boutilimit (17°33'N/14°42'W) receives rain only in August and early September, and mean annual precipitation at Nouakchott, on the coast (18°06'N/15°57'W), is only 139 mm. Here mean monthly totals are 12 mm in July, 58 mm in August, 42 mm in September and 10 mm in October. Thus at this centre, 88% of the annual rain falls in 4 months and 72% in August-September. In the central region, neither Tidjikdja (18°33'N/11°35'W) nor Atar (20°31'N/13°03'W) has a truly rainy month. Both these towns are situated on the edge of the peneplain. Atar receives a mean annual total of 103 mm of rain per year, and Tidjikdja 140 mm. At Atar the wettest months are August and September with mean monthly totals of 33 and 37 mm respectively, i.e. less than 1 inch per month. Still farther north, mean annual rainfall at Nouadhibou (20°54'N/17°04'W) is less than 50 mm, while Fdérik (22°41'N/12°43'W) and points farther north are virtually rainless. Annual rainfall variations are large throughout the country, e.g. at Kiffa 65 mm were received in 1924 and 663 mm in 1933.

The mean temperature of the coldest month at Nouakchott is 21°C and that of the warmest month 30°C. Farther north, but still on the coast at Nouadhibou the corresponding figures are 20°C and 26°C. Here the lower temperature for the warmest month reflects the influence of the cold Canary Current which flows close to the shore at Nouadhibou, but swings away westwards to the south. Mean temperatures for the coolest and warmest months at interior centres are 23°C and 34°C for Kiffa, 24°C and 34°C for Tidjikdja, 20°C and 35°C for Atar, and 18°C and 33°C for Fort Gouraud. The mean annual temperature at Akjoujt (19°44'N/12°20'W) is 28.4°C which makes it among the very hottest centres in the Sahara. Potential evaporation exceeds 3500 mm over most of the country and reaches 4500 mm in the north. Relative humidity is generally low 10-30% across the country, except during the rainy season in the south when values as high as 80% may be reached.

Wetlands

Tidal wetlands occur in the Senegal River Delta and along the coast between Cape Timirist (19°23'N/16°33'W) and Nouadhibou, but mangrove vegetation reaches a northern limit in the vicinity of Tidra Island (19°38'N/16°23'W). Other, non-tidal, wetlands occur along the coastal strip immediately behind the beach; here drainage from the interior is impeded by the barrier beach with the consequent development of broad brackish marshes. However, economically, the most important wetlands in Mauritania are along the Senegal River. There are several large pans in the interior which may contain lakes of standing water for short periods after ephemeral rains, and the floors of some wadis occasionally contain running water. Surface water collects into semi-permanent pools (gueltas) in the upper reaches of some gorges on the escarpments of the Adrar and Tagant. Some oueds have water tables sufficiently close to the surface, sufficiently often, to support arborescent vegetation, and there are springs (oases) in others.

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List of Wetlands Described

1. Tidal Swamps
2. Coastal Swamps & Marshes
   (a) The Marais de Toumbos
   (b) Marshes of the Aftoût es Sâheli
   (c) Coastal Pans
3. The Floodplain of the Senegal River
4. The Senegal River Delta
5. Natural Lakes
   (a) Lake Rkiz
   (b) Lake Tianbrank
   (c) Mare du Diaouling
   (d) Mare de Nier
   (e) Lake d'Aleg
   (f) Lake du Mâl
   (g) Mare de Kankossa
   (h) Mare de Mamoude
   (i) Lake le Bheyr
6. Interior Pans - Sebkhets
7. Oases: Oueds, Gueltas & Springs
   (a) The Oum Lem Har Gorge
   (b) The Springs of Terjit
   (c) The El Berbera Oasis
   (d) The Tartega Gueltas
   (e) The Gamra Ouarbi Gueltas & Oued of El Housseiniya
8. Artificial Impoundments

1. Tidal Swamps

General: There are close to 63 000 ha of tidal land in Mauritania, excluding mudbanks. Vegetated tidal land occurs in the far south of Mauritania, in the delta of the Senegal River, but is absent between there and Cape Timirist. Between these points the sandy beaches are backed by a high ridge and are exposed to strong wave action.

A small tidal swamp, of 200 ha, is situated immediately behind Cape Timirist, with other swamps at either side of the mouth of the Bay of Saint-Jean. Other tidal swamps are found half way along the southern shore of this bay, and also at the head of the bay where the Sebkhet Râs el Mâ is 3 km wide and tapers to a point 7 km inland. On the northern shore there is a small swamp, midway along, and another at the head of an arm of the bay which branches off from the north shore. Altogether there are about 3100 ha of

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tidal swamp and marshland on the bay, and several hundred hectares of mudbank near the mouth, which are exposed at low tide.

Immediately to the north, tidal swamps are well developed in the vicinity of Tidra Island (19°36'-19°49'N/16°18'-16°27'W). Such a swamp runs for 37 km along the eastern shore of the island covering 7400 ha. Other tidal swamps occur across the 2-6 km wide channel that separates the island from the mainland. Here there are some 1400 ha of mangrove swamp on emergent mudbanks and a further 1700 ha in bays on the mainland. A 2800 ha swamp lies behind the mainland beach in a 22 km long depression, oriented SW-NE, which is open to the sea at both ends. The sea ward shore of Tidra Island carries a 20 km long, 1600 ha swamp, which is rather more than 2 km wide in places, while other swamps occur on Kîji (19°40'-19°44'N/ 16°27'-16°31'W) and 13 smaller islands. Some of the small islands are 5 km long and 1 km wide, and are all completely covered by mangroves, while the swamp on Kîji is 7 km wide and 2.5 km wide at the southern end. To the northwest the two Arel Islands are also totally mangrove clad. A rectangular mudbank, 24x22 km, separates the Arel Islands (19°54'-19°57'N/16°30'-16°34'W) from Tidra and Kîji, most of which is exposed by the lowest tides. Excluding emergent banks, there are nearly 19 000 ha of tidal swamp in the Tidra area.

North of Tidra a tidal swamp, some 16 km long and 1-3 km wide, extends up the coast from latitude 20°00'N to Râs (Cape) Tafarit (20°08'N). North of this, the southern shore of the Bay of Tanoûdêrt is devoid of swampland, but the sea again inundates a low lying area beginning on the north shore of the bay near Tanoûdêrt village (20°13'N) and extending northwest for 72 km, to the head of the Bay of Arguin (20°48'N). This long salt-marsh varies in width from a few hundred metres to over 5 km and comprises 18 000 ha of tidal land. Other salt-marshes, to landward of extensive mudbanks, occur on the shores of Marguerite, l'Ardent and d'Arguin Islands in the bay of Arguin. Other mudbanks and narrow salt-marshes extend for 18 km up the western bayshore from Cape d'Arguin to the bayhead. There are some 19 000 ha of tidal marsh in this coastal sector.

In the most northern coastal section, salt-marshes are well developed along the shores of the Bay of Lévrier. Leaving Cape d'Arguin, the first 18 km of coastline, running NW, is of high relief, but thereafter 3 large salt-marsh blocks occur on the eastern bayshore. The southernmost (20°40'-20°48'N/16°38'-16°47'W) is 14 km long and 2 km wide in places; the second (20°49'-20°58'N/16°44'-16°47'W), separated from it by a 3 km stretch, is also 14 km long, but reaches a width of 6 km. A gap of 12 km intervenes between this and the final salt-marsh (21°02'-21°17'N/16°48'-16°58'W), which runs for 24 km round the head of the bay and extends inland for 13 km in a block 8 km wide. This is known as the Sebkhet Aloueifat. This last salt-marsh covers 14 600 ha. Other tidal marshes occur down the western shore of the bay to Nouadhibou in discontinuous fashion, and another small marsh occurs on the Atlantic side of the Cape Blanc Peninsula, north of Cape Blanc (20°46'N/17°03'W) in a depression behind Cape Dubouchage (20°51'N/17°06'W). There are more than 21 500 ha of salt-marsh on the Bay of Lévrier.

Hydrology: Spring tidal range on the northern coasts is close to 2.1 m and as coastal slopes are gentle, the tide penetrates several kilometres inshore. However, a consequence of this is that at neap tides, with an amplitude of only 60 cm, vast areas of the marshes are unflooded for substantial periods and salts crystallise at the surface.

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The landward fringes are therefore highly saline. The sea between Cape Blanc and Cape Timiris is remarkably shallow and is mostly less than 5 m deep at low tide. Direct precipitation over the salt-marshes is minimal, averaging less than 40 mm/yr.

Flora & Fauna: Mangroves occur on the Senegal River Delta where *Rhizophora racemosa* is dominant along creeks and *Avicennia africana* covers the back-swamps, with occasional specimens of *Conocarpus erectus* on sandy ridges. *Avicennia africana* forms monospecific tidal woodlands around Tidra Island and the mainland opposite. This species also dominates the tidal zones of the swamps on the Bay of Saint-Jean. North of Tidra, herbaceous vegetation covers tidal marshes which often contain large barren salinas. Vegetation is frequently confined to the landward fringe and a seaward belt subject to daily inundation. The middle zones, subject to infrequent inundation, are extremely saline. *Sesuvium portulacastrum* and species of *Salicornia* and *Suaeda* predominate. Some typical strand species, such as *Ipomoea pescaprae* and *Sporobolus virginicus* occur on the margins of the salt-marshes. *Cymodocea nodosa*, *Halodule wrightii* and *Zostera* sp. dominate the lower mudflats, with *Spartina maritima* at upper levels immediately to seaward of the mangroves.

The shallow offshore waters are an important breeding ground for fish, and details of local fish populations can be found in the Bulletins of the Laboratoire des Pêches de Nouadhibou. Four species of turtle breed on the northern beaches, *Caretta caretta*, *Chelonia mydas*, *Dermochelys coriacea* and *Eretmochelys imbricata*. All are endangered.

The Banc d'Arguin is in the Atlantic flyway and it is estimated that several million waders, which breed in northern Europe, overwinter in the region each year, and quite possibly as many as 2 million birds frequent the Banc d'Arguin National Park. These include *Calidris alpina*, *C. canutus*, *C. ferruginea*, *Charadrius hiaticula*, *Limicola falcinellus*, *Limosa lapponica*, *Platalea leucorodia* and *Pluvialis squatarola*. Various African species breed on the islands, among them *Ardea cinerea*, *Chlidonias nigra*, *Egretta gularis*, *Gelochelidion nilotica*, *Hydroprogne caspia*, *Larus genei*, *Pelecanus onocrotalus*, *Phalacrocorax africanus* and *Phoenicopterus ruber*.

Most of the common wetland mammals associated with the West African and North African regions are absent in this transition zone. Other species, which extend into this zone on the Atlantic coast of the Sahara, have expanded their ecological amplitudes and occupied the niches of the absent species. Rodents are present in the landward parts of the marshes, and among the carnivores recorded in wetlands here are *Canis aureus*, *Felis lybica* (often referred to *F. sylvestris*), *F. margarita*, *Genetta genetta*, *Vulpes rupelli* and *Poecilogale albinucha*. *Monachus monachus* occurs on the coast around Cape Blanc.

Human Impact & Utilisation: Much of the coast is very sparsely populated and human interference is minimal. The peripheral wetlands are browsed by camels and goats. The offshore waters are fished intensively by an international fishing fleet and there is a concern in some quarters that a consequent reduction in the fish populations will adversely affect the aquatic bird populations.

Conservation Status: A very substantial area of the coast, including both mangrove and salt-marsh, is protected in the Banc d'Arguin National Park between 19°21'N and 21°51'N. This includes all the mangrove and salt-marsh in the Tidra district, and all tidal marshes in the Bay of Arguin.

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2. Coastal Swamps & Marshes

(A) THE MARAIS DE TOUMBOS

Location: 16°32'-16°47'N/16°18'-16°26'W
Area: c. 5000 ha (1400 ha permanent water)
Altitude: 1-2 m asl
Nearest Towns: Keur Massène (19 km E); Nouakchott (140 km N)

General: The swamps consist of a series of vegetated, permanently inundated depressions, situated in an area of wet sands parallel to the barrier beach. The swampy basin is 29 km long, with a SSW-NNE axis, and the largest of the flooded depressions, known as the Marais de Toumbos, is 12 km long and up to 1.3 km wide. It is situated 2.8 km from the beach and is entirely surrounded by an area of permanently wet sands. Immediately to the south of this lake, an isolated shallow lakelet, known as Chott Boul, approaches to within 400 m of the beach. Flats subject to periodic inundation lie to the south of the system in the delta of the Senegal River, and also to the north along the Aftoût es Sâheli where coastal marshes stretch up the coast for 140 km to Nouakchott.

Hydrology: The swampy basins are flooded semi-permanently although the water levels fluctuate considerably during the course of a year. Water is derived from direct precipitation, and from run-off and seepage from the hinterland, and collects behind the beach barrier. The water is generally brackish.

Flora & Fauna: The swampy lakes contain *Phragmites mauritianus* and *Typha domingensis*, and the surrounding sands support *Acacia nilotica* and *Tamarix senegalensis* as well as bushes of *Arthrocnemum*. The fauna is as for the Senegal River Delta.

Human Impact & Utilisation: Relatively undisturbed.

Conservation Status: Unprotected.

(B) MARSHES OF THE AFTOUT ES SAHELI

Location: 16°00'-18°00'N/16°00'-16°30'W
Area: 120 000 ha
Altitude: 0-1m asl
Nearest Towns: Nouakchott (at N end); Keur Massène (at S end)

General: The coastal strip known as the Aftoût es Sâheli stretches from the Senegal River Delta to the vicinity of Nouakchott, 175 km north. The southern end of the strip encompasses the Marais de Toumbos, and thereafter it is subject to periodic inundation all the way to Nouakchott. The southern part of the strip is over 12 km wide, but the marshes narrow towards the north where they may be only 3-5 km wide. The wetland is a mosaic of vegetational zones which reflect the depth and duration of inundation. In general the side nearest the beach is subject to deeper and more prolonged inundation than the landward side, but the zones interdigitate. The most deeply flooded zones hold water for up to 6 months in some years. The hinterland is covered with scrubby savanna in the south and steppes in the north and comprises a lowland, 20-30 m asl, with a series of SW-NE oriented parallel ridges.

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Hydrology & Water Quality: The waters rise following the late summer rains, between July and September. Much water is lost to the sea by seepage, and much more by evaporation, but there is a slow longshore flow to the south, to the Senegal River Delta. The surface waters are always brackish, and the soil water is saline. All the wells along the landward margin produce saline water.

Flora & Fauna: *Tamarix senegalensis* is very common locally, as are bushes of *Arthrocnemum glaucum*, and these two species dominate large areas subject to minimal inundation. Species of *Salicornia* and *Suaeda* are locally abundant on lower sites and *Juncus*, *Phragmites*, *Scirpus* and *Typha* occur where inundation is more prolonged. *Avicennia africana* grows on the fringes of these marshes in places, in non-tidal and very infrequently flooded sites. Fauna as described in the introduction for coastal wetlands.

Human Impact & Utilisation: The area is extremely sparsely populated and has been little interfered with. A road from Keur Massène and the delta towns runs along the landward side of the marshes to Nouakchott, but there are few settlements along this.

Conservation Status: Unprotected.

(C) COASTAL PANS

General: The most important group of coastal pans occurs behind the beach between Nouakchott and Nouâmghâr (19°20'N/16°30'W) on the Plain of Inchiri where the SW-NE lines of dunes are less pronounced. There once were 4 separate major pans. From south to north these were the Sebkhet Te-n-Dghâmcha (18°19'-18°48'N/15°46'-16°07'W), the largest pan, some 6 km from the beach, two pans (18°56'-19°03'N/15°47'-16°01'W) and (18°48'-19°07'N/15°27'-15°49'W), 15 and 25 km from the sea respectively, and the Sebkhet Te-n-Loubrar (19°01'-19°14'N/16°01'-16°16'W) right on the sea. Sebkhet Te-n-Dghâmcha measured 55 km along a N-S axis parallel to the coast. It had a mean width of 15 km and an area of 37 500 ha. Altogether the 4 sebkhets covered more than 100 000 ha. However, there appears to have been some reduction in the size of the northern pans and the amalgamation of some of the southern pans in recent years.

Hydrology & Water Quality: All the pans are subject to shallow periodic and very temporary inundation, but small areas representing perhaps 1% of the total area, are subject to deeper and more prolonged inundation. When the pans are covered to depths of 5-10 cm these depressions form pools 1-2 m deep. These pans do not contain any fully permanent lakes. Water collects in the pans from direct precipitation, by seepage from the hinterland, and by direct run-off. All the pans are saline.

Flora & Fauna: The vegetation of these pans is halophytic and there are substantial barren areas. Genera such as *Arthrocnemum*, *Frankenia*, *Salicornia*, *Salsola*, *Suaeda* and *Tamarix* are in evidence. The fauna is as described for coastal wetlands in the regional introduction.

Human Impact & Utilisation: Unknown.

Conservation Status: Unprotected.

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3. The Floodplain of the Senegal River

Location: 14°48'-17°11'N/12°14'-16°30'W
Area: c. 256 000 ha in Mauritania.
Altitude: 5-23 m asl
Nearest Towns: Kaedi (on floodplain); Sélibabi (70 km NE)

General: A floodplain is well developed along the right bank of the Senegal River in Mauritania all the way from Diogountourou (14°48'N/12°14'W) where the borders of Senegal, Mali and Mauritania meet, to the delta above St. Louis. The river forms the Senegal/Mauritania border continuously between Diogountourou and the sea. The floodplain is only 100 m wide at Diogountourou, but increases in width to 8 km opposite Semme (15°11'N/12°57'W). Thereafter it varies from 1-8 km wide all the way to the delta. Other floodplains occur on right bank tributaries such as the Niordé, Garta and the Gorgol and their affluents. The floodplain on this latter stream is the best developed and reaches 7.5 km in width over the lower reaches. It extends 75 km upstream, and thereafter for a further 60 km on each of two affluents, the Gorgol el Abiod and Gorgol el Ahkdar. The main floodplain includes numerous oxbow lakes and lagoons at its lower levels. A detailed description of the floodplain is given in section 3.13.1.

Flora & Fauna: Lagoons and oxbow lakes are fringed by *Phragmites mauritianus* and *Typha domingensis*. *Phragmites mauritianus* also occurs along the banks of the affluents in their upper reaches. The floodplain supports typical floodplain grasses, with *Oryza barthii* at the levels of deepest inundation, and species such as *Echinochloa pyramidalis* at middle depths. *Andropogon gayanus*, *Oryza longistaminata*, *Panicum anabaptismum*, *Paspalum orbiculare*, *Vetiveria nigritana* and numerous other species occur on the margins. Strips of swamp forest occur along the river, dominated by *Cola laurifolia*, *Cynometra vogellii* and *Diospyros elliotii*. *Acacia nilotica* is however, the commonest riparian tree, but grows in sites subject only to seasonal inundation.

Few large native mammals now occur on the floodplain, having been ousted by domestic cattle. The fauna is as described for Soudanian river floodplains in the introduction to Region 3. Some crocodiles, both *Crocodylus cataphractus* and *C. niloticus* remain in the rivers, but both are scarce. Monitor lizards, *Varanus* sp., are more common and there are numerous snakes. Bird life is prolific and is dealt with in the introduction to Region 3. Small mammals are common in the river banks and reed beds and include species such as *Aonyx capensis*, *Atilax paludinosus*, *Dasyinys* sp., *Lutra maculicollis* and *Thryonomys swinderianus*.

Human Impact & Utilisation: Numerous small centres of population along the margins of the floodplain depend for their existence directly on the floodplain, and plans to build dams across the river will doubtless have a fundamental effect upon the life of the floodplain. See section 3.13.1 for more detail.

Conservation Status: Unprotected.

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4. The Senegal River Delta

Location: 15°44'-16°29'N/15°35'-16°29'W
Area: 320 000 ha (c. 120 000 ha in Mauritania)
Altitude: 0-5m asl
Nearest Towns: Nouakchott (175 km N); Keur Massène (on N delta)

General: The delta comprises large areas of low lying, seasonally flooded land, some small areas of dry land, areas of semi-permanently wet sand, river channels, islands, and numerous lakes, some of which are 6 km long and 2-3 km wide. The main channel of the Senegal River constitutes the border with Mauritania through the delta. The river approaches the delta from the east and swings abruptly southwest at the head of the delta which is 74 km long and is sandwiched between a system of dunes, oriented SW-NE on the eastern, Senegal side, and a sandy barrier beach on the western, Mauritanian side. The delta has an unusual shape, being wider at the head (c. 40 km) than it is at the point where it reaches the sea (c. 24 km). This latter region, the Langue de Barbarie, south of Saint Louis, is an area of sandbars, tidal lagoons and saline mudflats. A string of small lakes lies in Mauritania between the main river channel and the western barrier beach, and among these, Lake Tianbrank and the Mares du Diaouling and Nter are dealt with individually in the next section (1.3.5. Natural Lakes).

Hydrology: The seasonal flood at the delta rises in August and persists through November. Maximum flood depths are 1.5 m over the lowest lying areas.

Flora & Fauna: Floodplain grasses occur on the delta, and permanent reed swamps fringe some of the lakes and river channels. Some stunted trees occur on the dunes and levées, including *Acacia nilotica*, *A. seyal*, *Balanites aegyptiaca*, *Borassus aethiopum*, *Parkinsonia aculeata* and *Tamarix senegalensis*, but the area is saline due to the regular intrusion of sea water and has a harsh Sahelian climate with a severe dry season. Thus trees are not a prominent feature of the delta. For much of the year, only the vegetation fringing watercourses and waterbodies is noticeably green. At the river mouth, stable sandbars are colonised by littoral species such as *Alternanthera maritima*, *Ipomoea pescaprae*, *Sesuvium portulacastrum* and *Sporobolus virginicus*. Farther back in the delta *Sporobolus robustus* covers large areas subject to regular brackish inundation, and *Arthrocnemum glaucum* and *Salsola boryosma* occur on the fringes of the inundated zones.

Sandbars at the river mouth provide nesting sites for the marine turtles *Dermochelys coriacea* and *Chelonia mydas*, and both *Python sebae* and *Varanus niloticus* are common in the swamps. The many lakelets are important sites for the rich and prolific avifauna of the district, especially when the other delta wetlands dry up. The mangrove swamps support breeding colonies of *Ardea purpurea*, *Nycticorax nycticorax*, *Phalacrocorax carbo* and *Platalea alba*. Other species which breed in the delta include *Anhinga rufa*, *Ardeola ralloides*, *Bubulcus ibis*, *Casmerodius albus*, *Egretta garzetta*, *E. intermedia*, *Ibis ibis*, *Pelecanus onocrotalus*, *Phoenicopterus ruber* and *Threskiornis aethiopicus*. Other birds present include *Pandion haliaeetus*, which overwinters here, together with *Alopochen aegyptica*, *Anas acuta*, *A. angustirostris*, *A. clypeata*, *A. querquedula*, *Nettapus auritus*, *Plectropterus gambensis* and *Sarkidiornis melanota*. Manatees visit the delta, and almost the full spectrum of small aquatic mammals is present, as detailed in

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the introduction to Region 3, West Africa. *Felis caracal* and *Herpestes ichneumon* are known from the delta, and together with *Varanus niloticus*, prey upon young birds and their eggs. The last two species are present in large numbers. Dupuy (1971a,b,c; 1972) and Roux (1973a,b) give some account of the mammal and bird faunas of the delta.

Human Impact & Utilisation: Proposals to alter the flooding regime of the delta are recorded in section 3.13.1, The Senegal River Floodplain. Many dyke systems have been constructed in the delta to influence flooding patterns, and these have been detrimental to the wildlife of the delta. The various future programmes to control the hydrological regime (see sections 3.13.1 and 3.13.2) will all result in a reduction of flooding and a loss of wetland habitat in the delta.

Conservation Status: In Mauritania two areas encompassing Lakes Diaouling and Nter are projected Strict Nature Reserves, and a National Park has been proposed. In the Senegalese part of the delta important wetland sites are protected in the Djoudj and Langue du Barbarie National Parks and the Ndiael Bird Reserve.

5. Natural Lakes

(A) LAKE RKIZ

Location: 16°45'-16°55'N/15°10'-15°27'W
Area: 12 970 ha (total wetland area)
Altitude: 1 m asl
Nearest Towns: Rkiz (on lakeshore); Rosso (50 km SW)

General: Lake Rkiz consists of a narrow semi-permanent lake fringed by marshland subject to inundation during the rainy season. The lake is 34 km long and up to 8 km wide at high water, while the permanent lake has a maximum width of 5 km. It lies in a depression oriented SW-NE, leading to the Senegal River. It is fed by several small streams and drains to the Senegal River via the Laouinga Stream.

Flora & Fauna: *Phragmites* and *Typha* fringe the lake and floodplain grasses including *Echinochloa pyramidalis* occur in the peripheral zone. A rich avifauna is present, as described for West African Coastal Wetlands in the introduction to Region 3. Snakes are abundant. *Crocodylus cataphractus* persists here, and there is an abundant small mammal fauna including such species as *Aonyx capensis*, *Atilax paludinosus*, *Dasymys incomtus*, *Lutra maculicollis* and *Thryonomys swinderianus*.

Human Impact & Utilisation: The lake is fished and reeds are cut for thatching.

Conservation Status: Projected Nature Reserve.

(B) LAKE TIANBRANK

Location: 16°28'-16°29'N/16°22'-16°25'W
Area: 680 ha (open water)
Altitude: 1 m asl
Nearest Towns: Keur Massène (22 km NE); Rosso (59 km ENE)

General: Lake Tianbrank, on the Senegal River Delta, has an open water surface 5.9 km long and just over 1 km wide. It is a brackish lake with a water surface barely 1 m above

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mean sea level, which drains to the Mare du Diaouling through a channel 7 km long and 200–400 m in width. The lake is oriented E-W and is set against low banks of moist sand on its northern and western flanks, but with broad expanses of periodically inundated flatland immediately to the south and east. These latter extend to encompass the chain of Marigots de Bileyti to the southwest and the Mare du Diaouling to the southeast.

Flora & Fauna: The moist sandy banks support *Acacia nilotica*, *A. seyal*, *Balanites aegyptiaca* and *Borassus aethiopum*, while *Tamarix senegalensis* and *Arthrocnemum glaucum* bushes grow along the waters edge, along creeks, and on elevated sandy patches on the floodplain. The flats support *Echinochloa colanum*, *E. pyramidalis*, and other floodplain grasses, and in places, dense swards of *Sporobolus robustus*. The fauna is typical of the delta as described in the preceding section, 1.3.4.

Human Impact & Utilisation: The lake is fished and birds are hunted in the area.

Conservation Status: Unprotected.

(C) MARE DU DIAOULING

Location: 16°13'-16°28'N/16°18'-16°26'W
Area: 17 500 ha (total wetland area)
Altitude: 1 m asl
Nearest Towns: Keur Massène (18 km NE); Rosso (55 km ENE)

General: The so-called Mare du Diaouling lies in the northwestern part of the Senegal River Delta. It consists of an area of floodplain 31 km long and 13 km wide, with the small permanent mare, 6 km long and up to 2 km wide, in the north. Another small permanent lake and an open tidal creek lie to the south. The floodplain area is bounded on the east by the main channel of the Senegal River. The northern mare drains via an effluent stream which runs close to the western boundary of the floodplain to reach the Senegal River near its mouth, but the eastern part of the floodplain drains directly to the Senegal River.

Flora & Fauna: *Tamarix senegalensis* and *Arthrocnemum glaucum* occur on elevated patches of the floodplain, and *Acacia nilotica* is to be found beside the streams and lakeside in the north. However, much of the lower floodplain area is covered by the halophyte *Sporobolus robustus*, with fringes of *Salsola baryosma* on the margins and around raised 'islands'. A mangrove swamp in the south has *Rhizophora racemosa* along a tidal creek, with an expanse of *Avicennia africana* behind. The fauna is as described in the preceding section 1.3.4.

Human Impact & Utilisation: The lake is fished.

Conservation Status: Projected Strict Nature Reserve.

(D) MARE DE NTER

Location: 16°21'-16°24'N/16°24'-16°27'W
Area: 1750 ha
Altitude: sea level
Nearest Towns: Keur Massène (25 km N); Ndiago (25 km S)

General: This is a small permanent lake at sea level in the Senegal River Delta. It is situated immediately to the west of the Mare du Diaouling. The waters are brackish and

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the surrounding area is subject to tidal inundation, especially during the rainy season when fresh waters back up behind the tide. The lake is long and narrow having the form of an inverted "V", with the main body of the lake, 2 km long and 2 km wide, situated on the eastern arm of the V. The lake drains from its western arm to the Senegal River near its mouth. The peripheral zone, subject to periodic inundation extends to the back of the barrier beach which is just 3 km distant from the nearest part of the lake.

Flora & Fauna: There is some mangrove vegetation, with *Avicennia africana* and *Rhizophora racemosa* on the tidal channel and on an arm of the lake, and *Tamarix senegalensis* and *Arthocnemum glaucum* around the head of the lake. *Paspalum distichum* occurs in openings in the mangrove and along the tidal channels, while other halophytes such as *Salsola baryosma, Sesuvium portulacastrum* and *Sporobolus virginicus* occur on the margins of the tidally flooded zones. The fauna is typical of the delta and is as described in the preceding section 1.3.4.

Human Impact & Utilisation: The lake is fished.

Conservation Status: Projected Strict Nature Reserve.

(E) LAKE D'ALEG

Location: 17°02'-17°09'N/13°54'-14°04'W
Area: 4275 ha (including seasonal inundation zone)
Altitude: 30 m asl
Nearest Town: Aleg (on floodplain)

General: The small endorheic semi-permanent saline lake, 4 km long and just over 1 km wide, is situated some 10 km from the town of Aleg in the valley of the Oued Katchi. The lake is surrounded by a broad floodplain, 4-5 km wide and 21 km long which extends to Aleg.

Flora & Fauna: The lake is fringed by halophytic vegetation including species of *Arthrocnemum* and *Tamarix*. Some *Acacia nilatica* trees occur along the Oued Katchi, also *Adansonia digitata, Balanites aegyptiaca, Hyphaene thebaica* and *Tamarix senegalensis*. Baobabs also occur around the margins of the floodplain. Some halophytic grasses, including a species of *Sporobolus*, are found in the seasonally inundated zone.

Human Impact & Utilisation: Little information is available except that the lake has been fished intensively.

Conservation Status: Projected Nature Reserve.

(F) LAKE DU MAL

Location: 16°55'-16°59'N/13°17'-13°26'W
Area: 870 ha (including peripheral inundation zone)
Altitude: 68 m asl
Nearest Towns: Kaedi (83 km S); Mâl (on lakeshore)

General: This small lake is situated near the source of the Guéllouâr River which flows through it. The lake lies immediately to the west of, and parallel with, a low SW-NE scarp line which rises 28 m over the lake to an altitude of 96 m asl. The lake has two basins, separated by about 2 km, and the Kaedi to Magta Lahjar road passes between them. The upper basin is 5.5 km long and up to 2 km wide, but contains no permanent

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water, being subject only to seasonal inundation. The lower basin is 11 km long and 2 km wide and contains a permanent lake, 5 km long at its lower end. The upper part of this basin is also subject to seasonal inundation.

Flora & Fauna: Gallery forest occurs on the Guéllouâr River, dominated by *Acacia nilotica*, and trees of this species are common around the margins of the seasonally flooded zone. Reeds fringe the lake proper while the zones of seasonal inundation are covered by typical floodplain grasses as described in the regional introduction. We have no information concerning the fauna.

Human Impact & Utilisation: The 'lakes' are fished on a small scale.

Conservation Status: Projected Nature Reserve.

(G) MARES DE KANKOSSA

Location: 15°50'-16°00'N/11°30'-11°36'W
Area: 1540 ha
Altitude: 70 m asl
Nearest Towns: Kankossa (on lake); Kiffa (75 km N)

General: The Karakoro River, which rises from several intermittent tributaries in the vicinity of Kiffa, flows almost due south to the Senegal River in a flat floored valley edged by two escarpments. About 20-25 km to the west is a tall embayed scarp line which rises to heights of over 400 m and to 882 m in the vicinity of Kiffa. The eastern escarpment is 60-75 km distant from the river and rises to a maximum altitude of 373 m asl. The river is only a few metres wide, but as it flows past the town of Kankossa it widens over a 10 km stretch to some 250 m, forming the so-called Mare de Kankossa. The river narrows below the town, only to swell again, almost immediately, into the Mare de Kaora. This is 7 km long and wider than the previous mare, reaching widths of 500 m. Over this latter stretch the river receives three intermittent tributaries, the Oued Niarhlé, the Oued Ouéringuel and the Haraj Kamdi, and these contribute to the local seasonal flooding. A shallow floodplain, 11 km long and up to 3 km wide, surrounds the Mare de Kaora.

Flora & Fauna: Thin and disturbed galleries of woodland occur along the watercourses and grasses occur on the floodplains, as discussed in the regional introduction. The banks of the river support reed beds dominated by *Phragmites mauritianus* and *Typha domingensis*. We have no information concerning the fauna.

Human Impact & Utilisation: The river is fished and the gallery woodlands have been cut for fuel.

Conservation Status: Projected Nature Reserve.

(H) MARE DE MAMOUDE

Location: 16°18'-16°31'N/7°31'-7°44'W
Area: 40 000 ha (2000 ha open water + 38 000 ha floodplain)
Altitude: 185 m asl
Nearest Towns: Nema (38 km NE); Ayoûn el Atroûs (212 km W)

General: The Mare de Mamoude is a seasonal lake, 6 km long and 4 km wide, situated at the end of an intermittent watercourse. The stream which feeds it may not flow every

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year, but once full, the lake persists as an open water surface for many months and during pluvial cycles the lake is perennial. High floods inundate over 40 000 ha of the sandy plain surrounding the lake, to depths of 50 cm or more, after which the sand tends to remain humid throughout the dry season. A number of smaller areas of humid sand occur in the district and they too are occasionally flooded.

Flora & Fauna: *Phragmites* and *Typha* occur around the mare, while floodplain vegetation occurs on the seasonally inundated areas, being best developed along the affluent water course. Here, *Acacia nilotica* and bushes of *Tamarix senegalensis* may be found. *Adansonia digitata*, *Balanites aegyptiaca*, *Borassus aethiopum* and *Hyphaene thebaica* occur around the periphery of the floodplain, and locally grow upon it.

Human Impact & Utilisation: No information.

Conservation Status: Projected Nature Reserve.

(l) LAKE LE BHEYR

Location: 16°33'N/12°05'W
Area: 1200 ha (high water)
Altitude: 77 m (high water)
Nearest Towns: Kiffa (70 km E); Sélibabi (158 km S)

General: This perennial lake is situated in a sheltered depression at the foot of the western escarpment of a mountainous promontory which reaches south from the Tagant Plateau. It receives surface run-off from the highlands, but is believed to be springfed as well. At times of high water, following heavy rains, when the lake reaches 6 km in length, there is overflow to an intermittent affluent of the Gorgol el Akhdar. By contrast, during dry seasons it contracts into 2 or 3 smaller lakes, thus having a season floodplain. The lake water is fresh, but turbid and eutrophic.

Flora & Fauna: The lake margins are virtually devoid of emergent macrophytes being heavily trampled by cattle, but the periphery supports floodplain vegetation dominated by *Piliostigma reticulata*. Ponds occur upstream in the gorges of some affluent streams and these support *Phragmites* and *Typha*. Dumont (1976) gives some account of the invertebrate fauna which includes mosquitoes and *Bulinus* sp., thus both malaria and bilharzia are indigenous in the district. Among fishes, *Clarias anguillaris*, *Oreochromis galilaeus* and *O. niloticus* are common. Species of *Bufo* and *Ptychadena* occur here, and while *Crocodylus niloticus* is believed to be extinct in the lake, it still survives, together with *Varanus niloticus*, on several watercourses in the area.

Human Impact & Utilisation: There are several permanent settlements close to the lake which is a centre for cattle grazing, and supports a fishery.

Conservation Status: Unprotected.

6. Interior Pans – Sebkhets

General: If rainfall in northern Mauritania is heavy enough to produce run-off, the water collects into watercourses which terminate in flat bottomed basins, which may then be flooded to depths of 10-50 cm for a period. Water is lost from these pans (sebkhets-sebkhas) by seepage and evaporation and their soils are inevitably saline. Some sebkhets

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contain temporary lakes and ponds. These arise in depressions where flood waters accumulate to depths of several metres. In general, sebkhets carry very little vegetation and tend to remain dry for long periods; those in the far north may not hold standing water for years on end. However, temporary ponds may carry a fringe of reeds, including *Phragmites* and *Typha* spp. Among halophytic plants sometimes found on pan floors are species of *Arthrocnemum*, *Salicornia*, *Suaeda* and *Tamarix*.

The most northerly area subject to occasional shallow inundation (26°40'N/8°00'W) is 6 km long and up to 3 km wide along the Oued el Haure. Farther south some small temporary lakes form in the Sebkha Ouderat el Kiam (25°37'N/11°55'W) which is fed by several shallow wadis, and a large temporary lake, up to 18 km long, forms to the east at a point 25°53'N/8°55'W. Another large temporary lake, up to 18 km across, and four smaller lakes, develop at Gleibat-te-n-Ebdar (25°00'N/10°10'W), here providing a potential water surface of 11 400 ha. The three largest northern pans are the Sebkha Igueni (24°59'-25°10'N/ 9°34'-9°48'W), fed principally by the Oued Kherir, the Sebkha Oumm ed Drofs Telli (24°25'-24°28'N/11°08'-11°44'W) and the Sebkha Oumm ed Drofs Guebli (23°55'-24°15'N/11°36'-11°52'W). The first contains some temporary ponds, but neither of the others support open water surfaces for any length of time. However, 2 temporary ponds occur in the smaller Sebkha Iguelt or Lakakine (25°00'N/9°48'W), and a small group of temporary ponds develops in the Sebkha Bouir el Ahmar (24°44'N/8°40'W). A small temporary lake develops in the Sebkha Oued el Mâ, which receives the discharge of the Oued el Mâ, one of the large interior watercourses. Another temporary lake forms in the Sebkha Rhall Amane (23°35'-23°43'N/ 9°47'-9°54'W). Close to the border with Western Sahara, the Sebkhet ej Jill (22°40'-22°57'N/12°47'-12°53'W) is an almost barren salina.

7. Oases: Oueds, Gueltas & Springs

General: In some dry watercourses, strips of sandy soil along the thalweg may remain moist for considerable periods after rain and there may be supplies of subterranean water. Such places support perennial vegetation. The river or stream which flows in such a watercourse is known as an oued, but the watercourse *per se* may also be referred to as an oued. Gueltas are semi-permanent pools in the higher reaches of some sheltered gorge-like watercourses on the edges of the escarpments. Springs occur at faults on the walls and floors of canyons, or sometimes at the feet of dunes which have intruded into gorges. Any site of permanent water in the desert can be described as an oasis and there are a number on the edges of the Adrar Plateau near Atar, and others on the edge of the Tagant Plateau.

(A) THE OUM LEM HAR GORGE

Location: 20°35'N/13°07'W
Area: a few ha open water - variable
Altitude: 245-450 m asl
Nearest Towns: Atar (10 km E); Akjoujkt (160 km WSW)

General: The floor of the gorge descends from 450 m to 245 m over a distance of 6 km and contains many pools. The lower pools are small and tend to dry up between floods

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which may occur 2-3 times a year, while the upper pools are permanent although they may become stagnant between floods. They have maximum depths of 4-5 m between floods and mostly receive a constant small input of water from seepage. The pools show a decreasing gradient of salinity in passing up the gorge, the lower pools being highly saline before drying, while the upper ones are merely brackish.

Flora & Fauna: Species of *Equisetum*, *Juncus*, *Phragmites* and *Scirpus* grow around the upper gueltas, and 4 species of *Potamogeton* grow in them. *Adiantum capillus-veneris* grows on the wet rocky walls and there is a report of relict *Ficus sycomorus*. Four species of fish, all of tropical affinity, have been recorded in the gueltas and 4 species of amphibians. The fish are *Barbus deserti*, *B. pobeguini*, *Clarias anguillaris* and *Oreo-chromis galilaeus*, and the 4 amphibians are *Bufo maurianicus*, *B. regularis*, *Prychadena occipitalis* and *Tomopterna cryptoris*. *Varanus griseus* is abundant and there are several species of snakes in the gorge.

Human Impact & Utilisation: *Phoenix dactylifera* has been planted around the upper pools, and wood gathering over the years has probably led to the disappearance of several tree species. Cattle and goats are occasionally brought into the gorge.

Conservation Status: Unprotected.

(B) THE SPRINGS OF TERJIT

Location: 20°15'N/13°06'W
Area: c. 30 ha wetland
Altitude: c. 450 m asl
Nearest Towns: Atar (25 km NNE); Akjoujt (140 km WSW)

General: The main springs are situated at the foot of a fault across a gorge draining into the Oued el Abiod, but several minor seepages occur elsewhere in the gorge. A chain of pools, connected by a trickle of running water, stretches for about 1 km below the main springs. At least one of the springs is warm (32°C) and the waters are rich in calcium sulphate.

Flora & Fauna: Similar to that at the Oum Lem Har Gorge, but *Ficus sycomorus* is more abundant. *Barbus deserti*, *Bufo regularis* and *Prychadena occipitalis* are present, together with a mollusc, *Bulinus guerne*, which transmits bilharzia.

Human Impact & Utilisation: There is a permanent settlement and an extensive *Phoenix dactylifera* plantation. Small scale gardening is carried out using traditional irrigation methods.

Conservation Status: Unprotected.

(C) THE EL BERBERA OASIS

Location: 19°59'N/12°49'W
Area: c. 30 ha (total moist area)
Altitude: c. 380 m asl
Nearest Towns: Atar (68 km NNW); Akjoujt (162 km WSW)

General: A guelta some 30 m across and 6 m deep, is situated near the head of a narrow gorge, oriented SE-NW, which opens into the Oued Timinit. Springs in the wall of the gorge feed the pond, and the gorge widens gradually towards the oued for 3 km. Running

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surface water is found in the gorge below the guelta, but it is not continuous all the way down the gorge. The water is brackish and rich in sodium.

Flora & Fauna: *Phoenix dactylifera* has been planted along the gorge where once *Acacia* sp., *Ficus syconorus* and *Hyphaene thebaica* prevailed, but the pond at the top is still fringed by *Phragmites mauritianus* and *Typha domingensis*, with some *Juncus* sp., and a sedge. *Barbus deserti* occurs in the stream below the pond. We have no information regarding the rest of the fauna, although the gorge is infested with mosquitoes, and *Varanus griseus* is common in most gorges of the Adrar Escarpment.

Human Impact & Utilisation: There is a permanent settlement on the rim of the gorge, and the floor is utilised for gardening and date production.

Conservation Status: Unprotected.

(D) THE TARTEGA GUELTAS

Location: 17°50'N/12°07'W
Area: 140 ha (maximum wetland + open water area)
Altitude: c. 350 m asl
Nearest Towns: Tidjikdja (117 km NE); Moudjéria (20 km NW)
General: This oasis is situated in the escarpment of the Tagant Plateau, in its southwestern extension towards Kiffa. A promontory over 500 m asl reaches south from the main plateau, falling 400 m by steep scarps to the lowlands on the western and eastern sides. In addition, the plateau dips gently inwards towards its centre from the rims, forming a broad wadi which opens to the lowlands in the northwest. However, at places, there are scarps falling to the interior wadi, and many of these are deeply gullied. The Tartgega-Matmata Gorge is situated on the western side of the broad interior wadi wall. It is 7 km long and slopes from W-E to the wadi, with a floor 200 m wide and very steep walls. Water flows down the gorge from springs at the head and its floor is covered by ponds, springs, marshes and little streams. At the bottom these discharge into a permanent lake which is also fed by springs. Following rain this lake may have an open water surface of up to 30 ha. Its waters are always brown and turbid. The waters of the small ponds in the gorge are relatively fresh, as are those of the little stream, but the lake at the bottom of the canyon is quite saline with high sodium and chloride concentrations.

Flora & Fauna: The marshes of the gorge are covered by species of *Juncus*, *Phragmites* and *Scirpus*, and the ponds have peripheral reed beds. There are *Tamarix* bushes and relict *Ficus sycomorus*, but no palms in the gorge, and the main lake has no submerged macrophytes. *Clarias anguillaris* is common in the gorge, and *Crocodylus niloticus* still survived in the gorge and main lake in 1976.

Human Impact & Utilisation: There is little human interference. No horticulture occurs in the gorge, but sheep and goats are grazed there occasionally and crocodiles are hunted.

Conservation Status: Unprotected.

(E) THE GAMRA OUARBI GUELTAS & OUED OF EL HOUSSEINIYA

General: This system, which discharges to the Oued Bourraga is also associated with the southern promontory of the Tagant, discussed above, but is situated below the western outer scarp. According to Dumont (in press) Gamra Ouarbi is composed of a

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string of gueltas situated in the hollows of a cascading riverbed (17°44'N/12°23'W). El Housseiniya (17°38'N/12°23'W) is a powerful spring that flows into a riverbed several kilometres long, producing stagnant pools which persist through the dry season. Strong floods occur during the rainy season which flush the beds of both systems into the Oued Bourraga. The guelta waters are fresh.

Flora & Fauna: The Gamra Ouarbi gueltas are devoid of macrophytes, but contain algae, principally *Volvox rouseleti*. The ground about El Housseiniya supports a luxuriant growth of Juncaceae, with *Nymphaea* and *Potamogeton* spp. in standing water, while the whole valley floor has been planted with *Phoenix dactylifera*. Dumont (1979) describes the invertebrate fauna which includes species of *Bulinus*, the vectors of bilharzia. *Clarias anguillaris* is abundant in the system, especially at El Housseiniya. *Hemichromis bimaculatus* has also been recorded there. Species of *Bufo* and *Phrynobatrachus* occur here, and *Varanus niloticus* is recorded from Gamra Ouarbi.

Human Impact & Utilisation: The system is used for date production and for limited horticulture. The system is fished for *Clarias* and the lush vegetation of the Oued Bourraga is grazed by sheep, goats, cattle and camels. Domestic cattle use the lower gueltas for water.

Conservation Status: Unprotected.

8. Artificial Impoundments

THE RESERVOIR OF FOUM GLEITA

Location: 15°56'-16°18'N/12°24'-12°40'W
Area: 37 500 ha
Altitude: 40 m asl
Nearest Towns: Mbout (on lake); Kaedi (108 km W)

General: This reservoir is on the Gorgol el Ahkdar (Gorgol Noire) River, near Mbout. The river, flowing due west at this point, traverses the low N-S ridge of the Oua Oua Hills, and a barrage has been constructed on the eastern side to create a lake spreading 42 km N-S along the face of the hills and 36 km upstream.

Flora & Fauna: Reeds have become established on the lake margins near to the dam where water level fluctuations are not great.

Human Impact & Utilisation: A fishery has been established and water is used for irrigation.

Conservation Status: Projected Nature Reserve.

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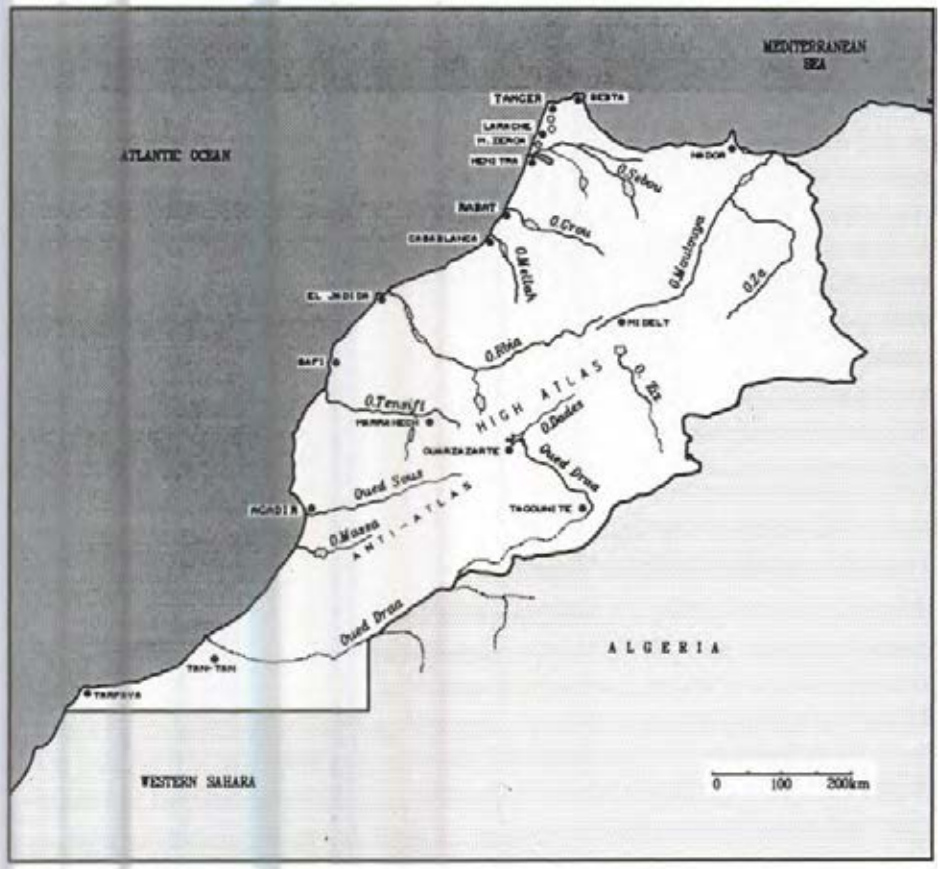

Map of Morocco

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1.4 MOROCCO

Introduction

Morocco lies at the northwestern extremity of the African continent, being bounded by Western Sahara in the south, by Algeria in the east, by the Mediterranean Sea in the north and the Atlantic Ocean in the west. It occupies 458 730 km^2, has a population (1982) of 21 000 000, and thus a mean population density of 45.8 persons/km^2. It stretches 1100 km from north to south, between the Strait of Gibraltar and the parallel 26°N, and approximately 1240 km from east to west between longitudes 0°59' and 12°10'W.

The country is dominated by the great mass of the Atlas Mountains which run SW to NE, parallel with the sea. In the centre the High Atlas forms a chain, 450 km of which is almost continuously over 3000 m, with maximum heights of 4165 m at Jbel Toubkal (31°03'N/7°55'W) and 4071 m at Irhil M'Goun (30°30'N/6°26'W). Adjacent to this great ridge, on the south side, is the volcanic massif of Jbel Sarhro (31°N/6°W), which connects with a subsidiary mountain range, the Anti-Atlas, running SW-NE to the sea at Cape Rhir (30°38'N/9°54'W), parallel with the main range but separated from it by the ever-widening valley of the Oued Sous. On the north side of the High Atlas, the Middle Atlas Range branches off NNE, culminating in the peak of Jbel Bou (33°35'N/3°53'W), 3340 m asl. The valley of the Oued Moulouya, which leads down to the Mediterranean Sea, separates these last two ranges. Yet another mountain range, rather lower, but still exceeding 2000 m, runs roughly W-E along the coast from the Gibraltar strait to the mouth of the Moulouya. This is the Rif Atlas, and it is the most ancient of the Moroccan mountains.

Most of the country is above the 500 m contour, and the few lowlands, below the 100 m contour, are located along the coast. The coast is often very rocky and of high relief, but in the far south, along the border with Western Sahara there is an extensive lowland containing the saline pans of Sabkhat Tah. Farther north, the Plage Blanche at the mouth of the Oued Draâ, is alluvial and extends alongshore for 75 km and inland for 15 km. Yet farther north, another alluvial plain, 75 km long and 15-20 km wide, occurs at the mouth of the Oued Sous which rises on the slopes of Jbel Toubkal some 200 km distant. However, the largest coastal plain extends NE from Essaouira (31°31'N/9°46'W) to Casablanca (33°37'N/7°35'W), a distance of over 350 km, and in the north it widens to 45 km. This is another alluvial plain, having been built up by the floods of the Oued Tensift and Oued Oum er Rbia. At the far north of the Atlantic coast, between Rabat (34°02'N/6°50'W) and Tanger (35°48'N/5°48'W) are the Rharb Plains, lying at the foot of the Rif Atlas from which they have been derived. The coastal strip is very narrow, or non-existent along the Mediterranean coast.

To the southeast of the High Atlas Range the land slopes quite steeply to the Algerian border, but in the northeast of Morocco, it flattens into a high plateau between 1000-1600 m asl.

Drainage of the complex of Atlas Ranges is either directly to the sea, or to the Sahara. Because rainfall is highly seasonal, and even then may come in short rainstorms, the rivers of the Atlas are quickly turned into torrents. The southernmost rivers, including

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the Oued Draâ, flow only intermittently, but the Oued Sous, and all more northern streams are perennial, though highly seasonal in terms of their volumetric discharge. All rivers flowing down from the northwestern slopes of the High Atlas have floodplains, and those of the Oued Sous, Oued Tensift, Oued Rbia, Oued Sebou and Oued Loukkas have led to the development of the alluvial plains so important to Moroccan agriculture. On the Mediterranean coast, the Oued Moulouya also has a floodplain. Flow in this stream varies from 991 m^3/sec in winter to 5 m^3/sec in summer. The most important streams draining the drier southeastern slopes of the Atlas are the Oued Draâ, the Oued Ziz and the Oued Guir. These are all intermittent streams, but they flow strongly in their upper courses each year. The waters of the latter pair reach the desert and are dissipated in a series of saline pans, but by contrast the Oued Draâ, after collecting the waters of several affluents, swings southwestwards to the sea which it enters near Cape Draâ in the far south.

Climate

During the northern summer the Azores anticyclone produces a northerly airstream over almost the entire North African region, but although this crosses the Mediterranean, it is a dry stream and brings virtually no rain. These dry winds blow right across Morocco to the Sahara. High pressure prevails over the Sahara during the northern winter and winds then blow off the desert towards the southwest and northeast. They are hot, dry and dusty, but a stream of humid westerly air from the Atlantic penetrates along the northern coasts at this time, and brings rain to the coastal fringe. Consequently northern and central Morocco have a Mediterranean type of climate with cool wet winters and hot dry summers. In the Rif and northern part of the Middle Atlas mean annual precipitation may exceed 850 mm and the dry season lasts only 3 months. Falls of up to 1600 mm/yr may occur on the peaks of the High Atlas, but in moving over the mountains towards the interior, and in moving south, annual rainfall decreases and the dry season lengthens. In the central south, arid conditions prevail, and in the extreme southwest the desert reaches the sea.

At the coast at Tan Tan (28°30'N/11°02'W) mean annual precipitation is 97 mm. At Agadir (30°24'N/9°36'W) it is 224 mm, and at Safi (32°18'N/9°20'W) 327 mm, while Casablanca receives 406 mm of rain per year and Tanger 887 mm. Rainfall then decreases slightly along the Mediterranean coast but is generally greater than 750 mm/yr. Inland, at an altitude of 470 m asl on the northwestern slopes of the High Atlas, Marrakech (31°38'N/8°00'W) has a mean annual rainfall of 253 mm. Here, some rain falls every month, but in no month does the mean exceed 50 mm. Precipitation is highest in November and March, and lowest in July. At greater altitude (830 m asl) and farther north, Khenifra (23°00'N/5°40'W) receives 627 mm of rain/yr and no month is totally rainless. By contrast, the southeastern side of the mountains is in a rainshadow and falls are much lower. Here, at 1117 m, Ouarzazate (30°57'N/6°50'W) has a mean annual receipt of 107 mm, and Midelt at 1501 m (32°41'N/4°43'W) receives only 229 mm/yr.

Tanger has a mean temperature of 12°C in January and 24°C in August, while the respective figures for Casablanca are 12 and 23°C and those for Essaouira are 15 and 20°C. Inland the range is greater, being 10 and 25°C at Meknès (33°54'N/5°33'W) and 11 and 28°C at Taza (34°13'N/4°01'N). In the High Atlas the temperature often falls to -20°C, and snow above

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2000 m persists for many months each year. When the hot dusty wind (chergui) is blowing from the Sahara, temperatures in almost any lowland part of the country may exceed 40°C, and even the mountains become very warm.

Wetlands

Tidal wetlands occur along the Moroccan coast, principally in lagoons, and in the south there are large saline pans along the border with Western Sahara. Most rivers crossing the coastal strip have small floodplains and there are a number of permanently marshy areas along the rivers in their lower courses. There are a number of natural lakes and bogs in the mountains and over 30 reservoirs with a total combined area in excess of 50 000 ha.

List of Wetlands Described

1. Tidal Wetlands
    (a) Sebkha Tazra (Khnifiss Lagoon)
    (b) Merja Zerga
    (c) Nador Lagoon
2. Coastal Pans & Marshes
    (a) Oualidia & Sidi Moussa Lagoons
    (b) Douiya Sidi Bou Rhaba (Mehdiya Lagoon)
    (c) Merja Sidi Mohamed Ben Mansour & Merja Daoura
    (d) The Rio Martine Lagoons & Marshes
3. River Systems
    (a) The Oued Draà
    (b) The Oued Massa & the Oued Sous
    (c) The Oued Tensift & the Oued Rbia
    (d) The Oued Sebou & the Rharb Plains
    (e) The Oued Moulouya
4. Natural Lakes
    (a) Merja de Douiyet
    (b) Lakes Iseli & Tislu
    (c) Lake d'Ifni
    (d) Small Montane Lakes
5. Artificial Impoundments

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1. Tidal Wetlands

(A) SEBKHA TAZRA (KHNIFISS LAGOON)

Location: 28°03'N/12°15'W
Area: 5000 ha
Altitude: sea level
Nearest Towns: Tarfaya (25 km SW); Agadir (425 km NE)

General: This lagoon has a narrow mouth through the barrier of sand dunes which separates it from the Atlantic Ocean. It is fully tidal, being mostly inundated by high spring tides, and with large mudflats being exposed by all tides. To landward there are the vast salt flats of the Sabkha Tah along the border with Western Sahara. These latter are very seldom inundated, except perhaps by occasional direct precipitation which is less than 100 mm/yr in this area.

Flora & Fauna: As described in the regional introduction. *Ruppia* and *Zostera* occur on the mudflats, *Juncus*, *Limonium*, *Salicornia* and *Suaeda* on the salt flats. The lagoon is an important wintering and staging post for wading birds. *Phoenicopterus ruber* sometimes nests here, e.g. 750 pairs in 1974, and it is the only Moroccan nesting site for *Sterna hirundo*. *Larus genei* also nests here. Further details are available in Pienkowski (1975).

Human Impact & Utilisation: Considerable hunting pressure.

Conservation Status: Unprotected. Listed under Ramsar Convention.

(B) MERJA ZERGA

Location: 34°46'-34°58'N/6°13'-6°18'W
Area: 6000 ha wetland
Altitude: 0-2 m asl
Nearest Towns: Tanger (110 km NNE); Kénitra (70 km S)

General: This Atlantic wetland is on the seaward edge of the Rharb alluvial plain. The total wetland area is 12.5 km long and up to 7 km wide. It consists of a lagoon (7x3.5 km) surrounded by saline marshland and mudflats, separated from the sea by a beach barrier system. A small river, the Oued Drader, enters the northeastern end of the lagoon, and leaves it at the northwestern extremity to reach the sea through a deep tidal channel set in an area of salt-marsh. The lagoon itself is shallow, with a maximum depth of 6 m. The mean annual temperature is 17.4°C. Mean annual maxima and minima are 23°C and 12°C respectively.

Hydrology & Water Quality: Direct precipitation over the lagoon varies between 600-700 mm/yr, but the mean annual discharge of the Oued Drader into the lagoon has been less than 1 m^3/sec since the construction of a barrage upstream. The tidal channel at the northwestern end experiences currents of up to 1 m/sec and tidal amplitude at the mouth is 1.56 m. A canal now drains the higher marshes at the southern end of the lagoon. Surface water temperatures range from 28°C in the lagoon in summer, to 12.8°C in winter, while bottom water temperatures range from 29°C to 12°C. Salinities range from 36‰ in the tidal channel and northern part of the lagoon, to less than 2‰ near the mouth of the Oued Drader in winter.

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Flora & Fauna: Essentially as described in the regional introduction. *Ruppia spiralis* and *Zostera noltii* occur on the lower mudflats of the lagoon, while the upper levels are dominated by *Juncus maritimus* with some *Cladium mariscus* and *Scirpus maritimus*, and locally, some beds of *Phragmites australis*. Salinity increases towards the mouth at the northern end and the salt-marsh there is dominated by *Salicornia arabica*, *S. europaea* and *Juncus acutus*. *Iris pseudacorus*, *Phragmites australis* and *Scirpus lacustris* occur along the Oued Drader and along the Canal du Nador in the south.

Carcinus moenas, *Crassostraea angulata*, *Mytilus* sp., *Nassa* sp., *Ostrea stentina* and *Pholas dactylus* occur in the tidal channel. *Cerastoderma edule*, *Solen marginatus*, *Uca teageri* and *Venerupis semidecussata* occur around the lagoon. The fishes of the tidal channel are principally marine and here *Mullus* spp. and *Torpedo ocellata* predominate, while in the lagoon *Anguilla anguilla* and *Dicentrarchus* spp. are common. Amphibians present include *Pelobates varaldii*, *Pleurodeles waltii* and *Rana esculenta*, while *Natrix maura* is the commonest snake. This is a very important site for birds, harbouring hundreds of thousands of wintering and migrating species each year. Among the most abundant are species of *Anas*, *Calidris*, *Charadrius*, *Limosa* and *Tringa*. Other species of special interest are *Asio capensis*, *Glareola pratincola*, *Himantopus himantopus*, *Recurvirostra avosetta*, *Sterna albifrons* and *Vanellus vanellus*. Small mammals in the system include *Gerbillus campestris*, *Lepus capensis* and *Mus spretus*.

Human Impact & Utilisation: Hunting, which was once intense, has been prohibited since 1978. Some 8000 people live in the vicinity and make a living from fishing and making rush mats.

Conservation Status: Included in a biological reserve since 1978. Hunting is forbidden, but the local population is still permitted to fish. This is a site listed under the Ramsar Convention.

(C) NADOR LAGOON

Location: 35°07'-35°16'N/2°44'-2°56'W
Area: c. 10 000 ha open water
Altitude: sea level
Nearest Towns: Tanger (270 km WNW); Nador (on lagoon)

General: This lagoon on the Mediterranean coast is 22 km long with a maximum width of 6 km. It opens to the sea at the northwestern end to the southeast of which it is separated from the sea by a 20 km long spit with dunes up to 20 m high. To landward there is a saline alluvial plain, separated by hills rising to 772 m, from the Moulouya Estuary to the east. Wind speeds are moderate, with a mean daily maximum of about 11 km/hr. Mean annual maximum and minimum temperatures are 22.3°C and 13.1°C.

Hydrology & Water Quality: Precipitation over the lagoon ranges between 320 and 400 mm each year, and tidal amplitudes within the lagoon are small. The lagoon is fed by some small intermittent streams, and water from irrigation projects discharges into it. Salinities are always high, generally ranging from 30-35‰ but concentrations of 40‰ were recorded in 1961. Surface temperatures range from maxima of 26°C in summer to minima of 15°C in winter. Bottom temperatures are always close to 15°C and there is little stratification.

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Flora & Fauna: Essentially as described in the regional introduction. *Salicornia europaea* is dominant on the shores, with beds of *Zostera marina* to depths of 3.5 m, below which *Posidonia caulinii* is dominant. On the saline plain to landward, *Sarcocornia fruticosa* and *Limonium sebkharium* are common. Among invertebrates *Carcinus moenas* and *Leander serratus* are the principal crustaceans while *Cardium tuberculatum*, *Mactra* spp., *Octopus vulgaris*, *Pinna nobilis*, *Sepia officinalis* and *Venerupis decussata* are the chief molluscs. *Anguilla anguilla*, *Chrysophrys aurata*, *Mugil* spp., *Mullus barbatus*, *M. surmuletus* and *Pagellus mormyrus* are common fishes. The avifauna includes a number of species which are locally uncommon, e.g. *Himantopus himantopus*, *Recurvirostra avosetta* and *Sterna albifrons*, but is otherwise typical of the Mediterranean coast.

Human Impact & Utilisation: Prior to the construction of the port of Beni Anzar, outside the lagoon, the mouth was dredged to facilitate an important fishery, which involved both marine and lagoonal waters, but since 1981 the mouth has very largely closed and the fishery has become centred upon Beni Anzar. As a consequence, direct human interference with the lagoon has declined. However, the discharge of irrigation effluent into the lagoon carries pesticides, and since the mouth has become closed, concentrations of pesticides have begun to build up in the lagoonal food chains. Further, the effluents of a new iron and steel industry will also be discharged into the lagoon.

Conservation Status: Unprotected.

2. Coastal Pans & Marshes

(A) OUALIDIA & SIDI MOUSSA LAGOONS

Location: 32°44'-33°00'N/8°50'-9°08'W
Area: c. 1000 ha
Altitude: sea level
Nearest Towns: El Jadida (50 km NE); Safi (50 km S)

General: A chain of lagoons, 15 km long and 200-700 m wide, on the seaward edge of the Doukkala Plain. The lagoons are parallel with the Atlantic Ocean and separated from it by a dune covered beach. They are not normally open to the sea, and are flooded mainly by direct precipitation and run-off. Salt-marsh vegetation dominates the lagoon floors, with some reed beds around pools and along minor watercourses. On the landward side the marsh grades into agricultural land.

Flora & Fauna: Vegetation as described in the regional introduction for coastal sites. An important wintering and passage site for wading birds, including the rare *Numenius tenuirostris*. Further details are available in Pienkowski (1972, 1975).

Human Impact & Utilisation: There is heavy hunting pressure, domestic cattle graze the area, and reeds are cut for thatching and making mats. Some artificial ponds have been constructed for oyster culture. Part of the Oualidia Lagoon has been drained for development projects.

Conservation Status: Unprotected.

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(B) DOUIYA SIDI BOU RHABA (MEHDIYA LAGOON)

Location: 34°15'N/6°40'W
Area: 200 ha
Altitude: sea level
Nearest Towns: Kénitra (10 km NE); Rabat (60 km SSW)

General: This is a narrow brackish coastal marsh, no longer in permanent contact with the sea, from which it is separated by a wide dune system. It is flooded each winter by direct precipitation.

Flora & Fauna: The vegetation is dominated by meadows of *Juncus*, but with some *Phragmites* and *Scirpus*. Fauna as described in the regional introduction for coastal wetlands, but an important passage site for migrating waders, and a wintering site for small numbers of herons. Breeding species include *Bubulcus ibis*, *Egretta garzetta*, *Fulica cristata*, *Marmaronetta angustirostris* and *Nycticorax nycticorax*.

Human Impact & Utilisation: This is a proposed biological reserve and hunting is presently prohibited. Recreational activities, particularly camping, are having an adverse effect upon the marsh and its wildlife.

Conservation Status: Unprotected. Site listed under the Ramsar Convention.

(C) MERJA SIDI MOHAMED BEN MANSOUR & MERJA DAOURA

Location: 34°35'N/6°30'W
Area: 8000 ha
Altitude: sea level
Nearest Towns: Kénitra (25 km SW); Larache (80 km NE)

General: These are two lagoons behind the barrier beach just north of Kénitra. They are no longer connected with the sea, and receive water from the overflowing Sebou River. Following drainage operations they have ceased to be permanent water bodies and now become dry each summer.

Flora & Fauna: As described in the regional introduction. Important wintering and passage sites for wading birds.

Human Impact & Utilisation: Drainage of adjacent land for development has altered the nature of these wetlands. Cattle are grazed on the peripheral meadows.

Conservation Status: Unprotected.

(D) THE RIC MARTINE LAGOONS & MARSHES

Location: 35°36'-35°46'N/5°16'5°22'W
Area: c. 3000 ha (500 ha open water)
Altitude: sea level
Nearest Towns: Sebta (30 km N); Tanger (55 km NW)

General: This is a group of small lakes (lagoons) on he floodplain of the Oued Martine which reaches the sea at the village of Rio Martine on the Mediterranean Coast. They are (or were) fringed by *Juncus* and *Phragmites*, and with narrow beds of *Phragmites* and *Typha* extending upstream. A further isolated lake occurs 10 km north, just north of

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Cape Negro. None of these lagoons is fully tidal, but all are brackish. Their floras and faunas are as described in the regional introduction.

3. River Systems

(A) THE OUED DRAA

General: This is the longest river of Morocco. It has several headwater tributaries, all of which rise in the High Atlas. One of its principal affluents, the Oued Dades, rises (31°52'N/5°35'W) at 2800 m and flows southwestwards along the mountain flanks of Irhil M'Goun, receiving the eastern drainage from that mountain, to the vicinity of Ouarzazate (30°55'N/6°55'W) where it is impounded behind the Barrage d'El. The lake receives several affluents, draining the high peaks of Jbel Toubkal and Jbel Siroua, and overflows the barrage as the Oued Draâ. From here it flows SE for 175 km, descending swiftly to Tagounite (29°58'N/5°35'W), where it swings sharply to the SW and traverses the feet of the Anti-Atlas for 550 km, again receiving numerous tributaries en route. The Iriqui Depression (29°46'-29°55'N/6°30'W) occupies about 20 000 ha north of the course of the Oued Draâ, and this may be flooded by seepage after heavy winter rains. It then becomes an important site for birds of passage, and occasionally, e.g. in 1968, it is an important breeding site for such species as *Anas acuta*, *Himantopus himantopus*, *Marmaronetta angustirostris*, *Phoenicopterus ruber*, *Recurvirostra avosetta* and *Tadorna ferruginea*. Over its final 200 km the valley of the Oued Draâ becomes deeply entrenched as it flows along the Jbel Ouarkziz, after which it swings northwestwards to reach the Atlantic coast immediately south of Cape Draâ and just north of Tan Tan (28°31'N/11°05'W). The sections of the system above the barrage are perennial, but below the barrage they no longer flow continuously. The river seeps into the sands below Tagounite, but reappears at the surface in places and forms a saline surface stream near its mouth. Here it is sluggish and semi-stagnant, just 6-10m wide in summer, but in winter it often swells and floods some adjacent marshy land.

Flora & Fauna: As described for coastal marshes in the regional introduction. The zone subject to inundation each winter is dominated by *Salicornia* sp. with bushes of *Arthrocnemum* and *Tamarix* spp. on the least deeply flooded sites. Inland, the subterranean river produces strips of humid sand on which *Acacia* and *Tamarix* trees grow profusely, thus these trees follow the river upstream in a long, but discontinuous, riparian woodland.

Human Activity & Utilisation: In the past the area flooded freely after heavy rain in the catchments, and the river flowed at the surface throughout its length, but since the impoundment at Ouarzazate the floods have ceased.

Conservation Status: Unprotected.

(B) THE OUED MASSA & THE OUED SOUS

General: The Oued Massa is a short steep river which rises on the seaward slopes of Jbel Lekst (2359 m) in the Anti-Atlas. It is dammed some 60 km from the sea, but prior to impoundment it used to inundate a coastal floodplain regularly. This plain extends northwards and merges with the floodplain of the Oued Sous, a much larger river. The

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Oued Sous rises high on the seaward slopes of Jbel Siroua and flows almost due west down a deep and dramatic valley for 200 km to the sea. The river descends swiftly throughout its course, but begins to meander about 40 km from the sea when its bed flattens on the coastal plain. It floods a considerable area each year and there are several hundred hectares of marshland on its plain.

Flora & Fauna: The surviving marshes support typical marshland vegetation as described in the regional introduction, but no major wetlands occur upstream in the valley of the Oued Sous.

Human Impact & Utilisation: The dam on the Oued Massa has greatly reduced its capacity to flood each year, but the floodplain is now used for irrigation agriculture, indeed the entire plain is intensively cultivated and much marshland has been drained.

Conservation Status: Unprotected.

(C) THE OUED TENSIFT & THE OUED RBIA

General: The Oued Tensift has sources on the southwestern slopes of Jbel Igdet and Jbel Toubkal in the High Atlas. One of its headwater streams, the Oued Nfiss is impounded, as discussed later. The river descends steeply to the coastal plain flowing west for 250 km. It floods a narrow plain along its final 20 km, after exceptionally heavy rain, and there is an estuarine wetland at its mouth.

The Oued Rbia has sources farther east, on the southwestern slopes of Irhil M'Goun and in the Middle Atlas. Two of its headwater tributaries are impounded, the Oued Tessaout and the Oued el Abid, also discussed in the section on artificial impoundments. The Oued Rbia is further impounded downstream at Imfout (32°46'N/7°57'W) and Boulaouane (32°54'N/8°03'W), after which it meanders for 75 km across the northern end of the Doukkala Plain before reaching the Atlantic Ocean at Azemmour (33°18'N/8°25'W). Once it flooded its banks in its lower course following heavy rain in the catchments, but the impoundments upstream now preclude this. There is a small estuarine wetland at the river mouth.

(D) THE OUED SEBOU & THE RHARB PLAINS

General: The Oued Sebou has sources in the Middle and Rif Atlas Mountains and is the most important river in Morocco. There is a major impoundment on one of its headwater tributaries, the Oued Inaouene just above the confluence with the Oued Sebou. Thereafter the river flows slowly across the full width of the Rharb Plain to the Atlantic Ocean at Kénitra (34°20'N/6°34'W), receiving several meandering affluents on the way. The most important of these are the Oueds Ouerrha and Beth. Immediately north of Kénitra there is an extensive wetland oriented E-W, cut by both the Oued Sebou and the main coast road from Kénitra to Larache (35°11'N/6°09'W). This area of marshland and floodplain (34°20'-34°30'N/5°53'-6°33'W) once covered 42 000 ha, but it has been depleted by drainage in recent years. Two smaller isolated wetland areas lie to the north. One of these, 15 km long and 2 km wide (34°30'-34°37'N/6°21'W), is oriented due N-S, and occupies 3000 ha, while the other is a circular area (34°39'N/6°16'W) which covers 960 ha. The last area is entirely separate from the river channel, but the others both lie alongside the river for short distances. Floodwaters may pass into the depressions from

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the river each year, and also accumulate in them from direct precipitation and peripheral run-off. Towards the river mouth the major depression becomes saline and tidal, but most of it is above sea level. These areas are covered by rushes, sedges and wetland grasses, and support a fauna as described in the regional introduction. They are currently being converted for agriculture.

To the north a wetland occurs on the Oued Loukkos (35°04'-35°15'N/5°50'-6°09'W), upstream from its mouth at Larache, to the confluence with the Oued Mekhasene some 13 km inland. From here the wetland continues up the Oued Loukkos for 7 km and up the Oued Mekhasene for 15 km, and also up one of its minor affluents for 7 km. In the region of the confluence of the Oueds Loukkos and Mekhasene the wetland is over 12 km wide. It is saline and tidal at the river mouth where salt extraction pans have been established, but it grades into brackish and then freshwater marshes upstream, and these support extensive beds of *Phragmites australis* and *Typha capensis* (= *T. latifolia*). In total there were 18 000 ha of wetland here, but some areas away from the rivers have recently been drained. Another small marsh, 5 km long, lies just to the south (34°59'N/5°58'W) covering 500 ha near the town of El Ksar el Kbir. Both sites are important for their avifaunas.

Still farther north there are two small wetlands just south of Tanger on the Atlantic Coast of the Rharb Plain. One lies along the lower courses of the Oueds Hachef and Mharhar which reach the sea in a common estuary (Tahadart Estuary) 25 km south of Tanger, and the other is at the mouth of an un-named stream 7 km south of Tanger. The first of these wetlands (35°31'-35°40'N/5°48'-6°00'W) comprises estuarine tidal marshes and brackish marshes farther inland along both rivers. In total it is 20 km long, up to 5 km wide and covers some 8000 ha. The second marsh (35°43'N/5°55'W) is saline and covers about 600 ha. Both carry floras and faunas similar to those described in the regional introduction, and both are wintering sites for waterfowl.

(E) THE OUED MOULOUYA

General: The Oued Moulouya has sources above 2000 m in both the High and Middle Atlas Ranges, from where it flows swiftly northeastwards for 575 km to the Mediterranean Sea which it reaches in a short flat alluvial valley on that part of the coast known as the Sebkha Bou Areg, just east of Nador Lagoon. In the lowest reaches of its valley there is an area of lagoons and brackish marshes which are separated from the sea by dunes, and the lower part of the valley is subject to flooding in winter. The lowest lying areas are covered by dense beds of *Salicornia europaea*, with meadows of sedges and rushes on higher, but semi-permanently wet, ground behind. Most of these meadows are close to sea level, and water depths in the winter are seldom more than a dozen centimetres. Altogether there are approximately 3000 ha of wetland close to the river mouth and in the lower river valley.

Flora & Fauna: As described for coastal and estuarine sites in the regional introduction. This is a wintering area for various Ardeidae, *Platalea leucorodia*, *Phoenicopterus ruber*, *Porphyrio porphyrio* and numerous ducks and waders. *Larus audouinii*, a rare gull, has been observed here in considerable numbers. This species nests on Isabella Island (a Spanish possession) some 10 km NW of the river mouth, and the local population may account for as much as 60% of the world population. Some account of

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the importance of this locality to the survival of this gull is given by Brosset & Olier (1966).

Human Impact & Utilisation: A pumping station takes water from the river and there is an impoundment upstream, both of which influence the extent of flooding.

Conservation Status: Unprotected.

4. Natural Lakes

(A) MERJA DE DOUIYET

Location: 34°05'N/5°00'W
Area: 100 ha
Altitude: c. 625 m asl
Nearest Town: Fes (7 km)

General: This is a shallow depression fed by springs and run-off from the peripheral land. It is semi-permanent, drying completely in the summers of some years. The water is brackish and the margins are fringed by dense beds of *Phragmites australis*. The fauna is as described in the regional introduction for inland natural lakes. The lake is royal property and is therefore protected from public interference.

(B) LAKES ISELI & TISLU

Location: centred 32°13'N/5°40'W
Area: c. 400 ha (both lakes)
Altitude: c. 2200 m asl
Nearest Towns: Midelt (90 km NE); Tanger (400 km N)

General: These are two small oligotrophic montane lakes about which very little information has been gathered. They have depths approaching 100 m and are reputed to contain interesting fish faunas, but we have no detailed information.

Human Impact & Utilisation: The lakes are fished for sport but are otherwise undisturbed.

Conservation Status: Unprotected.

(C) LAKE D'IFNI

Location: 31°02'N/7°53'W
Area: 40 ha
Altitude: 2300 m asl
Nearest Towns: Marrakech (60 km NNW); Ouarzazate (100 km WSW)

General: This is a high montane lake near the western end of the High Atlas, on the slopes of Jbel Toubkal, with a maximum water depth of 65 m. The lake is a natural impoundment, the waters of a stream having built up behind a landslip. The lake is used for sport fishing and is unprotected. We have no information regarding its flora and fauna.

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(D) SMALL MONTANE LAKES

General: There are a large number of small lakes high in the mountains, at elevations of 500-2500 m. Most are mesotrophic, support beds of submerged macrophytes and are fringed by reeds. Some, such as Lake d'Affenourir (380 ha), are moderate size. Aguelmane Azigza Lake (29°58'N/5°27'W) is alkaline and especially rich in phytoplankton.

5. Artificial Impoundments

General: There were some 25 impoundments in Morocco by 1980, the most important being on the Oueds Massa (29°47'N/9°18'W), Draâ (30°59'N/6°40'W), Nfiss (31°23'N/8°06'W), Tessaout (31°41'N/7°14'W), Ziz (32°00'N/4°22'W), El Abid (32°07'N/6°22'W), Rbia (32°44'N/7°57'W) and (33°00'N/8°06'W), Mellah (33°25'N/7°14'W), Brou Regreg (33°52'N/6°43'W), Beth (34°01'N/5°54'W), Sebou (34°13'N/4°49'W), Moulouya (34°43'N/2°56'W) and Loukkos (35°00'N/5°50'W). Water from some of these dams is used for power generation, but all are utilised for irrigation and it is expected that the total area under irrigation will reach 1 000 000 ha in the late 1980s. Details of some bodies of standing water are given by Morgan & Boys (1982) and Morgan (1982a,b).

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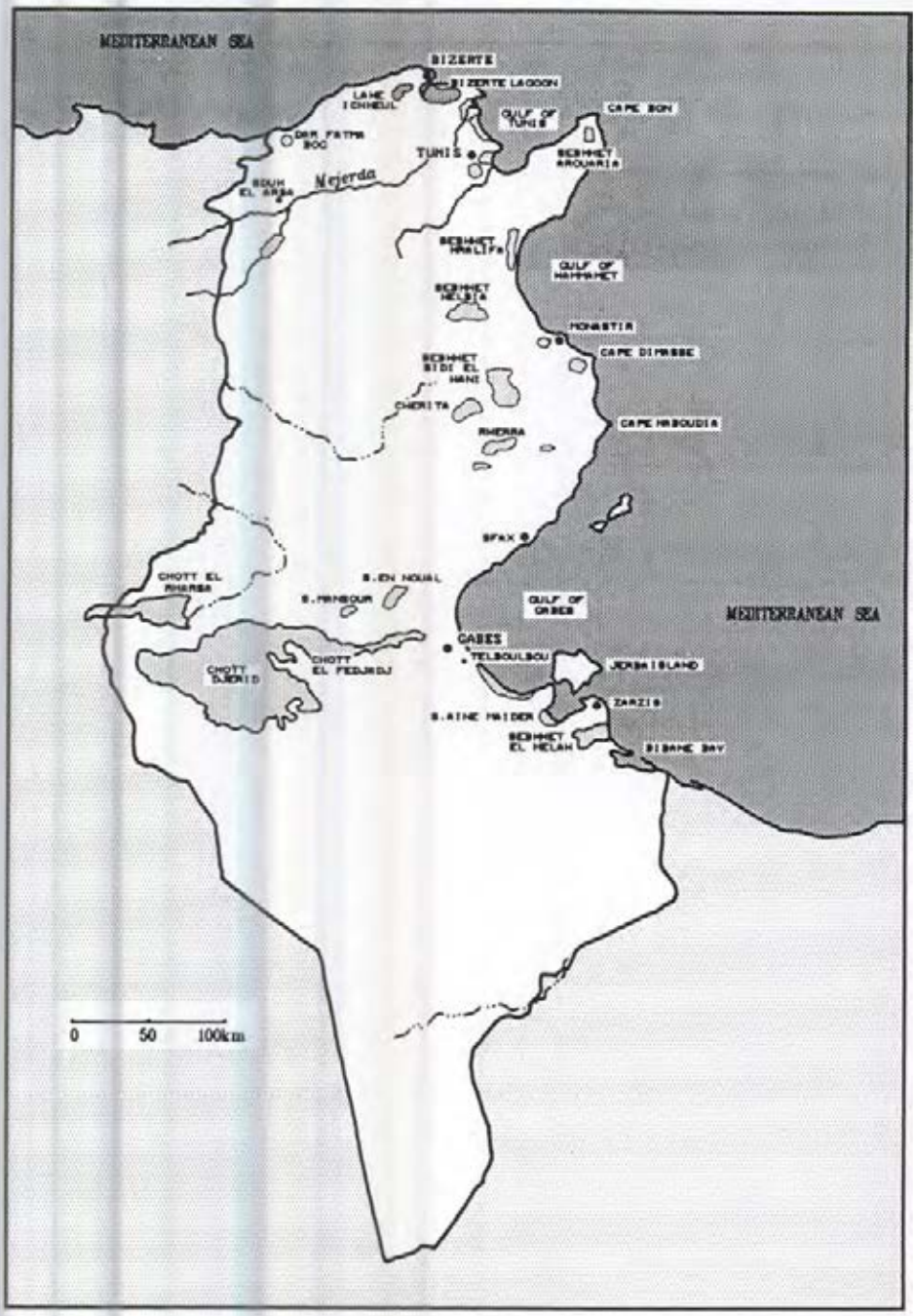

Map fo Tunisia

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1.5 TUNISIA

Introduction

Tunisia is the smallest of the North African countries. It covers 164 150 km^2, has a population of 6 945 000 (1983), and therefore a mean population density of 42.3 persons/km^2. It is bounded by Algeria in the west, Libya in the southeast, and the Mediterranean Sea to the east and north. It has a highly indented coastline, 1470 km long including the islands of Jerba, Gharbi and Chergui. The country stretches 755 km from N-S between latitudes 30°16' and 37°20'N, and 380 km from west to east between longitudes 7°32' and 11°32'E. Cape Blanc, 37°20'N, is the most northerly point of the African continent.

Except in the extreme northwest, at the border with Algeria, there is a broad coastal plain. This reaches a maximum width of 60 km near the Libyan border in the southeast. The Tell Atlas extends into the north of Tunisia, dominating the northern third of the country which is mountainous. Here, on the southern flank of the mountains, Jebel Chambi (35°13'N/8°38'E) rises to 1544 m, the highest point in Tunisia. From these mountains, undulating steppes, broken by occasional hilly ridges, slope gently southeastward to the sea. The central third of the country is occupied by a great triangular depression with its apex on the coast at Gabès (33°52'N/10°06'E) and its base along the Algerian border, where it descends to 23 m below sea level in the Chott el Gharsa. Other large salt pans occur in this depression, notably the Chotts el Djerid and el Fezzaz. The southern third of the country is largely occupied by a plateau, 200-400 m asl, onto which the sand desert of the Grand Erg Oriental extends from Algeria. This plateau reaches up into Tunisia from the far south, narrowing to a mountainous ridge reaching 715 m asl where it terminates just south of Gabès, with the broad coastal plain along its eastern flank.

The principal river of the north is the Oued Mejerda, which is perennial, and together with its tributaries, drains much of the northern plateau. It traverses a series of fossil lake basins, covered by deep alluvium, and reaches the sea at the Gulf of Tunis. Other small streams reach the northern coast, and numerous intermittent streams flow towards the chotts of the central basin. Rainfall in the south is scant and erratic and there are no important drainage systems, but a series of dry wadis reaches north towards the chotts from the chain of southern hills.

Climate

Winter rains fall over the northern highlands, with the highest readings along the coast. On parts of the Monts de la Mejerda and Mogod Mountains, annual falls of 1500 mm have been received in what is the wettest part of North Africa. However, at sea level, at Bizerte (37°18'N/9°52'E), mean annual precipitation is 625 mm, declining inland to 490 mm at Zaghouan (36°24'N/10°08'E) some 600 m asl, although again, higher falls are recorded on the nearby massif of Jebel Zaghouan (1294 m). Rainfall is 500 mm/yr at Makthar (35°50'N/9°12'E), 934 m asl, farther south and east, while at an altitude of 68 m asl on the central lowlands, Kairouan (35°42'N/10°01'E) receives an average of 286 mm/rain/yr. Off the east coast, Jerba Island has an average annual receipt of 207 mm/yr. Rainfall varies considerably from year to year, e.g. Mekthar received over

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900 mm in 1963-64, but only 400 mm in 1966-67. Coastal temperatures are moderated by cool sea breezes, but may occasionally be raised to extremes by a hot dust laden wind from the Sahara. August is the warmest month and mean daily maxima at the coast are then in the region of 31-33°C, while in the northern interior they are 36-38°C. January is the coldest month, when mean daily minima range from 7-8°C at the coast and 3-4°C in the northern interior. Summer temperatures in the far south may exceed 48°C.

Wetlands

There are some important coastal wetlands including the marshes of the delta of the Mejerda River in the Gulf of Tunis, and several lakes, lagoons and pans. Tidal rise and fall, unusual along the Mediterranean coast, is most marked on the Gulf of Gabès and here there are some tidal habitats. The vast pans of the central basin provide large wetland areas in winter and there are oases in the far south. Some intermittent watercourses in the northern mountains have been impounded to form small reservoirs and there is a small peat bog in the extreme northwest of Tunisia.

List of Wetlands Described

1. Coastal Wetlands
    (a) Lake Ichkeul
    (b) Bizerte Lagoon
    (c) The Mejerda Delta
    (d) Sebkhet Ariana
    (e) The Lakes of Tunis
    (f) Wetlands of the Gulf of Hammamet
    (g) Wetlands of the Gulf of Gabès
    (h) Wetlands of the Southeast Coastal Zone
2. Chotts of the Central Basin
    (a) Chott el Rharsa
    (b) The Chott Djerid & Chott el Fedjadj Complex
3. Other Wetlands & Impoundments
    (a) The Dar Fatma Bog
    (b) The Lake of Sduk el Arba
    (c) Artificial Impoundments

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1. Coastal Wetlands

(A) LAKE ICHKEUL

Location: 37°10'-37°12'N/9°34'-9°45'E
Area: c. 10 000 ha (maximum in winter)
Altitude: c. 2 m asl
Nearest Towns: Bizerte (15 km NE); Tunis (52 km SE)

General: Lake Ichkeul (Achkel) is brackish in winter but tends to become highly saline in summer due to the infiltration of sea water. The permanent lake is eutrophic and 5-6 km long, but the swampy extensions which develop in winter increase the length to 15 km and the mean width to 5 km. The peripheral inundation zones are covered by marsh vegetation. The lake has a mean depth of 90 cm and is fed by the Oueds Malah and Sedjenane which drain highlands to the west. It lies close to the foot of the isolated peak of Djebel Ichkeul (509 m) and loses water by seepage to the sea via Bizerte Lagoon immediately to the west.

Flora & Fauna: The lake contains beds of *Potamogeton pectinatus* and *Ruppia spiralis*. The peripheral marshes support dense beds of *Phragmites australis*, *Scirpus littoralis* and *Typha capensis*. The fishes include *Anguilla anguilla*, *Dicentrarchus labrax*, *Mugil cephalus*, *M. ramada*, *Solea vulgaris* and *Syngnathus abaster*. The system provides important habitats for a range of amphibians (*Bufo viridis*, *Rana ridibunda*), reptiles (*Clemmys leprosa*, *Natrix maura*) and mammals (*Bubalus bubalis*, *Lutra lutra*) as discussed in the regional introduction. It is an important habitat for wintering and migrating waterfowl including *Anas penelope*, *Anser anser*, *Aythya ferina* and *Fulica atra*, and reed species such as *Acrocephalus arundinaceus*, and it is (or was) a nesting site for many species including *Anas angustirostris* and *Oxyura leucocephala*.

Human Impact & Utilisation: The lake is visited by many people and the level of disturbance is quite high. The local fishery produces about 125 tonnes per year.

Conservation Status: The lake and adjacent mountain are state owned and the lake was classified as a National Park in 1980, and is both a World Heritage Site and a Biosphere Reserve. However, the peripheral marshland is mostly in private ownership. Plans to dam the oueds feeding the lake to provide water for irrigation threaten the entire habitat, since lowering the water level would almost certainly increase salinity and destroy the peripheral marshland.

(B) BIZERTE LAGOON

Location: 37°08'-37°17'N/9°46'-9°55'E
Area: 11 000 ha
Altitude: sea level
Nearest Towns: Bizerte (on lagoon); Tunis (45 km SE)

General: Often called Lac de Bizerte, this is a salt water system open to the sea. It is 13 km long, up to 9 km wide, and communicates with the sea through a channel 8 km long at the northeastern end. It supports salt-marsh vegetation along its shores and some marshland at its eastern extremity.

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Flora & Fauna: As described in the regional introduction for coastal wetlands. It is a habitat for wintering and migrating waterfowl.

Conservation Status: Unprotected.

(C) THE MEJERDA DELTA

Location: 36°59'-37°10'N/9°57'-10°11'E
Area: c. 6000 ha wetland + 4500 ha lagoon
Altitude: sea level
Nearest Towns: Tunis (40 km S); Bizerte (40 km N)

General: The Mejerda River has sources in the high mountains of Algeria and drains a long alluvial valley in Tunisia before reaching the sea on the Gulf of Tunis. Its volumetric discharge is very seasonal, and in spate, in the northern winter, it carries a deal of suspended matter. The delta proper occupies at least 60 000 ha, but much has been reclaimed for agriculture leaving (1983) some 6000 ha of permanent marshland. The river enters the sea in a very shallow lagoon. This is 7 km long and almost as many wide, with a mouth at the eastern extremity between low dune covered spits. Depths in the lagoon reach about 2 m and the floor comprises alluvium from the Merjerda. Salinity reaches 46‰ in summer when river flow is minimal, but falls in winter to about 28‰.

Flora & Fauna: Mudbanks in the lagoon support *Zostera marina* together with species of *Cladophora*, *Enteromorpha* and *Ulva*. Swampy land at the head of the lagoon and in the delta is dominated by *Phragmites australis*, and there are salt-marsh areas both in the delta and along the lagoon. Floras and faunas are essentially as described in the regional introduction. The delta is an important wetland habitat for rodents, snakes, and wintering and migrating waterfowl, periodically supporting large numbers of ducks and sandpipers.

Human Impact & Utilisation: The remaining delta wetlands are not managed and the threat that more wetland will be reclaimed remains. The lagoon is fished, producing chiefly *Mugil cephalus*, but also some *Anguila* and *Dicentrarchus*.

Conservation Status: Unprotected.

(D) SEBKHET ARIANA

Location: 36°52'-36°58'N/10°10'-10°17'E
Area: c. 4000 ha (2500 ha regularly inundated)
Altitude: 1 m asl
Nearest Towns: Tunis (10 km SW); Bizerte (45 km NW)

General: This marshy saline pan, close to the site of the ancient city of Carthage, is almost contiguous with the southernmost wetlands of the Mejerda Delta and lies on deltaic alluvium. It is 14 km long and up to 4 km wide and is separated from the sea by a line of dunes. It is seldom deeply flooded and tends to dry out completely in most years.

Flora & Fauna: As described in the regional introduction for coastal wetlands. It is an important habitat for migrating and wintering waterfowl and, among other species, is frequented by *Calidris alba*, *C. alpina*, *Grus grus*, *Phoenicopterus ruber*, *Recurvirostra avosetta*, *Tadorna tadorna* and *Tringa totanus*.

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Human Impact & Utilisation: Some hunting occurs and tourist developments are taking place along the dunes between the wetland and the sea.

Conservation Status: Unprotected.

(E) THE LAKES OF TUNIS

Location: 36°42'-36°53'N/10°07'-10°18'E
Area: 7100 ha
Altitude: sea level
Nearest Town: Tunis (on lakes)

General: The 'lake' of Tunis, with an area of 4500 ha, is situated east of the city of Tunis and is bisected by a new motorway. The southern half of the lake is now called Lac de Radès after the town at its southeastern extremity. It is a highly eutrophic, saline lake, with water depths which seldom exceed 2 m. It has been freely open to the sea in the past, but its mouth is now silted and blocked by various biota. Salinities reach 45‰ in the southern section in summer, falling to 42‰ in winter, while in the northern section they range between 33-38‰. There is a small island, Chikli Island, in the NW corner. The Sebkhet es Sedjoumi is located immediately SW of Tunis, less than 2 km from Lac de Radès and is separated from it by an urban area which includes two major roads and a railway. It is a shallow saline pan of 2600 ha. It dries out almost completely every year and is seldom flooded to depths greater than 1 m.

Flora & Fauna: The lakes are much disturbed because of their urban environment, but nevertheless they support peripheral marshland vegetation and a rich avifauna. Important species using the system include *Anas acuta*, *A. clypeata*, *A. angustirostris*, *A. platy-rhynchos*, *Aythya ferina*, *Egretta garzetta*, *Fulica atra*, *Larus argentatus*, *Phalacrocorax carbo*, *Phoenicopterus ruber* and *Oxyura leucocephala*.

Human Impact & Utilisation: The lake of Tunis is fished commercially, and hunting pressure is high on both lake and sebkhet, despite the fact that the lake is a reserve. Sewage is discharged into both the lake and the sebkhet. Fish production is in the region of 500 tonnes/yr.

Conservation Status: The lake has been declared a National Reserve, but the sebkhet is unprotected.

(F) WETLANDS OF THE GULF OF HAMMAMET

General: A number of important wetlands are situated on the shores of the gulf or on the coastal plain immediately inland between Cape Bon (37°05'N/11°03'E) and Sfax (34°44'N/10°46'E). The Sebkhet Arouaria (36°57'-37°02'N/10°59'-11°02'E) is a pan 11 km long and 4 km wide, subject to temporary inundation which is situated immediately south of Cape Bon (393 m) at the tip of the El Aouaria Peninsula. It is just above sea level, occupies 4250 ha, contains a small, brackish, semi-permanent lake with peripheral marshland, and supports a typical coastal flora and fauna as described in the regional introduction. It is unprotected.

Some 90 km SSW of this, stretching along the coast behind the dunes for 26 km, and very close to the sea, is the narrow (1 km) Sebkhet Kraiifa (36°02'-36°15'N/10°28'E).

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Southwest of this and 20 km inland is Sebkhet Kelbia (35°47'-35°55'N/10°12'-10°21'E). This pan, which is close to 18 m asl, is 17 km long and up to 9 km wide. It contains a shallow eutrophic freshwater lake (c. 1200 ha) that seldom dries up. This contains beds of *Althenis filiformis* and dense stands of *Phragmites australis* and *Scirpus* sp., and the full pan, which occupies about 11 600 ha, is fringed by *Sarcocornia perennis* and *Tamarix gallica*. It is fed by the Oueds Merguellil, Nebhana and Zeroud, but the Oued Nebhana is now impounded and its flow much restricted, while the other two streams are extremely seasonal in their flows. They can be very destructive when in spate. The silt load in these two oueds is increasing and thus the basin is slowly silting up. Schemes have been proposed for the utilisation of the waters of these two streams which are likely to lead to the eventual desiccation of the wetland. This is presently an important habitat for wintering and migrating waterfowl including *Anas acuta*, *A. clypeata*, *A. penelope*, *Grus grus* and *Phoenicopterus ruber*. Species which breed here include *Anas angustirostris*, *Himantopus himantopus* and *Tadorna tadorna*, but hunting and egg collecting occur. There is a fishery which yields about 80 tonnes of fish/yr. The site is unprotected.

The largest pan in the area is situated some 20 km south of Sebkhet Kelbia, 25 km inland and 75 km NNW of Sfax at an altitude of 28 m asl. This is the Sebkhet Sidi el Hani (35°24'-35°38'N/10°18'-10°36'E) which is 30 km long, 19 km wide and covers 36 000 ha. It is a shallow saline pan containing a permanent lake with several small islets in the centre. The area inundated varies quite dramatically from year to year, depending upon rainfall, and extensive mudflats may be exposed at the southern end during summer. Water depths seldom exceed 1 m. There are beds of rushes and peripheral salt-marsh vegetation. This is another important habitat for wintering and migrating waterfowl, and *Phoenicopterus ruber* sometimes breeds on the islands. Hunting and egg collecting occur and the system is unprotected.

Some 15 km west, farther inland, is Sebkhet Cherita (35°18'-35°24'N/10°14'-10°23'E), 75 km NW of Sfax. This pan is 18 km long and 8 km wide and contains patches of semi-permanent saline water and much salt-marsh vegetation. Farther south are the Sebkhets Mta el Rhera (35°08'N/10°30'E), Mta el Djem (35°09'N/10°47'E), Bou Djemel (34°58'N/10°25'E) and Mecheguigue (34°56'N/10°02'E). Also in this region are two more coastal sebkhets, both at sea level. These are the Monastir Sebkhet and Lagoon (35°45'N/10°47'E) 110 km north of Sfax, and the Sebkhet Moknine (35°32'-35°38'N/10°54'-11°01'E) 89 km north of Sfax. Both are saline. Monastir lagoon is small, covering only 175 ha, while the sebkhet occupies nearly 3000 ha. Moknine Sebkhet covers 5500 ha.

(G) WETLANDS OF THE GULF OF GABES

General: This section extends alongshore from Sfax (34°44'N/10°46'E) to Zarzis (33°28'N/11°07'E) and includes the offshore islands. This part of the coast is tidal and mudflats are exposed around the Kneiss Islands (34°22'N/10°19'E) at low tide. Here there are small lagoons on the coast and the total wetland area, lagoons and mudflats, may exceed 12 000 ha. The vegetation of the area is typical of the North African coast, with *Zostera noltii* on the mudflats, *Ruppia maritima* in the lagoons, and species of *Limoniastrum*, *Halocnemon*, *Salicornia* and *Sarcocornia* at the upper tidal limit. The area is important to wintering water-fowl. *Egretta garzetta*, *Larus genei* and *Tringa*

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totanus breed here, while *Ardea cinerea*, *Calidris* spp., *Egretta alba*, *Limosa limosa*, *Numenius arquata*, *Phoenicopterus ruber*, *Platalea leucorodia* and *Plegadis falcinellus* are common winter species. The area is unprotected. Other tidal and non-tidal coastal salt-marshes occur between Gabès (33°53'N/10°07'E) and the island of Jerba, and around the northern coast of Jerba. Tidal salt-marshes are continuous for 60 km from Teboulbou, 5 km south of Gabès, to the southern extremity of the gulf. Over this stretch the coast is indented to produce narrow bays, e.g. on either side of Gourine (33°39'N/10°34'E). Another salt-marsh occurs at the head of the Gulf of Bou Grara (33°28'N/10°47'E), known as the Sebkhet Aïne Maïder, covering 5000 ha.

Inland on the arid coastal plain there are two important pans, the Sebkhet en Noual (34°19'-34°27'N/9°41'-9°57'E) and the Sebkhet Sidi Mansour (34°13'-34°15'N/9°27'-9°33'E). The Sebkhet en Noual is situated 7-10 km from the slopes of the Djebel ben Kreir, Djebel bou Hedma and Djebel en Nedjilet, and is 23 km inland from the sea. Nevertheless, it is hidden from the sea by a range of low hills rising to 183 m, and is fed by 8 streams which drain these hills and the mountains close by, the latter rising to over 700 m. The pan is 25 km long, oriented SW-NE, and has a maximum width of 10 km. It contains a semi-permanent brackish lake and extensive peripheral marshes. The Sebkhet Sidi Mansour is smaller, c. 3000 ha, and is situated 6 km from the southeastern slopes of Djebel ben Kreir. It lies just below the 100 m contour and dries up completely in some years. At such times it may be ploughed and planted with cereals.

(H) WETLANDS OF THE SOUTHEAST COASTAL ZONE

General: Just south of Zarzis the Sebkhet el Melah extends inland from the coast for 19 km, with a mean width of 8 km. This pan is separated from the sea by dunes and is saline. A further 10 km south is the Bay of Bibane (33°11'-33°19'N/11°05'-11°27'E) reaching almost to the Libyan border. This is a shallow lagoon, almost entirely cut off from the sea by a narrow spit, 30 km long, but with several small central openings between what are effectively dune islands. There are mudflats and peripheral salt-marshes and the lagoon is hypersaline with summer concentrations reaching 48.5‰ and winter ones falling to 42‰. It is fed by the Oued Fessi, the annual discharge of which is small and varies greatly from year to year, indeed in some years it does not flow at all. Tidal amplitude here is 50 cm (maximum), but the lagoon levels seldom fluctuate by more than 5 cm. Beds of *Cymodocea nodosa* and *Ruppia maritima* occur in the lagoon, together with algae which include species of *Caulerpa*, *Chaetophora*, *Cladophora* and *Limnothamnium*. The lagoon is an important nursery for *Sparus aurata* and a habitat for wintering and migrating waterfowl including *Phoenicopterus ruber*. It is fished, but not intensively, and is neither managed nor protected. *Diplodus annularis*, *Solea vulgaris* and *Sparus aurata* form the bulk of the catch.

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2. Chotts of the Central Basin

(A) CHOTT EL RHARSA

Location: 34°00'-34°11'N/7°38'-8°07'E
Area: 42 000 ha
Altitude: below sea level (-23 m lowest point)
Nearest Towns: Tozeur (10 km SE); Gabès (185 km E)

General: This, the smallest and most westerly of the three great chotts of Tunisia, extends into Tunisia from Algeria. Its perimeter lies inside and below the 0 m contour, and its greatest depression is 23 m below sea level towards the eastern end. The surrounding country is arid and the margins of the chott are salt encrusted. The chott is fed by the Oued el Melah which enters at the eastern end, and by a system of oueds which reach the northeastern margins. However, the rest of the surrounding land, to the south, north and west, is not deeply gullied or marked by prominent watercourses and any run off which reaches the chott from this area is ephemeral. Occasionally water reaches the chott via the eastern watercourses, but there is never any extensive inundation. During rain the surface is moistened. Much of the chott is barren and salt encrusted with some halophtyic vegetation on the periphery, as described in the regional introduction.

(B) THE CHOTT DJERID & CHOTT EL FEDJADJ COMPLEX

Location: 33°18'-34°03'N/7°45'-9°50'E
Area: 495 000 ha
Altitude: 15-38 m asl
Nearest Towns: Tozeur (5 km NW); Gabès (115 km E)

General: These two chotts are continuous, stretching 193 km from east to west, approaching to within 21 km of the sea. A few kilometres north of the complex the land surface rises steeply to a long ridge of hills comprising the Djebel Morra, Djebel el Asjker, Djebel Sif el Laham, Djebel Lefaïa, and Djebel Hadifa ranges which reach an altitude of 285 m asl at the eastern end. Ten kilometres south of Chott el Fedjadj is the Djebel Tebaga range which rises to 469 m, but by contrast, to the south of Chott Djerid, the land grades gently upwards to the 100 m contour situated some 35 km distant on the edge of the desert.

Precipitation decreases inland, away from the coast, while temperatures increase. Mean annual precipitation is only 185 mm at Gabès and just 96 mm at Kebili (33°39'N/8°59'E), despite which rainfall over the chotts may be intense. The mean maximum and minimum temperatures of the warmest month (July) are 32°C and 22°C at Gabès and 42°C and 22°C at Tozeur (33°55'N/8°07'E), while the corresponding figures for the coldest month (January) are 16°C and 6°C at Gabès and 15°C and 4°C at Tozeur. The average potential evaporation over the chotts is 2500 mm or greater.

The floor of the two chotts has a minimum altitude of 15 m asl and comprises barren clay and gypsum. Chott Djerid receives flows of artesian water on both its northern and southern borders, deriving from rain on the Atlas and Dahar Ranges. Some of the springs discharge at rates up to 5 m^3/sec and many are thermal. Those on the northern border are more saline than those on the south. However, direct precipitation over the chotts is the principal source of surface water, and over large areas this may do little more than

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moisten the surface. Where water does collect it is usually turbid and of short duration. A number of oueds draining towards the chotts may flow periodically, but will not necessarily carry surface water as far as the chotts.

Flora & Fauna: The southwestern 'shore' carries a wide belt of halophytic vegetation, but elsewhere the strip of fringe vegetation is narrower. Brine pools occasionally develop a deep purple colour due to blooms of purple bacteria, and cyano-bacteria occur under salt crusts and at the saline spring of El Mensof in the chott. *Artemia* is present in the chotts, but is uncommon. The chotts proper are devoid of amphibians, reptiles and mammals, but are of some importance to birds. *Chlamydotis undulata* has been recorded on the fringes and *Phoenicopterus ruber* nests at the edges in some years.

By contrast much more diverse floras and faunas are found in the beds of the oueds that feed the chotts and in the springs around the margins. The crustacean *Thermosbaena mirabilis* lives in the hot springs at El Hamma, some of which have water temperatures as high as 51°C. Cyano-bacteria and diatoms live in all hot springs, being replaced where the waters cool, by Characeae, and in more saline waters by *Enteromorpha* sp. and *Ruppia spiralis*. *Scirpus littoralis* and *Zannichellia palustris* are found on the fringes of streams and pools and stands of *Typha capensis* occur in swampy places. The invertebrate fauna is quite rich. *Bulinus* spp. are present (but molluscicides are widely used and have reduced the bilharzia problem greatly). Several species of fish live in the oases, including *Aphanius fasciatus*, *Barbus antinorii*, *Haplochromis desfontainesi* and *Hemichromis bimaculatus*. *Gambusia affinis* has been introduced to control mosquitoes at several sites. *Bufo viridis* and *Rana ridibunda* are abundant, and *Mauremys caspica* occurs in the Oued Gabès if not in Chott Fedjadj. Rodents, two species of *Felis*, and many birds are also found at the oases.

Human Impact & Utilisation: The chotts proper are unmanaged. The oases around them have long been exploited for date production and horticulture. Tourism is increasing rapidly, and large centres of population have developed at several oases, e.g. Nefta (33°53'N/7°53'E) and Tozeur. There are problems with sewage disposal, and much swampland around the oases, which previously supported stands of *Typha*, has been reclaimed.

Conservation Status: Unprotected, but it has been suggested that the northern portion of the chott be included in a proposed National Park.

3. Other Wetlands & Impoundments

(A) THE DAR FATMA BOG

General: There are montane bogs in Algeria but this (36°48'N/8°45'E) is the only one in Tunisia. It is situated in the Kroumerie Region of the Mejerda Mountains, at an altitude of 770 m asl, in the wettest part of Tunisia. It is fed by a small stream and is about 25 km southwest of Tarbarka and 145 km west of Tunis. It covers about 3 ha and while the flora includes *Sphagnum subsecundum*, this is dominant over only small areas. Other species include *Anagallis crassipes*, *Asphodelus microcarpus*, *Eleocharis multicaulis*, *Erica scoparia*, *Isoetes hystrix*, *Montia fontana* and *Phragmites australis*. We have no information concerning the fauna of the bog and the site is not protected.

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(B) THE LAKE AT SDUK EL ARBA

General: There is a freshwater lake in the Mejerda Valley (36°29'N/8°51'E) near Sduk el Arba, at an altitude close to 160 m asl on the south side of the river. The lake is fed by a small stream and drains to the Oued Mejerda. It is fringed by *Phragmites australis* and other emergent macrophytes. We have no information regarding its fauna.

(C) ARTIFICIAL IMPOUNDMENTS

General: There are 14 large reservoirs in Tunisia with a total surface area of 17 600 ha, one of the largest being at Sidi Saad (35°22'N/9°50'E). There are small reservoirs at the 9 principal oases in the south.

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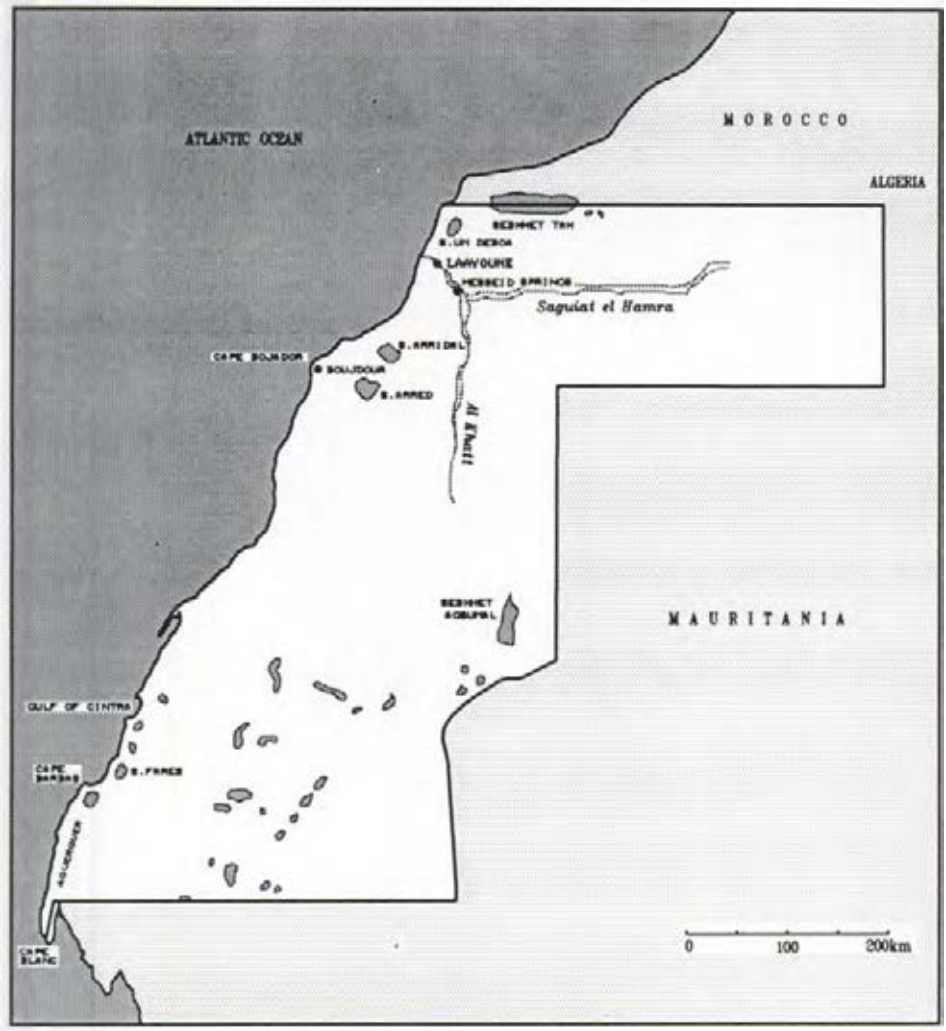

Map of Western Sahara

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1.6 WESTERN SAHARA

Introduction

Western Sahara has an area of 266 000 km^2. The population, determined by census in 1982, was 163 868, and the mean population density is thus amongst the lowest in Africa at 0.6 persons/km^2. The country extends 730 km from north to south between latitudes 20°21' and 27°37'N, and over 800 km from east to west between longitudes 8°39' and 17°06'W. It is bounded by Mauritania in the south and west, by Algeria in the northwest, by Morocco in the north, and by the Atlantic Ocean in the west. The Atlantic coastline is close to 1100 km long. There is a narrow coastal plain, below the 100 m contour, which contracts from 50 km wide in the south to little more than 5 km in the north. Towards the east the coastal plain rises to a low hinterland, less than 200 m in height, but with inselbergs rising to over 400 m. This interior plain stretches right across the country in the south, but a higher plateau intrudes across the eastern border of the country in central and northern districts. The highest point, 688 m asl, is reached on this plateau some 40 km north of Galat Zémmour (24°10'N/12°20'W).

There are no perennial streams in Western Sahara and drainage lines are marked by watercourses which are almost permanently dry. A number of these dry wadis run northwestwards from the low hinterland to disappear in the sand dunes along the coastal strip, but the longest and largest reaches the sea in a zone of moist sands north of Laâyoune (27°10'N/13°11'W).

Climate

Western Sahara is extremely arid. Mean annual rainfall is unreliable and most of the country receives less than 50 mm/yr, and there are extreme annual variations. The country is also extremely hot, but the cold Canary Current modifies coastal temperatures and produces morning fogs which penetrate several kilometres inland. These lead to lower morning temperatures than might otherwise be expected. NE Trade Winds from the Sahara Desert prevail over the country for most of the year. The SW monsoon which brings rain to southern Mauritania does not reach Western Sahara, but in summer, during June-August, winds generated by the Azores anti-cyclone, sweep across the Atlantic from the NW. They may later veer and blow southwestwards parallel with the coast. The influence of these winds extends some kilometres inland and they may bring light rain to the coastal strip at this time, together with a reduction in temperatures.

In passing up the coast, mean annual precipitation rises from 26 mm at Cape Doubouchage (20°51'N/17°06'W) to 76 mm at Ad-Dakhla (23°43'N/15°57'W), but falls again to 48 mm at Tarfaya (27°58'N/12°55'W), recently ceded to Morocco and now just across the northern border. Ad Dakhla is perhaps the wettest place in Western Sahara, and may receive 35 mm of rain in September. The interior is drier than the coast and potential evaporation is everywhere very high, except on canyon floors, and mostly ranges from 4000 - 4500 mm/yr.

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Wetlands

Ephemeral rains over the country may produce run-off which collects into saline pans (sebkhets) which are scattered throughout the interior and along the coastal strip. There are about 75 major sebkhets in the country, marked on most national maps, and a host of minor ones which are not marked. Some of the major ones have been known to support a few centimetres of standing water for short periods, but they are usually dry for years on end, and are saline, and generally devoid of vegetation. In the coastal strip there are other sebkhets which contain little temporary lakes. These are also saline, but they have vegetated margins which remain moist throughout the year, and some are surrounded by extensive marshes.

In addition there are gueltas (semi-permanent pools) in the upper parts of gorge-like watercourses which are common in the interior. Gorges, being deep and narrow, preclude excessive evaporation, and the gueltas receive water from springs in the canyon floors and walls, and from occasional floods which rush down the watercourses. Typical oasis vegetation is found around the gueltas, as described in the regional introduction.

List of Wetlands Described

1. Tidal Wetlands
2. Coastal Wetlands
3. Interior Wetlands - Pans & Oases.
   (a) The Saguiat el Hamra
   (b) The Springs of Messeit
   (c) The Oued el Jat
   (d) Interior Sebkhets

1. Tidal Wetlands

General: Tidal salt-marshes occur on the coast, but they are small and the coast is generally of high relief. Vegetation is confined to a seaward and a landward fringe, the middle portion being a barren salina. All the vegetation is strongly halophytic comprising species of *Salicornia*, *Sarcocornia* and *Suaeda*. Little is known of the resident or visiting fauna, but several endangered species of turtles visit the beaches including *Caretta caretta* and *Dermochelys coriacea*. The avifauna is typical of that described for North West African wetlands in the regional introduction.

Salt-marshes also occur at the few sites where the mouths of intermittent watercourses reach the sea instead of disappearing in the dunes. Examples of oued mouths which occasionally discharge to the sea, albeit rarely, are at 24°47'N/14°51'W, where an un-named watercourse reaches the beach, and at 27°20'N/13°18'W, where the Saguiat el Hamra reaches the sea north of Laâyoune. Although the tidal marsh at the mouth of this oued is comparatively small, the system has been known to carry running water to the sea, and when not flowing at the surface, there remains a subterranean discharge. The spectrum of plants found in the tidal zone at the river mouth therefore has brackish estuarine affinities, as described in the regional introduction.

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2. Coastal Wetlands

General: As in the interior, ephemeral rains and seepage often lead to the temporary collection of water in large flat pans variously called sabkhets, sebjets or sebkhets. Along the coastal strip, water from the interior may seep into these fairly continuously, so that even when it has not rained for long periods, the soils of the pans and their surroundings may be moist. Thus saline, non-tidal, coastal marshes arise. In a few cases, where seepage is great, or where a watercourse directly channels the run-off, these coastal pans may support temporary saline lakes.

In moving up the coast from south to north, Sebkhets Edjolla (21°48'N/16°56'W), Tenmud (21°53'N/16°49'W), Lemheiris (22°07'N/16°48'W) and El Mahariat (22°13'N/16°35'W), all lie on the coastal plain between Cape Blanc and Cape Barbas. Between this latter place and the Gulf of Cintra there are three more pans, Sebhket Fares (22°30'N/16°22'W), Sebkhet Tentauralet (22°44'N/16°17'W) and Sebkhet Ain el Beida (22°53'N/16°17'W), while an un-named pan is situated north of the gulf and some 15 km inland (23°14'N/15°56'W).

The next 340 km of coast is devoid of pans, but five large pans occur in a cluster in the El Hasian District, just inland of Cape Bojador. These tend to be more humid than the southern pans. Their names and locations are Sebkhet El Oreier (25°40'25°49'N/13°38'-13°46'W), Sebkhet Udel el Móher (25°46'-25°55'N/13°46'-13°48'W), Sebkhet Ulad Salem (26°00'-26°05'N/13°26'-13°31'W), Sebhket Aarred (25°55'-26°01'N/14°04'-14°13'W) and Sebkhet Arridal (26°04'-26°16'N/13°54'-14°10'W). Both Sebkhets Arridal and Aarred contain semi-permanent ponds, and both are fed directly by small intermittent streams as well by underground seepage.

The last major group of coastal pans lies along the northern border with Morocco. Here the Sebkhet Tah (27°41'27°48'N/12°29'-12°56'W) is 28 km long and up to 6 km wide and subject to more frequent, though still irregular inundation. The entire pan, with an area of 10 400 ha may become temporarily wet at the surface. In the vicinity there are other smaller pans, notably Sebkhet Um Deboaa to the south (27°28'-27°35'N/12°55'W-13°03'W); Sebkhet Tiefurin (27°46'N/12°51'W) and Sebkhet Lehmera (27°48'N/12°56'W) to the northwest; Sebkhet Huisi Elgal (27°47'N/12°25'W) to the east; and Sebkhets Tasya (27°57'N/12°19'W) and an un-named pan (28°00'N/12°20'W) to the northeast. These are all situated on land recently ceded to Morocco, but Sebkhet Tah straddles the new border.

Flora & Fauna: Many of the pans, especially in the south, are barren and encrusted by salts. The plants they support, where they are vegetated, are halophytes. Species of Chenopodiaceae and Salicorniaceae are common, and the vegetation is as described in the regional introduction. Semi-permanent ponds support fringes containing species of *Cyperus*, *Juncus* and *Scirpus*, with *Phragmites australis* and *Typha capensis* near points of fresh water entry.

Human Impact & Utilisation: The pans are little utilised and many are undisturbed.

Conservation Status: Unprotected.

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3. Interior Wetlands - Pans & Oases

(A) THE SAGUIAT EL HAMRA

Location: 26°47'-27°13'N/10°15'-11°25'W
Area: c. 62 000 ha (sandy bed)
Altitude: 0-300 m asl
Nearest Town: Laâyoune (2 km S)

General: The longest and largest intermittent watercourse in Western Sahara runs roughly from east to west across the north of the country, reaching the sea approximately 30 km west of Laâyoune. Over its upper reaches, tributaries from the highlands in the northeast converge upon the main watercourse, which becomes deeply entrenched in the Saguiat el Hamra (= Red Canyon). The floor of this canyon, which in places is bounded by walls over a hundred metres high, is several kilometres wide, flat, sandy and locally moist over a distance of 160 km. Hereafter the watercourse traverses a rocky, and relatively open, middle section for some 75 km. Below this the canyon reappears, and the watercourse is again deeply entrenched, finally cutting through the Draâ Afrafir, a line of flat-topped hills 20-50 km inland and parallel to the coast. The oued reaches the sea and humid sands stretch inland, up into the canyon, in a belt 1-3 km wide, for a distance of 126 km from the mouth. There is a permanent discharge of fresh water to the sea, but this is seldom seen at the surface. Over the entire lower section the oued receives numerous fossil affluents.

Flora & Fauna: Some areas of moist sand in the canyon support *Acacia nilotica*, *A. tortilis*, *Balanites aegyptiaca*, *Hyphaene thebaica* and *Tamarix* spp., and marshy areas and gueltas (ponds) support *Juncus*, *Phragmites* and *Typha*. However, in the lower canyon, some of this vegetation has been replaced by small *Phoenix dactylifera* plantations.

(B) THE SPRINGS OF MESSEIT

Location: 27°04'N/13°09'W
Area: a few tens of ha under irrigation
Altitude: c. 10 m asl
Nearest Towns: Laâyoune (12 km NE); Tarfaya (113 km NNE)

General: Perennial springs occur in the walls of the lowest part of the Saguiat el Hamra, at Messeit. Some flow out from shallow caves, but most now collect into concrete tanks to provide water for the irrigation of *Phoenix dactylifera* plantations. The water is saline, containing high concentrations of sodium, sulphate and chloride.

Flora & Fauna: The springs support no macrophytes but sedges grow in the concrete storage tanks. The areas of moist sand on which the date palm plantations have been established probably once supported *Acacia nilotica*, *A. tortilis*, *Balanites aegyptiaca*, *Hyphaene thebaica* and *Tamarix* spp. Dumont & Van de Velde (1975) describe the invertebrate fauna. We have no information regarding the vertebrate fauna.

Human Activity & Utilisation: The oasis is uninhabited, yet the canyon floor is exploited for date growing and for small scale horticulture. A surfaced road runs from

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Laâyoune to Semara, which until 1976, was used to bring tourists from the Canary Islands to visit the oasis. However, this practice has ceased in recent years.

Conservation Status: Unprotected.

(C) THE OUED EL JAT

General: The Saguiat el Hamra cuts through the Draâ Afrafir below the Springs of Messeit, and is joined by the Oued el Jat almost immediately to the east of these hills. This oued flows from south to north, parallel with the line of the hills, joining the Saguiat el Hamra at Edchera (27°02'N/13°05'W). On the floor of this watercourse too, there is a series of marshy areas with moist sands and small gueltas. The most important are in the Ugranat District and are, from south to north, the Sebkhets Ugranat (26°11'-26°16'N/13°10'W) and El Jat (26°27'-26°38'N/13°07'W). These sandy pans are saline and subject to fairly frequent, albeit irregular, inundation, and there are some fresh water springs in the gorge walls.

Flora & Fauna: Some trees grow along the oued, including *Hyphaene thebaica* and *Tamarix africana*, and marshy patches support grasses, sedges, rushes and reeds. We have no details of the fauna.

Human Impact & Utilisation: We have no information.

Conservation Status: Unprotected.

(D) INTERIOR SEBKHETS

General: There are 37 major sebkhets on the central and eastern parts of the interior plateau, south of the Saguiat el Hamra system. They are very largely barren, but are poorly investigated. We have little information about them, other then their locations, and have no knowledge regarding the frequency with which they receive surface run-off. So far as we are aware they are not regularly utilised and are virtually undisturbed. The Sebkhet Aghzoumal (24°10'-24°29'N/12°41'-12°58'W) is the largest and among the easternmost. It is the sink for half a dozen intermittent watercourses.

Flora & Fauna: Mostly barren.

Human Impact & Utilisation: Seldom if ever utilised.

Conservation Status: Unprotected.

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REGION 2

NORTH EAST AFRICA

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Introduction

This, the largest of the five regions, covers 6 995 265 km^2 and comprises those countries which drain in substantial part to the Nile, together with Djibouti and Somalia. It is also the most populous region having supported more than 166 055 000 persons in 1983. It stretches 4790 km from north to south between Sidi Barrani (31°38'N) on the Mediterranean coast and a point (11°45'S) on the Rovuma River in Tanzania, and 3195 km from west to east between longitudes 21°49'E on the Sudan/Chad border and 51°22'E at Cape Xaafuun on the Somalian coast.

There is a coastline of some 10 370 km. The Mediterranean coast extends for approximately 1100 km between Libya and Israel, in addition to which there are 575 km of lagoonal shores in the Nile Delta. The eastern shore stretches from the head of the Gulf of Aqaba to the tip of the Sinai Peninsula, around the Gulf of Suez, along the western shore of the Red Sea to the Indian Ocean, and thence south to the Mozambique border, a distance of 8685 km. Parts of the eastern coast are rugged, falling precipitously into the sea, other parts are low lying and sandy, while yet other parts, particularly in the south, are highly indented and fringed by numerous small offshore islands.

The coastal plains are generally narrow, 3-30 km wide, except in Kenya and southern Somalia where they attain widths of 150 km. Mountains rise behind the coastal plains lining the old rift valleys of the Red Sea and its northern gulfs, reaching 2637 m asl at Gebel Katherina (28°30'N/33°57'E) and 2187 m at Gebel Shayib el Banat (26°59'N/33°29'E) in Egypt, 2260 m at Jebel Oda (20°08'N/36°40'E) in Sudan, and 2416 m at Shimbiris Peak (10°40'N/47°11'E) in Somalia on the Gulf of Aden. South of this is the great highland massif of Ethiopia, divided by an arm of the East African Rift Valley into western and eastern blocks. In the Western Highlands 6 peaks rise to over 4000 m asl; Mts. Ras Dashen (13°12'N/38°25'E-4620 m), Abune Yosef (12°08'N/39°13'E-4193 m), Guna (11°44'N/38°14'E-4231 m), Talo (10°44'N/37°54'E-4154 m), Abaye Meda (10°27'N/39°47'E-4000 m), and Margherita (6°10'N/37°25'E-4200 m). In the Eastern Highlands Ch'ilalo (7°45'N/39°23'E-4133 m), K'ech'a (7°24'N/39°06'E-4190 m) and Batu (6°56'N/39°47'E-4307 m) are the highest peaks.

Still farther south, major highlands occur to both east and west of Lake Victoria. East of the lake there are high points of 4321 m at Mt. Elgon (1°12'N/34°30'E) on the Kenya/

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Uganda border; 3994 m at Mt. Satimma (0°17'S/36°38'E) in the Aberdare Mountains; 5199 m at Mt. Kenya (0°11'S/37°23'E); 4565 m at Mt. Meru (3°16'S/36°44'E), and 5895 m at Mt. Kilimanjaro (3°04'S/37°20'E). There are other high peaks in the Cherangany Hills (1°12'N/35°27'E) and in the Ngorongoro district (3°01'S/35°49'E). Altogether 3185 km^2 of land rises above the 3000 m contour, and approximately 33 000 km^2 above the 2000 m contour. West of Lake Victoria, mountains rise along the eastern border of the Western Rift Valley, sloping steeply down to Lakes Kivu and Tanganyika on the valley floor. Land rises to 5110 m at Mt. Stanley (0°24'N/29°53'E), to 4127 m at Mt. Muhavura (1°24'S/29°40'E) and to 4507 m at Mt. Karisimbi (1°31'S/29°27'E) on the Rwanda/Zaire border. In the far south of the region the Kipengere Range at the northern end of Lake Malawi reaches 2959 m asl at Rungwe Mountain (9°08'S/33°41'E), while in the far west Jebel Gimbala rises to 3071 m (12°57'N/24°20'E) close to the Sudan/Chad border.

Climate

During the northern winter, northeasterly winds predominate over almost the entire region. These winds blow from SW Asia and Saudi Arabia and are hot and dry, but in the northern summer the wind systems are more complex. In the northern parts of the region, winds are then from the west, off the Sahara. Thus, the northern part of the region is arid all year round, generally receiving less than 100 mm rain/yr; indeed large areas of Egypt and the Sudan receive significantly less than this, although rain storms sometimes occur in the hills along the Red Sea in winter and there may be falls along the Mediterranean coast. Mean annual rainfall at Alexandria (31°12'N/29°58'E) is 175 mm, but at Cairo it is only 25 mm.

In passing inland the desert eventually gives way to a Sahel zone, extending between latitudes 12 and 16°N, and this in turn grades into a Soudanian Savanna zone, at latitudes below 12°N, with a progressive increase in rainfall to the south. Both these zones experience a harsh dry season in winter and a relatively short wet summer season. The Soudanian Savanna zone grades into more humid tropical savannas towards the equator, but conditions are modified by altitude and the presence of the highland massifs.

In summer, winds over most of the central and southern parts of the region are from the southwest. Humid air from the high pressure zones of the South Atlantic and Gulf of Guinea moves across central Africa, bringing rain to the highlands of Tanzania, Burundi, Rwanda, Uganda, Kenya and Ethiopia, and lighter falls to the Soudanian Savanna and Sahel zones. At the same time the SE Trade Winds blow in from the Indian Ocean across the coasts of Somalia, Kenya and Tanzania, again bringing rain. However, these winds are most persistent in the south of the region and bring little rain to Somalia. On rising inland, these winds veer southwesterly, joining the stream from the Atlantic, and contributing to the falls on the highlands.

At El Obeid (13°10'N/30°12'E) in the Sahel zone, 560 m asl, mean annual precipitation is 362 mm. In the Soudanian Savanna zone, Gallabat (12°57'N/36°10'E), 760 m asl in the western foothills of the Ethiopian Massif, receives an average of 890 mm rain/yr. Malakal (9°33'N/31°40'E), at the northern edge of the Sudd, receives 787 mm/yr, while Bor (6°16'N/31°33'E), at the southern edge, receives 905 mm. Still farther south, Mongalla (5°12'N/31°42'E) has a mean annual rainfall of 945 mm.

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Rainfall is generally between 1000-1500 mm over the Ethiopian Highlands, but reaches 2000 mm on the SW faces of the highest peaks. Adis Abeba (2440 m asl) in the centre of the massif has a mean annual receipt of 1302 mm, while Dese (11°05'N/39°40'E), 250 km NNE (2220 m), receives 1118 mm/yr. Adi Ugri (14°47'N/38°50'E) at the far northeastern end of the massif, close to the Red Sea, but again at a similar altitude (2022 m), receives only 730 mm/yr, the SW winds having lost much of their moisture before reaching here. The Rift Valley which divides the highlands into eastern and western blocks is quite arid, and the Danakil Desert occupies the area between the highlands and the Gulf of Aden, being in the rainshadow of the mountains. The southeastern lowlands of Ethiopia, which lead into Somalia and Kenya, have two rainy seasons, one in spring and another in autumn, but are comparatively dry, with annual falls of 400-500 mm. The higher plateau areas of Somalia and Kenya, east of the mountains, are semi-desert zones, locally receiving less than 250 mm rain/yr.

There is no harsh dry season around Lake Victoria nor over the Western Rift Valley. March-September is the wettest period and October-February the driest, but some rain falls in all months. Mean annual receipts may be as high as 3000 mm on some of the highest peaks, e.g. Mt. Stanley, but generally precipitation does not greatly exceed 2200 mm in these mountains. In the far south of the Western Rift, at an altitude of 1550 m, Tukuyu (9°14'S/33°39'E) on the SW slopes of the Kipengere Range, receives 2303 mm/yr. Close to, and over Lake Victoria, mean annual precipitation averages 1000-1500 mm, e.g. 1020 mm at Mwanza (2°31'S/32°56'E) on the central southern shore; 1295 mm at Kisumu (0°08'S/34°44'E) on the eastern shore; and 1505 mm at Entebbe (0°04'N/32°27'E) on the northwestern shore. However, Bukoba (1°19'S/31°49'E), on the midwestern shore, receives 2025 mm.

The northern coasts are extremely arid, e.g. 3 mm/yr at Hurghada (27°18'N/33°47'E) on the Red Sea, but precipitation increases patchily to the south so that Mits'iwa (15°38'N/39°25'E) in Ethiopia receives 165 mm/yr. Large annual variations occur; for example the lowest annual total recorded for Suakin (19°38'N/37°18'E) is 33 mm, and the greatest 617 mm. Although the Red Sea reaches 350 km in width, it is only 33 km wide at its confluence with the Indian Ocean and at this point a submarine ridge impedes the free exchange of water, so that the waters of the Red Sea are unusually warm and saline.

The north Somalian coast is extremely arid, but rainfall increases steadily in passing southwards reaching 600 mm/yr in southern Somalia, 900 mm/yr at Lamu (2°17'S/40°54'E) on the north Kenyan coast, and 1200 mm/yr at Mombasa (4°01'S/39°32'E). It is highest on the Tanga coast, probably reaching 1400 mm/yr locally, but then declines in passing farther southwards, to 1110 mm at Dar es Salaam (6°51'S/39°18'E) and 936 mm at Lindi (10°00'S/39°41'E). This rainfall is seasonal, deriving from the SE Trade Winds, and it decreases progressively away from the sea. However, falls on the series of scarp slopes, encountered in passing inland, tend to be equivalent to those at the coast, especially those inland of the Tanga coast. Here, at Amani (5°09'S/38°36'E), at the southern tip of the Usambara Mountains (910 m asl), mean annual rainfall is 1946 mm, and over 2200 mm falls on the summits (c. 2400 m asl). The flatter areas of the eastern interior, between scarps and peaks, are comparatively dry with mean annual receipts of 700-1100mm

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Large seasonal and diurnal temperature variations occur in the northern deserts. At Alexandria, on the Mediterranean coast, January minima and maxima range from 11- 18°C, while at Aswan they range from 10 to 23°C, but summer temperatures can reach 48°C in the interior and can fall to 10°C at night. Temperatures along the Red Sea may also reach 48°C in summer, but diurnal variations are not so great as in the interior. The Ethiopian Highlands enjoy a temperate climate because of their altitude. Although seasonal variations are not great here, diurnal ones are substantial, most stations having daily ranges of 13-16°C. The mean annual temperature at Adis Abeba, at an altitude of 2439 m is 16°C, while at sea level, at Mits'iwa, it is 31°C.

At Shambe (7°07'N/30°47'E), on the banks of the Nile in the Sudd, March is the warmest month with a mean daily maximum of 38.6°C (range 35-44°C) and a mean daily minimum of 23°C (range 18-26°C) and a mean monthly temperature of 30.8°C. August is the coolest month with a mean daily maximum of 31°C (range 27-34°C), a mean daily minimum of 21°C (range 19-23°C), and a mean monthly temperature of 26°C. The regime at Malakal, north of the Sudd, is very similar, but April is the warmest month with a mean temperature of 31.1°C, while August is the coolest month with a mean temperature of 26 °C. At Bor, on the southern edge of the Sudd, March is the warmest month with a mean temperature of 28°C and September is the coolest month with a mean temperature of 25°C.

Mean temperatures in Equatorial East Africa are closely related to elevation. The highest temperatures are recorded in the arid regions along the coast of Somalia, and in lands to the west of Lake Turkana. In these places mean night-time minima may be as high as 29°C. Frosts occur in the mountains above 3000 m, and permanent snows occur above 4850 m, e.g. on Mts. Stanley, Kenya and Kilimanjaro. Diurnal temperature ranges are of the order of 18°C in the highlands and 8°C at the coasts. March is the warmest month at Mombasa, with a mean daily maximum of 32.8°C, a mean daily minimum of 24°C, and a mean monthly temperature of 28.4°C. July is the coolest month with a mean daily maximum of 28°C, a mean daily minimum of 20.2°C, and a mean monthly temperature of 24.1°C. At Kisumu (1157 m) February is the warmest month, with corresponding figures of 31°C, 17.5°C and 24.2°C, while July is the coolest month with figures of 27.6°C, 16°C and 21.8°C. At Nakuru (1850 m), February is the warmest month, with figures of 29°C, 8.8°C and 18.9°C, while July is the coolest month with figures of 24°C, 10.2°C and 17.1°C. Here diurnal variations are much greater in February than in July.

Drainage

Drainage is complex. Run-off from the region finds its way to the Mediterranean Sea via the Nile and various minor watercourses, and to the Gulfs of Suez and Aqaba, the Red Sea, the Gulf of Aden, the Indian Ocean direct, the Indian Ocean via Lake Malawi and the Zambezi, the Atlantic Ocean via Lake Tanganyika and the Zaire River, and to numerous endorheic lakes and depressions.

The Nile

The principal drainage system is that of the Nile, the longest river in the world. The source furthest from the sea flows as the Luvironza River in Burundi (3°44'S/29°47'E), rising about 1750 m asl in mountains on the eastern side of Lake Tanganyika. From this

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point the river flows 6695 km to the Mediterranean Sea, which it reaches at 31°38'N at the extremity of its delta, having traversed 35°22' of latitude. The published area of the drainage basin varies greatly, e.g. by 1 448 870 km^2 between the Times Atlas (1985) which gives an area of 1 900 000 km^2 and the Encyclopaedia Britannica (1975) which gives 3 348 870 km^2. Most other sources place the area in the vicinity of the latter figure. Welcomme (1972) for example gives 3 004 400 km^2. These discrepancies probably arise because much of the northern basin is extremely arid and of little relief, and thus does not provide active drainage to the river. Our calculations for the basin give an area of 3 026 000 km^2. The eastern watershed runs SSE through Egypt and Sudan, along a mountainous crest parallel with the Red Sea. From Port Sudan it runs inland, SSW, passing east of Kassala in Sudan, it then snakes southeastwards through the Ethiopian Highlands to the vicinity of Dese, and then SSW, looping east of Adis Abeba, and passing west of Lakes K'ok'a, Ziway, Abiyata, Shala, Awasa, Abaya, Ch'amo and Turkana (Rudolph), thus encompassing much of the Western Highlands. Thereafter it passes east and south of Lake Victoria, closely skirting the southern shore, before finally running west to the source of the Luvironza in Burundi.

The western watershed at first runs SE across Egypt, roughly parallel with the river valley, but then swings westwards, encompassing a vast region including part of SE Libya, and Northern and Southern Darfur where it follows the Sudan/Chad border. Thereafter it runs SE through the Bahr el Ghazal District of Sudan along the Sudan/Zaire border. Finally it crosses into Zaire, where it encompasses Mt. Stanley (0°26'N/29°52'E-5110 m) by running along a crest just west of Lakes Albert and Edward, and finally runs up to Mt. Karisimbi and along a crest above the eastern shore of Lake Kivu to the source of the Luvironza.

The Nile proper has five major tributaries, the Bahr el Jebel (River of the Mountains), the Bahr el Ghazal (River of Gazelles) and the Sobat River, which unite to form the White Nile, and the Blue Nile and Atbara River. The southernmost headwater stream, the Luvironza River, flows south for some 20 km, then north for 100 km, before swinging eastwards past Gitega (3°23'S/29°56'E) when it becomes the Ruvuvu River. Two other important headwater streams, the Akanyaru and Nyawarungu Rivers rise well above the 2000 m contour in Rwanda, east of Lake Kivu, and some 150 km north of the source of the Luvironza. At first these both flow eastwards in parallel, but then they diverge, the Akanyaru to the south and the Nyawarungu to the north, until having both described imperfect semi-circles, they meet in central Rwanda. Prior to their confluence they both drain swampy lakes, and below it the combined stream traverses extensive swamps en route to the Rwanda/Tanzania border where it joins the Ruvuvu River, thereafter being known as the Kagera River. This latter stream is the largest affluent of Lake Victoria. It flows north for 250 km through a shallow swampy valley containing 14 major lakes and innumerable minor ones, before turning sharply east near Kakitumba (1°04'S/30°45'E) to flow for a further 230 km to Lake Victoria. It enters the lake through another 30 km of valley swampland near the midpoint of the western shore at an altitude of 1134 m asl.

Lake Victoria is the third largest lake in the world, in terms of area, after the Caspian Sea and Lake Superior. It is a shallow lake, with a maximum depth of 85 m, several small islands, and much swampy shoreline. Its southern shore receives many short seasonal streams, while its eastern shore receives a number of perennial rivers draining the

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mountains to the east. The most important of these rivers is the Mara which drains the Loita Plains and Lebetero Hills (2683 m) of SW Kenya, and the southern mountains of the Mau Escarpment along the western side of the Eastern Rift Valley, where there are several high wet peaks, e.g. Mau (3049 m) and Melili (3098 m). The Mara enters Lake Victoria about half way along its eastern shore, while a further 8 large perennial rivers, and several small ones, enter in the NE quadrant of the lake. These drain both the northern and central parts of the Mau Escarpment and the Cherangany Hills, and the massif of Mt. Elgon.

The western side of the Lake Victoria basin was tilted in the late Pleistocene. This reversed the flow of several rivers which used to flow westwards across the basin to Lakes Edward and Albert, and gave rise to Lake Victoria. The Katanga River now drains the country between Lake Victoria and Lake Edward, but a waterway is virtually continuous between the two lakes because there is now a swampy watershed from which the river flows both east and west. That the old river used to flow west to Lake Edward is clear from the incident angles of its tributaries, but since the basin was tilted, flow has reversed so that the eastern part now flows sluggishly to Lake Victoria, entering it through swamps. Moreover, flow in the old lower reaches, between Lake George and Lake Edward, is also sluggish and may reverse temporarily.

Some 86% of the water in Lake Victoria is derived from direct precipitation, and as much as 82% is lost by evaporation. Only 18% of the water which enters the lake continues downstream in the Victoria Nile, which leaves the lake close to its northern extremity at Jinja (0°27'N/33°12'E) in Uganda. The river used to cascade over waterfalls but these were submerged by the construction of the Owen Falls Dam in 1954. From here the river flows NNW for 150 km, before traversing the swampy southern basin of Lake Kyoga, to receive, still in swampland, the drainage of Lake Kwanta. Thereafter the river flows west to a confluence with the Kafu River, another stream in which drainage has been partially reversed, so that although the river appears on maps as a continuous watercourse between the Victoria Nile and the top end of Lake Albert, water in it flows in opposite directions at its two ends. The Victoria Nile then descends the eastern wall of the Western Rift Valley by the Murchison Falls to enter Lake Albert close to its northern end.

Lake Albert collects run-off from the mountains (Karisimbi and Muhavura) at the northern end of Lake Kivu, from the northern Mitumba Mountains of Zaire, and from Mt. Stanley, via Lake Edward and the Semliki River. These waters, together with those of the Victoria Nile, issue from the northern end of the lake as the swamp fringed, Albert Nile. Together with Lake Victoria, Lake Albert acts as a reservoir, collecting the run-off from the high rainfall areas of Equatorial East Africa. Both lakes remove sediment from the waters and buffer the flow of the upper Nile which, below Lake Albert, is clear. However, by contrast with the situation in Lake Victoria, only a small fraction of the water which enters Lake Albert is lost by evaporation. The mean annual discharge from Lake Albert was 22 102 million m^3 between 1905-1962, giving a mean rate of flow of 700 m^3/sec, but between 1963-1980 these figures doubled.

At a point (3°36'N/32°01'E) near Nimule, the river enters Sudan in a region of gorges, culminating in the Fola Rapids, and is then known as the Bahr el Jebel (River of the Mountains). It flows swiftly, and is confined to a narrow bed until Juba (4°44'N/31°37'E), about 330 km downstream, where it flows smoothly onto a very flat clay plain at an

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altitude of about 430 m. This plain descends a comparatively narrow valley, with hills on either side, at a mean gradient of 1:13 000. Here the river overtops its banks following seasonally heavy rain in the catchments, and inundates almost the entire valley floor.

A vast permanent swamp, known as the Sudd, begins below Mongalla (5°12'N/31°42'E), 75 km downstream from Juba. At first the Bahr el Jebel traverses a broad swampy trough in a well defined, but branched channel, with raised banks. However, below Bor the river banks are not discernible, the swamp widens progressively and there are numerous peripheral lakes and parallel streams, e.g. the Atem River. The river channels are deep, but beset with islands of floating vegetation, and the swamp extends northwards for 400 km, attaining a width of 100 km locally. Another river, the Bahr el Zeraf, rises in the swamps to the east of the Bahr el Jebel and the two streams are artificially united by short canals where they approach each other at Zeraf Cuts (7°47'N/30°32'E). Today only the southern canal remains open and water flows through this from the Bahr el Jebel to the Bahr el Zeraf, only to re-enter the Bahr el Jebel at a confluence east of Tonga (9°22'N/31°06'E). A large area, 180 km long and up to 65 km wide, known as Zeraf Island, is thus isolated between the two streams. This was once mostly dry land, but following the rise in water levels which has been sustained since 1963-1964 it is now almost totally inundated, and the total area of the swamps now approaches 1 650 000 ha. Around the periphery of the swamp is a large seasonal floodplain occupying about 1 500 000 ha.

Some 26 920 million m^3 of water entered the Sudd each year between 1905-1960, but between 1961-1980 this had increased to 50 324 million m^3/yr. Approximately 17% used to be contributed by seasonal and torrential tributaries of the Bahr el Jebel, and 83% by discharge from Lake Albert, but these figures have changed slightly since 1961, with a higher % contribution from Lake Albert. In traversing the Sudd about 50% of the water is lost by evaporation and the rate of flow is much reduced. The mean annual discharge from the Sudd, measured above the confluence of the Sobat at Malakal, was 14 158 million m^3 until 1960, but has averaged 21 387 million m^3 in subsequent years. Long term changes in outflow from the East African lakes are responsible for the increased annual flows; they are well documented but poorly understood.

Because so much water is lost by evaporation in the swamps the Jonglei Canal is being cut to the east of the Sudd to bypass the swamp. The canal will run from Bor to a point just above Malakal. However, the reduction in volumetric flow is compensated for at the northern end of the Sudd by the inputs of three tributaries. The Bahr el Ghazal joins the Bahr el Jebel at Lake No, a large lagoon on the left bank, after which the stream swings sharply east for 150 km, receiving first the Atar and then the Sobat Rivers on the right bank. Below this the river again flows northwards and is referred to as the White Nile (Bahr el Abiad). Remarkably, although it flows freely after leaving the Sudd, the gradient of the river valley is less than in the Sudd, flattening here to 1:19 000.

The Bahr el Ghazal drains a dry plateau of that name on the Sudan/Zaire border, together with a part of Southern Darfur, but neither it nor the Atar contributes much water to the White Nile compared to the Sobat which drains the southeastern part of the Ethiopian Highlands. So high does the Sobat rise in flood that the volume of water carried between Malakal and Khartoum (15°34'N/32°32'E) may double in October and November.

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Nevertheless, the mean annual flow at Malakal is only 17 000 million m^3, 63% of what it is when entering the Sudd. The Jebel Aulyia Reservoir above Khartoum was constructed to hold back the floods created by the Sobat, and to regulate river flow downstream. This impoundment is the seventh largest in Africa with a surface area of 150 000 ha at capacity. Rain which falls on the catchments of equatorial East Africa reaches the lower Nile the following summer. This long delay is occasioned by retention in Lake Victoria and by the sluggish traverse of the Sudd. Between the Sudd and Khartoum much of the White Nile is fringed by swamps in strips generally about 300 m wide.

The volume of water carried by the Blue Nile changes quite dramatically through the year. Heavy rains fall over the Ethiopian Highlands in July and August and pass down the Blue Nile and Atbara Rivers to produce the deep sediment laden floods that develop in Egypt between September and November. The Blue Nile is said to rise as the Abbai, the longest of several torrential, but seasonal, streams feeding Lake Tana, from which the Blue Nile *per se* emerges (11°34'N/37°28'E) at an altitude of 1829 m. Lake Tana is shallow and is situated in the Western Highlands of Ethiopia, where it is ringed round by high peaks including Mts. Ras Dashen, Guna and Amedamit. On leaving the lake, the Blue Nile flows swiftly southeastwards, plunging over rapids for 200 km in a deeply cleft valley, before traversing a giant bend in which it sweeps through 135°, to flow almost due west for a further 400 km. All along this deep valley, often over 1200 m below the level of the plateau, it receives tributaries, but then flows NW in a widening valley for 200 km to Er Roseires (11°49'N/34°20'E) where it is impounded in the foothills of the mountains, producing a lake with a surface area of 29 000 ha (at capacity). Below the dam the gradient flattens and the river meanders across the Sudan Plains for 330 km to Sennar (13°33'N/33°37'E) where it is again impounded (lake area 16 000 ha), before continuing NW for a further 330 km, to a confluence with the White Nile just below Khartoum. On this latter stretch the river receives its two most important tributaries on the right bank. These are the ad-Dindar and the ad-Rahad, both of which are perennial and drain the western slopes of the Western Highlands. Following summer rains in the mountains the Blue Nile begins to rise in June, and reaches a maximum at Khartoum in September. It is estimated that a mere 7% of the water reaching the confluence at Khartoum is derived from Lake Tana, the bulk being contributed by the many tributaries.

The Atbara River, and its principal tributaries rise on the western slopes of the mountains enclosing Lake Tana, and following the summer rains, they flow swiftly northwestwards, for 550 km to an impoundment at Kashm el Girba (14°53'N/35°55'E), which has produced an artificial lake with an area of 12 500 ha. The river continues less swiftly below the dam, but in the same direction, for 600 km to reach a confluence with the Nile at Atbara (17°43'N/34°00'E), 310 km below Khartoum. While the Atbara River is an important tributary of the Nile, it is reduced to a trickle, and sometimes to a series of shrinking pools, towards the end of the dry season. Nevertheless, when both the Blue Nile and Atbara are in flood, the rate of flow in the White Nile, below Atbara may increase seven fold. The Blue Nile may rise by more than 6 m at Khartoum in August and its flood then holds back the flow of the White Nile, creating local floods south of the city.

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Below Atbara the Nile flows north for 100 km, then NW for 165 km, then sharply SW for 310 km, then sharply north again, thus describing a great zig-zag in the desert. Just above Ed Debba (18°01'N/30°54'E) where it resumes its northerly course, it receives on its left bank, a great wadi bringing subterranean drainage from Northern Darfur. This is the last major watercourse to join the Nile on its left bank. Below Ed Debba the river flows north for 325 km and then NE for 100 km to a point (20°27'N) where it widens to form the 400 km long Lake Nasser/Nubia behind the Aswan High Dam (23°58'N/ 32°54'E) situated in true desert, virtually devoid of vegetation.

The peak of the flood occurs at Aswan in September when the rate of flow may reach 8100 m^3/sec, of which the Blue Nile contributes some 68%, the Atbara 22% and the White Nile only 10%. By contrast, at low water in May, the White Nile contributes about 83% of the flow, the Blue Nile 17% and the Atbara none. Approximately 84% of the water stored at Aswan comes from the Ethiopian Highlands and 16% from Equatorial East Africa. The lake has a dead storage capacity below a depth of 147 m, of 31 billion m^3, below which the hydroelectric gear will not operate. Above this it has a live storage capacity of 90 billion m^3, representing water depths at the dam of 147-175 m asl. In addition there is a flood control capacity of 41 billion m^3, between water depths of 175-182 m asl. Thus at capacity the dam can impound 161 billion m^3 of water, when it will have a surface area of 717 400 ha, ranking as the second largest impoundment in Africa after Lake Volta. In recent years water levels have ranged between 175-179 m asl.

The straight line distance from the Aswan High Dam (127.6 m asl) to the tip of the delta is 875 km, but the river course is close to 1100 km, thus the mean gradient over this final sector is about 1:8333, i.e. the bed falls by less than 12 cm in every kilometre. In this sector the river receives numerous periodic tributaries from the western slopes of the hills separating it from the Gulf of Suez. These have deep water worn gullies, but are almost permanently dry; only after heavy winter rainstorms in the hills do they become torrents for short periods. Immediately below Cairo (30°01'N/31°14'E) distributaries spread through the delta which occupies over 26 000 km^2. This is symmetrical, 175 km deep from base to apex (i.e. from Cairo to the sea), and 300 km wide across the seaward face which is lined by swampy brackish lagoons. Averaged over a year, the mean rate of discharge of the Nile, determined above the delta, is 820 m^3/sec.

It is thought that the valley of the Blue Nile, and below this, that of the Lower Nile, are very old, dating back to Eocene times (Berry, 1976), and it seems that the vast bulk of the sediments which have always sustained Egyptian agriculture, and have built the delta, have been derived from the Ethiopian Highlands (McDougall *et al.*, 1975). However, the construction of the Aswan High Dam has greatly altered conditions on the Lower Nile by reducing the flood and trapping sediment.

The Nile has always been important for the transport of people and cargo, although the several cataracts preclude continuous transport between Sudan and the sea. However, river steamers are still important, especially in the Sudan south of latitude 15°N, where road transport is difficult between May and November. Most towns in Egypt and Sudan are close to the river and are served by boats which ply individual stretches between cataracts and/or dams; perhaps the most important service being between Khartoum and Juba, through the Sudd. The Blue Nile is navigable during the flood as far as Er Roseires,

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and the Sobat as far as Gambela (8°14'N/34°36'E). At high water the Bahr el Ghazal is also navigable for several hundred kilometres.

Other Drainage Systems

There are no perennial streams on the Sinai Peninsula. Drainage is by numerous short wadis to the gulfs of Aqaba and Suez, and by a very extensive anastomosing system which culminates in the Wadi el Arish, which discharges to the Mediterranean Sea.

A number of depressions, containing oases, occur in the Egyptian Desert, the most important being the Siwa Oasis and the Quattara Depression (133 m below sea level) in NW Egypt, and the Farafra, Dakhla and El Khârga Depressions in Central Egypt. Local drainage to all of these is virtually zero, but subterranean waters reach them from afar.

Lines of drainage from the eastern slopes of the hills along the Gulf of Suez and Red Sea, are marked by numerous wadis oriented NE or E, but there are no perennial streams on these coasts. Similarly, the arid mountains of the Horn of Africa, in northern Somalia, drain to the sea by wadis leading north to the Gulf of Aden or southeast to the Indian Ocean. Despite the lack of perennial waters, deltas have built up at the mouths of some Red Sea wadis.

In Ethiopia, run-off from the eastern slopes of the Western Highlands and the western slopes of the Eastern Highlands, finds its way by seasonal or perennial streams into the endorheic lakes of the Ethiopian (Eastern) Rift Valley, while that from the seaward slopes of the Eastern Highlands either collects into the Awash River which discharges into a series of endorheic lakes on the Ethiopia/Djibouti border, or into two major rivers, the Shabeelle and Jubba. These both drain huge basins and flow in parallel southeastwards into Somalia, where they descend from the plateau to the coastal plain in spectacular gorges with precipitous sides. On reaching the coastal plain, here 60 km wide, the northern stream, the Shabeelle, is diverted southeastwards by dunes, and flows parallel with the sea for almost 400 km before reaching a confluence with the Jubba below Kamsuuma (0°06'N/42°46'E). The Jubba then reaches the sea a short distance downstream at the town of Jubba (0°16'S/42°34'E). Much of northeastern Kenya also drains to the Jubba via a series of seasonal tributaries.

The Eastern Rift Valley bisects the mountains east of Lake Victoria, just as it does the Ethiopian Highlands, and another series of endorheic lakes lies in the valley here (Lakes Baringo, Bogoria, Nakuru, Elmenteita, Naivasha, Magadi, Natron, Manyara, Eyasi and Kitangiri). These receive drainage from the central mountains and from the south, while water from the eastern slopes of the mountains and the eastern plateaux finds its way directly to the Indian Ocean by a series of rivers running roughly from west to east. The most important of these are, from north to south, the Tana, Galana, Umba, Pangani, Msangasi, Mligasi, Wami, Ruva, Rufiji, Matandu, Mbemkuru, Likuledi and Ruvuma Rivers. In Kenya, the western slopes of the mountains drain to Lake Victoria, but in Tanzania they, and much of the plateau of Tanzania, drain to Lake Tanganyika via the Malagarasi River, and thence to the Atlantic via the Zaire River.

In the far south, the swamp fringed, endorheic, Lake Rukwa occupies a section of the Western Rift Valley situated between Lakes Tanganyika and Malawi. It receives the Rungwa, Kavu, Momba and Lupa Rivers, together with several minor streams. These drain the southern part of the interior plateau of Tanzania, the eastern slopes of the

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mountains along the shore of Lake Tanganyika, the highlands of the Zambia/Tanzania border and part of the Kipengere Mountains at the head of Lake Malawi. Other streams from the Kipengere Range flow into Lake Malawi and their waters thus reach the Indian Ocean via the Zambezi.

Vegetation

The vegetated strip along the Mediterranean coast is highly disturbed and quickly gives way to unvegetated desert in proceeding southwards. Deserts also flank the Red Sea and Gulf of Aden. The interior desert in this region extends to a latitude of 16°N in places, after which it gives way to Sahelian grass/scrub and this to Sahelian *Acacia* bushland, which extends to the vicinity of the parallel 12°N. This vegetation then merges into a broad belt of Soudanian woodland which stretches from the Southern Darfur and Bahr el Ghazal Districts of Sudan to the western flanks of the Ethiopian Highlands, interrupted in the south by the herbaceous swamps of the Sudd. In ascending the Ethiopian Highlands, Soudanian woodlands give way to evergreen woodlands, and these to montane vegetation.

South and east of the Sudd and the Ethiopian Highlands, at a latitude of 6°N, the Soudanian woodlands give way to deciduous *Acacia-Commiphora* bushlands which extend to to the coast and cover a vast area of SE Ethiopia, Central Somalia and NE Kenya. South and west of the Sudd, the Soudanian woodland grades into mosaics of a type of Guineo-Congolan rain forest and secondary vegetation, and this covers much of the inland plateau of Equatorial Africa. The NW shores of Lake Victoria support swamp forest, and pockets of rain forest occur on some of the islands in the lake. This vegetation gives way to montane, and eventually to Afro-alpine, vegetation on the various mountain ranges, and in the south of the region to various types of miombo woodland, dominated by *Brachystegia*, *Isoberlinia* and *Julbernardia*. The coastal districts, and slopes leading down to the sea from the interior plateaux, are covered by a characteristic type of coastal forest which extends from southern Kenya to Mozambique.

Wetlands

Saltmarshes occur on the Mediterranean, Red Sea and Indian Ocean coasts, and they are locally extensive in Kenya and Tanzania behind the mangroves. Mangrove vegetation occurs from the Gulf of Aqaba, near the tip of the Sinai Peninsula, to the southern limit of the region. It has a patchy distribution on Red Sea coasts in the north, and is absent from most of the Somalian coast. However, mangrove swamps are well developed at suitable sites from Lamu to southern Tanzania, reaching their most extensive development in the Rufiji Delta. Coastal lagoons are a prominent feature of the Nile Delta, and also occur in the Red Sea, but coastal lakes are uncommon in this region. Grass/sedge swamps are exceptionally well developed in the central and equatorial parts of the region, along rivers (e.g. the Sudd on the Nile), in valleys with impeded drainage, and around lakes where water level fluctuations are substantial. Permanent swamp forests occur around Lake Victoria, and forests subject to seasonal inundation occur on many rivers in the equatorial zone. Because rainfall is seasonal, riverine floodplains are common, many dominated by grasses. There are many lakes, including highly saline endorheic

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lakes (e.g. Lake Natron), large shallow lakes (e.g. Lake Victoria), large deep lakes (e.g. Lake Tanganyika) and numerous impoundments (e.g. Lake Nasser/Nubia). Mossy peat bogs occur in the high mountains. There are oases in the deserts, wadis subject to flash floods, rivers that dry up for many months each year and saline flats where subterranean waters moisten the surface after heavy rains over distant catchments.

Wetland Flora

Tidal Wetlands: No mangroves occur on the Mediterranean coast, but the principal mangrove species on the east coast are *Avicennia marina*, *Bruguiera gymnorrhiza*, *Ceriops tagal*, *Lumnitzera racemosa*, *Pemphis acidula* (on rocky substrates), *Rhizophora mucronata*, *Sonneratia alba* and *Xylocarpus granatum*. *Avicennia* has the greatest latitudinal range, extending from the lower part of the Gulf of Aqaba to the southern regional boundary. *Bruguiera*, *Pemphis* and *Rhizophora* have almost equally wide ranges, extending from middle Red Sea coasts to the southern boundary. *Ceriops* occurs north of the equator in Somalia and reaches the southern boundary. *Lumnitzera*, *Sonneratia* and *Xylocarpus* may occur in southern Somalia, but are common only from mid-Kenya to the southern regional boundary.

A number of salt and flood tolerant trees and bushes occur at the landward sides of tidal swamps in Kenya, in infrequently flooded sites separated from the frontal mangroves by bare or sparsely vegetated mudflats, or they may occur as islands of woodland in the middle of these mudflats. The most important species here are *Acacia zanzibarica*, *Borassus aethiopum*, *Casuarina equisetifolia*, *Dobera glabra*, *Ehretia petiolaris*, *Flacourtia indica*, *Hyphaene parvula*, *Salvadora persica*, *Sideroxylon diospyroides* and *Sterculia africana*. Occasionally *Avicennia marina*, *Bruguiera gymnorrhiza* and *Lumnitzera racemosa* occur with these landward trees, while the saltflats between them and the seaward trees, support halophytic herbs including *Arthrocnemum indicum*, *Cenchrus ciliaris*, *Crinum* sp., *Dactylactenium geminatum*, *Echinochloa haploclada*, *Ipomoea pescaprae*, *Panicum pinifolium*, *Paspalum distichum* (= *vaginatum*), *Sesuvium portulacastrum*, *Sporobolus virginicus*, *Stenotaphrum secundatum* and *Suaeda monoica*.

Other woody species occur on the mangrove fringes in equatorial and southern districts, in sites subject to infrequent tidal inundation. These include *Acacia kraussiana*, *Apodytes dimidiata*, *Brexia madagascariensis*, *Bridelia micrantha*, *Capparis sepiaria*, *Colubrina asiatica*, *Erythrina variegata*, *Guettarda speciosa*, *Hibiscus tiliaceus*, *Maytenus procumbens*, *M. senegalensis*, *Pluchea dioscoridis*, *Rapanea* sp., *Salvadora angustifolia*, *S. persica*, *Terminalia boivinii*, *Thespesia lampas*, *T. populnea* and *Vitex tangensis* among woody species and *Cladium mariscus*, *Crinum* sp., *Cyperus alternifolius*, *C. compressus*, *C. javanicus*, *C. ligularis*, *C. malaccensis*, *C. polystachyos*, *Fimbristylis dichotoma*, *F. obtusifolia*, *F. polytrichoides*, *Paspalum distichum*, *Scirpus litoralis*, *S. maritimus*, *Scleria angusta*, *Setaria pallidefusca*, *Spartina maritima*, *Sporobolus virginicus* and *Urochondra setulosa* among herbs.

In equatorial estuaries, where brackish conditions predominate, the seaward mangroves grade upstream into *Barringtonia racemosa-Heritiera littoralis* forests, with *Hibiscus tiliaceus*, *Garcinia livingstonei*, *Pandanus kirkii*, *P. rabiensis*, *Phoenix reclinata* and *Voacanga thouarsii* as occasional, but sometimes abundant, arborescent associates. *Acrostichum aureum* may provide dense ground cover, while other understorey species

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include *Commelina* spp., *Crinum* sp., and the aroid, *Typhonodorum lindleyanum*. *Artabotrys monteiroa* and *Entada pursaetha* are among the several robust climbers locally common in these forests.

On Red Sea coasts, reed swamps occur in the channels and creeks at the mouths of big wadis. These are dominated by *Phragmites australis* and *Typha domingensis*, both of which tolerate comparatively high salinities and some tidal rise and fall. Here the common associates are *Berula erecta*, *Cyperus articulatus*, *C. dives*, *Lemna gibba*, *Pycreus mundtii*, *Scirpus mucronata*, *S. tuberosus*, *Spirodela polyrhiza* and *Wolffia hyalina*.

Red Sea saltmarshes contain such species as *Aeluropus lagopoides*, *Alhagi maurorum*, *Arthrocnemum glaucum*, *Cressa cretica*, *Cyperus conglomeratus*, *Elusine compressa*, *Halocnemum strobilaceum*, *Halopeplis perfoliata*, *Haloxylon salicornicum*, *Imperata cylindrica*, *Juncus rigidus*, *Limonium axillare*, *L. pruinosum*, *Nitroria retusa*, *Salsola villosa*, *Sporobolus spicatus*, *Suaeda fruticosa*, *S. monoica*, *S. vermiculata*, *Tamarix mannifera* and *Zygophyllum album*.

Fresh Water Swamp Forests: In this region semi-permanent swamp forests are well developed around the shores of Lake Victoria, particularly on central western and northwestern shores, and at numerous other, smaller, sites in the equatorial sector, e.g. on the high dorsale of Rwanda and Burundi, and in depressions on riverine and lacustrine floodplains. Important species include *Acacia kirkii*, *Anthocleista grandifolia*, *A. schweinfurthii*, *Apodytes dimidiata**, *Baikiaea insignis*, *Bridelia micrantha* (Uganda), *Canarium schweinfurthii*, *Croton megalocarpus**, *Diospyros abyssinica*, *Dracaena laxissima*, *Erythrina excelsa*, *Ficus congensis*, *F. verruculosa* (Lake Victoria district), *Hibiscus diversifolius*, *Ilex mitis**, *Klainedoxa gabonensis*, *Kotschya africana* (Uganda & E Kenya), *Macaranga monandra*, *M. pynaertii*, *M. schweinfurthii*, *Mesopsis eminii*, *Mitragyna stipulosa*, *Musanga cecropioides*, *Pandanus chiliocarpus*, *Parkia filicoidea*, *Phoenix reclinata*, *Phyllanthus discoideus* (Uganda), *Podocarpus falcatus**, *P. latifolius**, *Pseudospondias microcarpa*, *P. preussii*, *Pycnanthus angolensis*, *Raphia farinifera*, *Rauvolfia oxyphylla* (western Rift Valley), *Sapium ellipticum* (Lake Victoria), *Sesbania seban*, *Spondianthus preussii*, *Strombosia scheffleri**, *Suregada procera**, *Symphonia globulifera*, *Syzygium cordatum*, *Terrapleura tetraptera*, *Trichocladus ellipticus**, *Uapaca guineensis*, *Voacanga thouarsii*, *Warburgia salutaris** and *Xylopia staudtii* (Uganda only).

The swamp forests on the western shores of Lake Victoria, at an altitude of 1200 m asl, lie in a basin between the mountains of the Western Rift Valley and the Kenyan Highlands. They contain a mixture of Guineo-Congolan species, whose affinities lie in the Zaire Basin, and Afro-montane species which are marked * above. Substantial areas of these forests are dominated by *Podocarpus falcatus*, while in Rwanda, *P. latifolius* dominates swamp forests at 1950 m asl. These are thought to be the only podocarp swamp forests in Africa.

Seasonally inundated gallery forests occur on the floodplains of many rivers, notably those flowing directly to the Indian Ocean from the interior plateaux and on the headwater streams of the Nile in southern Sudan. In the equatorial regions these are floristically rich. Among the trees and shrubs of galleries are *Acacia clavigera*, *A. elatior*, *A. goetzii*, *A. mellifera*, *A. nilotica*, *A. robusta*, *A. sieberana* (Soudanian zone), *Albizia*

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glaberrima, *A. gummifera*, *A. vogelianum*, *A. zimmermannii*, *Allophylus alnifolius*, *Antidesma membranaceum*, *Aphania senegalensis* (SW Kenya and N Tanzania), *Aporrhiza paniculata*, *Baikiaea insignis*, *Blighia unijugata*, *Borassus aethiopum*, *Bridelia micrantha*, *Capparis viminea*, *Catunaregam spinosa*, *Chytranthus obliquinervis*, *Cleistopholis patens* (Uganda only), *Combretum constrictum*, *Cordia goetzei*, *C. sinensis*, *Cynometra webberi*, *Deinbollia borbonica*, *Diaspyros abyssinica*, *D. mespiliformis*, *Dobera glabra*, *D. loranthifolia*, *Drypetes natalensis*, *Ehretia petiolaris*, *Ekebergia capensis* (SW Kenya and N Tanzania), *Elaeodendron schlecteranum*, *Euclea natalensis*, *E. schimperi*, *Ficus ingens*, *F. sycomorus*, *Flacourtia indica*, *Garcinia livingstonei*, *Grewia stuhlmanii*, *Harrisonia abyssinica*, *Hunteria zeylanica*, *Hyphaene coriacea*, *Indigofera schimperi*, *Khaya nyasica* (Tanzania only), *Kigelia africana*, *Kraussia kirkii*, *Lawsonia inermis*, *Lecaniodiscus fraxinifolius*, *Lepisanthes senegalensis*, *Maerua triphylla*, *Maytenus senegalensis*, *Mimosa pigra*, *Mimusops fruticosa*, *Mitragyna inermis* (Soudanian zone), *Newtonia erlangeri*, *N. hildebrandtii*, *Oncoba spinosa*, *Pachystela brevipes*, *Parkia filicoidea*, *Pavetta sphaerobotrys*, *Phoenix reclinata*, *Phyllanthus reticulatus*, *P. somalensis*, *Pluchea dioscoridis*, *Polysphaeria multiflora*, *P. parviflora*, *Populus ilicifolia* (Kenya only), *Rauvolfia mombasiana*, *Rawsonia lucida*, *Securinega virosa*, *Sorindeia madagascariensis*, *Spirostachys venenifera*, *Sterculia appendiculata*, *Suregada zanzibariensis*, *Syzygium cordatum*, *S. guineense*, *Tamarindus indicus*, *Terminalia brevipes*, *T. macroptera* (Soudanian zone), *Thespesia danis*, *Thylachium thomasii*, *Trichilia emetica*, *Ximenia caffra*, *Xylopia aethiopica* (Ethiopia, Somalia) and *Ziziphus pubescens*. *Mangifera indica* has become naturalised in some flood plain forests, e.g. in places along the Tana River in Kenya.

Low growing shrubs, including scandent species, are *Abutilon longicuspe*, *A. mauritianum*, *Azima tetracantha*, *Cadaba farinosa*, *Canthium zanzibaricum*, *Capparis erythrocarpos*, *C. sepiaria*, *Celtis wrightii*, *Ecbolium striatum*, *Erythrococca bongensis*, *Grewia densa*, *G. tenax*, *Heliotropium subulatum*, *Hibiscus calyphyllus*, *Lamprothamnus zanguebaricus*, *Maerua kirkii*, *M. subcordata*, *Maytenus undata*, *Ochna thomasiana*, *Pavonia zeylanica*, *Phyllanthus ovalifolius*, *Salacia erecta*, *S. stuhlmanniana*, *Salvadora persica*, *Tamarix nilotica* and *Uvaria welwitschii*.

Herbs providing ground cover, including prostrate and small herbaceous climbers, are *Achyranthes aspera*, *Aerva javanica*, *Amaranthus spinosa*, *Asparagus africanus*, *Asystasia gangetica*, *Basilicum polystachyon*, *Celosia argentea*, *Cenchrus ciliaris*, *Cissus rotundifolia*, *Coccinia grandis*, *Commelina benghalensis*, *C. imberbis*, *Conyza aegyptiaca*, *Crotalaria thomasii*, *Cucumis figarei*, *Cyathula coriacea*, *Cyperus alopecuroides*, *C. articulatus*, *C. rotundus*, *Cyrtococcum trigonum*, *Dactyloctenium aegyptiacum*, *Digitaria milanjiana*, *Dinebra retroflex*, *Echinochloa colonum*, *E. haplaclada*, *Eclipta prostrata*, *Enneapogon cenchroides*, *Enteropogon macrostachyus*, *Eragrostis aethiopica*, *E. ciliaris*, *E. superba*, *Fimbristylis bisumellata*, *Flagellaria guineensis*, *Glinus lotoides*, *Heliotropium ovalifolium*, *H. supinum*, *Hewitia sublobata*, *Justicia caerulea*, *J. flova*, *Leucas glabrata*, *Ludwigia erecta*, *L. stolonifera*, *Merremia hederacea*, *Momordica rostrata*, *M. trifoliata*, *Ocimum suave*, *Oldenlandia fastigiata*, *Panicum maximum*, *P. trichocladum*, *Parquetina nigrescens*, *Pergularia daemia*, *Phyla nodiflora*, *Portulaca oleracea*, *Puppalia lappacea*, *Ruellia amabilis*, *R. patula*, *Sesamum angustifolium*, *Setaria verticellata*, *Solanum incanum*, *S. taitense*, *Sporobolus helvolus*, *Tetrapogon tenellus*, *Urochloa setigera* and *Vernonia* sp.

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Permanent Herb Swamps: The region is noted for the remarkable development of *Cyperus papyrus* swamps. This species occupies sites characterised by large seasonal changes in water level. It regularly grows to 5 m in height, but may reach 9 m, and forms dense stands which rise from a tangled mass of rhizomes. At high water, parts of a stand at the open face have a tendency to detach as floating islands, and these drift out into lakes or down rivers, often blocking channels and diverting water flow. Papyrus is regularly associated with species of *Phragmites* and in the Sudd, with the tropical Indo-Pacific species *P. karka*. *Phragmites* grows as tall as, or taller than, papyrus, but remains rooted during floods and does not contribute to floating vegetation. *Phragmites spp. may survive in standing water which reaches depths of 4-5 m, and may still rise metres clear of the surface. Twining species, such as Impomoea fragrans*, are sometimes abundant in *Cyperus papyrus* and *Phragmites* stands, particularly if they are stunted and open.

In places, particularly in equatorial regions, *Miscanthidium violaceum* grows to 4.5 m in height, in dense beds behind the papyrus. In these cases it occupies the niche filled by *Phragmites* in other parts of the region, and in places, *Phragmites* and *Miscanthidium* grow adjacent to each other, in mosaics, or well defined belts.

Woody species are sometimes found in papyrus swamps in this region, the most important being *Aeschynomene elaphroxylon* (which may be a component of floating Sudds), *Bridelia micrantha*, *Hibiscus diversifolius*, *Pandanus* sp. and *Phoenix reclinata*. The last three may be co-dominant with papyrus in parts of Uganda.

Typha swamps are often very extensive and occur behind papyrus and *Phragmites* in shallower water. *Typha* species are more tolerant of salinity than papyrus, and are common with *Phragmites* in coastal swamps and around endorheic lakes. *Typha domingensis* (= *T. australis*) is widespread in the tropics, while *Typha capensis* (= *T. latifolia*) occurs only in the north of the region, e.g in the Nile delta. Both species may grow in association with *Phragmites*, but they usually form pure stands.

A grass, *Vossia cuspidata*, is commonly associated with *Cyperus popyrus* and contributes to the rafts of floating vegetation, but it also forms vast floating meadows on lakesides and riversides. These may develop in front of the papyrus in deep water, or in the absence of papyrus, along the shores. *Vossia cuspidata* can cope with moderately strong currents and is able to grow very quickly. It can often keep pace with a rapidly rising flood, and is therefore frequently the dominant species on river banks which are flooded deeply and quickly. By contrast, other grasses, e.g. *Oryza* spp., are more important on floodplains, where, although the floods rise rapidly, currents are not strong. *Vossia* may grow as an emergent grass often forming a sward 1-2 m high, rising from floating stems which may lie on the surface of water up to 5 m deep.

A number of other grasses occur in permanent swamps, and of these *Suddia sagittifolia* is probably endemic to southern Sudan. This species grows amongst *Cyperus papyrus* in the Sudd, or forms small pure stands up to 2.5 m high. Other grasses found in permanent or semi-permanent swamps include *Acroceras macrum*, *A. zizanioides*, *Diplachne fusca* (shallow alkaline swamps), *Echinochloa colonum*, *E. cruspavonis*, *E. pyramidalis*, *E. stagnina* (= *E. scabra*), *Hemarthria natans*, *Leersia hexandra*, *Oryza barthii*, *O. longistaminata* (= *O. perennis*), *Paspalidium geminatum*, *Phragmites australis* (Lower Nile), *P. mauritianus*, *Psiloleima jaegeri*, *Sacciolepis africana* and *S. auriculata*.

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Other emergent or semi-emergent species found in permanent herb swamps include the sedges *Carex monostachya* (high altitude swamps), *Ceratopteris thalictroides* (channel banks, often partly submerged), *Cladium jamaicense* (W only), *Crinum* spp., *Cyperus articulatus*, *C. latifolius*, *Eleocharis acutangula*, *Pycreus mundtii*, *Scirpus cubensis*, *S. inclinatus* and *S. isolepis* (shallow water), *S. microcephalus* (shallow water) and *S. setaceus* (highlands), together with such species as *Dissotis rotundifolia*, *Juncus effusus* (N only), *J. maritimus* (coastal), *Kniphofia thomsonii* (highlands), *Limnophyton* sp., *Ludwigia leptocarpa*, *L. stolonifera*, *Polygonum pulchrum*, *Thelypteris confluens* (chiefly *Miscanthidium* swamps), *T. striata* (chiefly papyrus swamps), *Tristemma incompletum* and *Typhonodorum lindleyanum*.

Waters of moderate depth, too deep for emergent species, were once dominated by rooted species with floating leaves, like waterlilies, while calm deep waters were often occluded by free floating species such as *Pistia stratiotes*, but over the past 80 years, following the introduction of *Eichhornia crassipes*, much has changed. This latter species is exceptionally aggressive and any 'open' waters in swamps, lakes or sluggish rivers, are now likely to be colonised by dense mats of *Eichhornia crassipes*, which may have a greater biomass/m^2 than stands of *Cyperus papyrus* or *Phragmites karka*. In such circumstances, unless the dense *Eichhornia* mats drift, little submerged vegetation survives for lack of light. *Eichhornia* is also known to oust *Vossia cuspidata* and other rooted species from lake margins.

The principal rooted, floating-leaved, species are *Ottelia ulvifolia*, *Nymphaea caerulea*, *N. lotus* and *Trapa natans*, while other free floating species found throughout the region include *Azolla nilotica*, *Lemna gibba*, *Pistia stratiotes* and *Spirodela polyrhiza*. Submerged species include *Ceratophyllum demersum*, *Limnophila indica*, *Myriophyllum spicatum*, *Najas pectinata*, *Potamogeton bunyaniensis*, *P. pectinatus*, *P. schweinfurthii*, *Utricularia* spp. and *Vallisneria spiralis*. A number of free floating submerged species become attached to the roots of floating vegetation, e.g. *Aldovanda vesiculosa* (carnivorous), *Ceratophyllum demersum* and several species of *Utricularia*.

Swamp climbers include *Cayratia ibuensis*, *Culcasia scandens*, *Cyclosorus interruptus*, *Ipomoea cairica*, *I. rubens*, *Luffa cylindrica*, *Melanthera scandens* and *Zehneria minutiflora*, while *Commelina benghalensis* is a prostrate species which grows in mats of floating vegetation, and over muddy swamp floors.

Seasonal Floodplains: These are dominated by grasses which are usually zoned according to depth and duration of inundation, but changing conditions often lead to mosaics. *Oryza barthii* and *O. longistaminata* tend to occupy the most deeply flooded sites. They have floating stems and keep pace with the rise of the flood waters. The former is an annual, the latter perennial. *Echinochloa pyramidalis* is the most important floodplain grass, occupying the next most deeply flooded zones and covering extremely large areas. *Leersia hexandra* and *Vossia cuspidata* also occur on floodplains in sites which tend to remain permanently wet. Among the other important grasses are *Brachiaria obtusiflora*, *B. orizantha*, *Cynodon dactylon* (fringes subject to grazing), *Echinochloa haploclada*, *Eragrostis aethiopica*, *E. ciliaris*, *E. mildbraedii*, *E. superba*, *Enneapogon cenchroides*, *Enteropogon macrostachyus*, *Eriochloa* sp., *Hyparrhenia diplandra*, *H. filipendula* (fringes), *H. rufa* (margins), *Loudetia kagerensis* (central western districts), *L. phragmitoides* (Uganda, S Sudan), *L. simplex*, *Panicum maximum*, *P. repens*, *P. trichocladum*,

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Paspalum commersonii, *P. suborbiculatum*, *Pennisetum glaucocladum*, *Setaria sphacelata* (S only), *S. verticillata*, *Sorghum lanceolatum*, *S. purpureo-sericeum* (W only), *S. verticilliflorum* (S only), *Sporobolus helvolus*, *S. pyramidalis*, *S. spicatus* (alkaline soils), *Tetrapogon tenellus*, *Urochloa setigera* and *Vetiveria nigritana* (floodplain margins).

The sedges include *Cyperus articulatus*, *C. denudatus*, *C. digitatus*, *C. haspan*, *C. laevigatus* (halophyte), *C. longus*, *Eleocharis atropurpurea*, *E. imbricata*, *E. nigrescens*, *Scirpus littoralis* and *S. maritimus*.

Montane Wetlands: These include peat bogs and fens which are either permanently or semi-permanently waterlogged, but which may be flushed by running water. They contain some low growing woody species, together with ferns, sedges, mosses and algae. Important macrophytes are *Erica kingaensis*, *Hypericum revolutum*, *Macaranga kilimandscharica*, *Mitragyna rubrostipulata*, *Myrica kandtiana*, *Rapanea rhododendronoides*, and *Xyris* spp. The ferns *Osmunda regalis* and *Thelypteris squamigera* are common in middle to high altitude bogs, while among mosses, *Sphagnum davidii*, *S. mildbraedii* and *S. rugegense* are important.

Irregularly Inundated Wetlands: These include the pans and wadis of the north, of the Red Sea coast, of Somalia and NE Kenya. The palms *Borassus aethiopum*, *Hyphaene thebaica* (Egypt and Sudan) and *H. ventricosa* often occur along watercourses subject to periodic flooding. *Borassus* is the most flood tolerant. *Dalbergia melanoxylon* is widespread in the Sahel zone along watercourses as are *Ficus* and *Tamarix* spp. *Juncus bufonius* (N only) is the common rush, *Scirpus holoschoenus* (N only - pans, wadis and oases) the common sedge, and both *Phragmites australis* and *Typha capensis* occur on the margins of pools.

Wetland Fauna

Fishes: The Nile Basin, the Rift Valley Basin, and the East Coast Rivers constitute three distinctive faunal provinces within the region, although they share many species. In the Western Rift Valley, Lake Kivu has an impoverished Nile fauna and once drained to the Nile via Lake Edward, but the Virunga volcanics, some 35 000 years ago, blocked the Western Rift Valley, so that the lake eventually spilled over to Lake Tanganyika. However, rapids on the Ruzizi River have prevented species from this lake entering Lake Kivu, with the exception of *Barilius moori*. Lake Tanganyika is an ancient lake, perhaps 15 million years old, and its high salinity suggests that it was an endorheic system for at least a few million years, at some time in the past. It has clearly had a long connection with the Zaire Basin because the Malagarasi River, which enters the lake on its eastern shore, shares several fish species (*Labeo weeksii*, *Polypterus ornatipinnis*, *Tetraodon mbu*) with the Lualaba River which receives the overflow from the western shore. However, none of these species is present in the lake itself.

Lake Victoria, which occupies a shallow basin between the Western and Eastern Rift Valleys, is a recent lake, probably having formed less than 750 000 years ago. Despite its connection with the Nile (which is only recent), it has a highly distinctive fish fauna, as also have Lakes Tanganyika and Malawi.

All three lakes have high proportions of cichlids and endemics. Of the 200 species so far described from Lake Victoria, 160 (80%) are cichlids, while 126 (64%) of 193 species

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described from Lake Tanganyika are cichlids, and 200 (82%) of the 245 species in Lake Malawi are cichlids according to Lowe-McConnell (1975). However more recent articles claim that the number of cichlid species in Lake Malawi is much greater than this, as discussed in Section 5.4.6. Most of these species are endemic to their lake. Of the non-cichlid fishes, 16 (42%) of 38 species in Lake Victoria are endemic, 47 (70%) of the 67 in Lake Tanganyika are endemic and 26 (62%) of the 42 in Lake Malawi are endemic. Lakes Edward and George also have high percentages of cichlids and endemics, whereas Lakes Albert and Turkana have not. For example, Lake George has 29 species, of which no less than 16 are endemic species of *Haplochromis*. The others are nilotic, and include *Bagrus docmac*, *Clarias lazera*, *Polypterus bichir*, *Protopterus aethiopicus*, *Oreochromis leucosticus* and *O. niloticus*. Lake Turkana has only recently been cut off from the Nile, and both it and Lake Albert, having been open to the full Nile river fauna, have provided little opportunity for the adaptive radiation of cichlids seen in the other great lakes. The endorheic lakes of the Eastern Rift Valley are all saline and have distinctive faunas, while the East Coast Rivers contain several groups of fishes with Asian affinities. These latter groups, e.g. the cyprinids, appear to have entered Africa from the north in late Tertiary times, and to have moved slowly southwards colonising successive east coast river basins. The cyprinids are far better represented in East Africa than they are in West Africa, and probably entered the latter region comparatively recently, having traversed the Sahara during pluvial periods of the Pleistocene. The east coast rivers also have high proportions of cichlids. While they have some species in common with the Nile, e.g. *Clarotes laticeps*, the more important nilotic species are conspicuous by their absence. A number of introductions have been made to these rivers and *Salmo trutta* now flourishes in some highland streams.

In Lake Victoria, *Haplochromis* is the dominant genus, with some 160 species, while among other cichlids *Oreochromis* (= *Tilapia*) *esculentus* and *O. variabilis* are indigenous, and *O. leucosticus*, *O. niloticus*, *Tilapia rendalli* and *T. zillii* were introduced. *Oreochromis esculentus* was once the basis of a gillnet fishery, but following overfishing, its importance has declined. *Astatoreochromis alluaudi* is a mollusc eater. There are several small species of *Barbus*, in addition to the large *B. altianalis*, and together with *Engraulicypris argenteus* and *Labeo victorianus* these are the prominent cyprinids. *Ctenopoma muriei* and *Mastacembalus frenatus* are cyprinodonts, and *Alestes jacksoni* and *A. sadleri* are the two characids present, *Hydrocynus* being absent. The mormyrids include *Gnathonemus longibarbis*, *Hippopotamyrus grahami*, *Marcusenius victoriae*, *Mormyrus kannume*, *Petrocephalus catostoma* and *Pollimyrus nigricans*. The principal catfishes are *Bagrus docmac*, *Clarias alluaudi*, *C. carsoni*, *C. mossambicus*, *Clariallabes petricola*, *Schilbe mystus*, *Synodontis afrofischeri*, *S. victoriae* and the endemic monospecific genus *Xenoclarias*. *Protopterus aethiopicus* is present, but *Polypterus* and indigenous *Lates* are absent, although *Lates niloticus* has recently been introduced, the intention (hope) being that it would feed chiefly upon small cichlids that are not exploited commercially.

In Lake Tanganyika the pelagic waters are dominated by two clupeid fishes, *Limnothrissa miodon* and *Stolothrissa tanganicae* and their predators, *Lates angustifrons*, *L. mariae*, *L. microlepis* and *Luciolates stappersii*. By contrast with Lakes Victoria and Malawi, the many cichlids are not concentrated in one large genus. There are 40 cichlid genera in the lake and of these *Lamprologus* has 34 species, *Xenotilapia* has 12, *Limnochromis* has 11, *Trematocara* has 8 and *Bathybates* 7. Among the other genera

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with one or two species each, are *Aulonochromis*, *Boulengerochromis*, *Cardiopharynx*, *Cyathopharynx*, *Collochromis*, *Ectodus*, *Grammatotria*, *Haplochromis*, *Hemibates*, *Julidochromis*, *Lestradea*, *Limnotilapia*, *Perissodus*, *Petrochromis*, *Plecodus*, *Simochromis*, *Tanganicodus*, *Tilapia*, *Trophesus* and *Tylochromis*. Among cichlids, *Boulengerochromis microlepis* occurs down to depths of 100 m. There are no mormyrids in the lake. There are 7 species of *Mastacembelus*. *Malapterus electricus* is present, as are *Polypterus congicus* and *P. ornatipinnis* (Malagarasi delta) and *Protopterus aethiopicus*. There are two species of *Distichodus* and a number of bagrid catfish, e.g. *Auchenoglanis occidentalis*, *Bagrus docmac*, *Chrysichthys cyclurus*, *C. sianenna* and *Phyllanemus* spp. Cyprinids include several species of *Barbus*, *Barilius moori*, the large *Engraulicypris minutus* and three species of *Labeo*. *Lamprichthys tanganicanus* is an endemic cyprinodont. There are two species of *Alestes* and two of *Hydrocynus*.

The affluent streams are characterised by *Amphilius platychir*, *Barilius moori* and *Varicorhinus tanganicae* in fast flowing sections and *Alestes macrophthalmus*, *Aplocheilichthys pumilis*, *Citharinus gibbosus*, *Distichodus maculatus*, *Haplochromis burtoni*, *Hippopotamyrus discorhynchus*, *Mormyrus longirostris*, *Polypterus congicus*, *P. ornatipinnis*, *Protopterus aethiopicus*, *Oreochromis karomo*, *O. upembae* and *Tilapia rendalli* in sluggish swampy sections.

In some isolated lakes the indigenous fish fauna is very poor, but many introductions have been made, often with the creation of profitable fisheries, e.g. that at Lake Naivasha in the Kenya Highlands depends upon four naturalised species, *Oreochromis leucostictus*, *O. niger* and *Tilapia zillii*, and the American *Micropterus salmoides*.

The Nile fish fauna includes the ancient fishes *Protopterus aethiopicus*, *Polypterus bichir*, *P. senegalus*, and the osteoglossid *Heterotis niloticus*. Other common species include the mormyrids *Gnathonemus cyprinioides*, *Hyperopisus bebe*, *Marcusenius isidori*, *Mormyrops anguilloides*, *Mormyrus caschive*, *M. kannume* and *Petrocephalus bane* together with *Gymnarchus niloticus*, the characids *Alestes baremose*, *A. dentex*, *A. nurse*, *Hydrocynus brevis*, *H. forskalii* and *H. lineatus*, the ichthyborid *Ichthyborus besse*, the citharinids *Citharinus citharus*, *C. latus*, *Distichodus engycephalus*, *D. nilaticus*, and *D. rostratus*, the cyprinids *Barbus anema*, *B. bynnie*, *B. neglectus*, *B. perince*, *B. werneri*, *Borilius loati*, *B. niloticus*, *Chelaethiops bibie*, *Discognathus vinciguerrae*, *Labeo coubie*, *L. forskalii*, *L. horie*, and *L. niloticus*, the clariids *Clarias anguillaris* and *C. lazera*, the schilbeids *Eutropius niloticus*, *Schilbe mystus*, *S. uranoscopus* and *Siluranodon auritus*, the bagrids *Auchenoglanis bicustatus*, *A. occidentalis*, *Bagrus bayad*, *B. docmac*, *Chrysichthys auratus*, *C. rueppelli* and *Clarotes laticeps*, the mochokids *Chilaglanis niloticus*, *Mochocus nilaticus*, *Synodontis batensoda*, *S. clarias*, *S. khartoumensis*, *S. schall* and *S. serratus*, the cichlids *Oreochromis galilaeus* and *O. niloticus*, the centropomid *Lates niloticus*, the malapturid *Malapterus electricus*, the anabantid *Ctenopoma muriei* and the tetraodont *Tetraodon fahaka*.

Amphibians: The amphibian fauna in the northern part of the region is small. It includes four species of *Bufo*; *B. dodsoni* (Nile Valley of SE Egypt, Sudan & Ethiopia), *B. regularis* (Nile Valley), *B. viridis* (N Egypt & Nile Valley) and *B. vinatus* (N Egypt), and also *Ptychadena mascareniensis* (N Egypt & Nile Valley). The fauna of the equatorial region is more diverse. Here the commonest and most widespread species are *Afrixalus fornasini*, *Hylararana galamensis*, *Hyperolius pusillus*, *H. viridiflavus*, *Rana* (*Eu-*

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phlyctis) occipitalis, Xenopus laevis and *X. muelleri*. Other widespread species, which are abundant locally, are *Afrixalus brachycrenis, A. quadrivittatus, Bufo kerinyagae* (breeds in lakes and swamps, but normal habitat is moist savanna), *Kassina maculata, K. senegalensis* and *Prychadena mascareniensis* (especially in temporary water).

Reptiles: The most important aquatic reptiles are *Crocodylus niloticus* (Sudan southwards) and *Varanus niloticus* (Egypt southwards). In addition there are several aquatic and semi-aquatic snakes, and some snakes found in gallery and swamp forest trees. Swamp and water snakes include *Atheris superciliaris* (Tanzania), *Boulengerina annulata* (Western Rift Valley), *Dromophis lineatus* (equator southwards), *Lycodonomorphus whytei* (Sudan southwards), *Natriciteres olivacea olivacea* (Sudan southwards) and *N. olivacea sylvatica* (Tanzania). These feed chiefly on fish and frogs. Species at home in the swamps, but generally found on the fringes, include *Crotaphopeltis hotamboeia* (Kenya southwards), *Naja mossambica* (SE Tanzania), *N. nigricollis* (Kenya southwards), *Philothamnus hoplogaster* (Kenya southwards), *P. irregularis* (Sudan southwards), *Psammophis sibilans* (equator southwards), and *Python sebae* (Sudan southwards). Tree snakes often found in swamp or gallery forests are *Dasypeltis fasciata* (nocturnal - rain forests), *D. scabra* (nocturnal - savannas), *Dendroaspis angusticeps* (Kenya southwards), *D. jamesonii* (western equatorial districts), *Thelotornis kirtlandii oatesi* (Sudan southwards), *Thrasops aethiopica* (equatorial forests) and *T. occidentalis* (savannas).

Birds: The avifauna of the wetlands is very rich. Common and widespread species south of the Sahara include *Accipiter badius, Acrocephalus arundinaceus, A. gracilirostris, A. palustris, A. rufescens, A. schoenobaenus, A. scirpaceus, Actophilornis africanus, Alopochen aegyptiaca, Alseonax aquaticus, Amandava subflava, Amblyospiza albifrons, Anas capensis, A. erythrorhyncha, A. hottentota, A. undulata, Anastomus lamelligerus, Anhinga rufa, Apus horus, Aquila wahlbergi, Ardea cinerea, A. goliath, A. melanocephala, A. purpurea, Ardeola idae, A. ralloides, Asio capensis, Aythya erythrophthalma, Bolearica regulorum, Bostrychia carunculata, Bradypterus baboecala, Bubulcus ibis, Butorides striatus, Casmerodius intermedia, Ceryle rudis, Charadrius tricollaris, Chlidonias hybrida, C. leucoptera, Circus ranivorus, Cisticola galactotes, Corvus albus, Corythornis cristata, Dendrocygna viduata, Egretta alba, E. garzetta, Elanus caeruleus, Eminia lepida, Ephippiorhynchus senegalensis, Estrilda astrid, Euplectes albonotatus, E. axillaris, E. orix, Falco ardosiaceus, Francolinus sephaena, Fulica cristata, Gallinula chloropus, Glareola pratincola, Hagedashia hagedash, Haliaeetus vocifer, Himantopus himantopus, Hirundo angolensis, H. griseopyga, H. semirufra, H. smithii, Ibis ibis, Ixobrychus minutus, Lagonosticta rubricata, L. senegala, Larus cirrocephalus, Leptoptilos crumeniferous, Limnocorax flavirostra, Lonchura cucullata, Megaceryle maxima, Merops boehmi, M. pusillus, Milvus migrans, Motacilla aguimp, M. capensis, Nettapus auritus, Nycticorax nycticorax, Oriolus auratus, Ortygospiza atricollis, Platalea alba, Plectropterus gambensis, Pelecanus onocrotalus, P. rufescens, Phalacrocorax africanus, P. carbo, Ploceus capitalis, P. intermedius, P. jacksoni, P. spekei, P. xanthops, Plegadis falcinellus, Podica senegalensis, Podiceps cristatus, P. nigricollis, P. ruficollis, Porphyrio porphyrio, Porzana marginalis, Prinia subflava, Recurvirostra avosetta, Riparia cincta, R. paludicola, Sarkidiornis melanotus, Saxicola torquata, Scopus umbretta, Threskiornis aethiopicus, Vanellus armatus* and *V. crassirostris*.

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Among less common, but still widespread species, are *Acrocephalus baeticus, Alcedo semitorquata, Anas sparsa, Anthus novaeseelandiae, Ardeirallus sturmii, Bias musicus, Bubo capensis, B. lacteus, Bycanistes bucinator* (riverine forest), *Centropus grillii, C. monachus, C. superciliosus, Charadrius pecuarius, Cisticola robusta, Corythaeola cristata* (wooded river banks), *Corythaixoides personata* (seasonal river banks), *Crinifer zonurus* (riverine vegetation), *Dendrocygna bicolar, Euplectes afer, Gallinago nigripennis, Gallinula angulata, Glaucidium capense* (river banks), *Ispidina picta* (forested rivers), *Laniarius erythrogaster, Lybius melanopterus* (gallery woodlands), *Macronyx ameliae, Malaconotus blanchoti, Merops bullocki* (river banks), *M. gularis* (forest streams), *Microparra capensis, Musophaga rossae* (gallery woodland), *Nectarinia erythrocerca, N. tacazze* (marshy forest glades), *Otus scops* (seasonal rivers), *Oxyura maccoa, Pandion haliaetus, Phoeniculus minor* (seasonal river banks), *Pirenestes ostrinus, Ploceus cucullatus, P. ocularis, Porphyrio alleni, Quelea erythrops, Rhynchops flavirostris, Rostratula benghalensis, Schoenicola platyura, Scotopelia peli, Sterna albifrons, Streptopelia decipiens* (savanna zone rivers), *Tauraco leucolophus* (savanna and sahel zone rivers), *Thalassornis leuconotus, Treron australis* (savanna zone rivers), *Vanellus albiceps* and *V. melanocephalus*.

Species with restricted distributions include *Alcedo quadribrachys* (western forests), *Alseonax cassini* (W Uganda), *Anthreptes collaris* (mangrove swamps), *A. platura* (Sudan, Ethiopia, Somalia - seasonal river beds), *Balaeniceps rex* (Sudd, Uganda - papyrus swamps), *Bradypterus carpalis* (Uganda & W Kenya - reed beds), *B. graueri* (SW Uganda - swamp forest), *Calamonastides gracilirostris* (Lake George area), *Caprimulgus clarus* (Ethiopia to Kenya), *Charadrius venustus* (endorheic lakes), *Chlidonias niger* (Sudan), *Ciconia abdimii* (Egypt, Sudan), *C. episcopus* (Uganda lakes, Kenya/Tanzania coast), *Cisticola carruthersi* (Uganda & SW Kenya – reeds), *C. tinniens* (Kenya Highlands), *Cossypha niveicapilla* (swamp forest - Uganda), *Cyanochen cyanopterus* (Ethiopian Highlands), *Dromas ardeola* (coasts, Red Sea to Kenya), *Egretta gularis* (Somalia & Kenya coasts), *Estrilda nonnula* (western equatorial districts), *Euplectes diadematus* (S Somalia, E Kenya, NE Tanzania), *E. franciscana* (Sudan, Ethiopia, Uganda, W Kenya), *E. gierowii* (Ethiopia, Uganda, N Tanzania), *E. hartlaubi* (Uganda, W Kenya, W Tanzania), *E. macrocercus* (Uganda, W Kenya), *E. macrourus* (Uganda, W Kenya, Tanzania), *E. progne* (Kenya Highlands), *E. psammocromius* (S Tanzania), *Halcyon badius* (Uganda, forests), *H. malimbicus* (central western districts), *H. senegaloides* (mangroves), *Hydroprogne tschegrave* (equatorial coasts), *Lagonosticta rara* (Uganda & W Kenya), *Lamprotornis corruscus* (C & E Kenya), *Laniarius mufumbiri* (papyrus swamps of Uganda & Kenya), *Merops superciliosus* (mangroves), *Nectarinia amethystina* (mangrove swamps), *N. nectarinioides* (E Kenya, NE Tanzania), *N. veroxii* (mangrove swamps), *Passer castanopterus* (Somalia, Ethiopia, N Kenya - wadis), *Pedilorhynchus comitatus* (S Sudan & SW Uganda), *Phalacrocorax nigrogularis* (coasts of Red Sea and Gulf of Aden), *Phoeniconaias minor* (endorheic lakes & pans), *Phoenicopterus ruber* (endorheic lakes & pans), *Ploceus aurantius* (western equatorial districts), *P. castaneiceps* (SE Kenya & NE Tanzania), *P. dichrocephalus* (Ethiopia, S Somalia & NE Kenya), *P. heuglini* (E Uganda & W Kenya), *P. pelzelni* (western equatorial districts), *P. reichardi* (S Tanzania), *P. spekeoides* (C Uganda), *P. subaureus* (E Kenya & E Tanzania), *P. taeniopterus* (Sudan, Uganda, NW Kenya), *P. weynsi* (S Uganda), *Pluvianus aegyptius* (Egypt, Ethiopia, Sudan,

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Uganda), *Sarothrura pulchra* (Uganda - swamp forests), *Spreo albicapillus* (Ethiopia, Somalia, N Kenya - seasonal river beds), *S. shelleyi* (C & E Kenya), *Sterna bengalensis* (coasts), *S. hirundo* (coasts), *Turdoides atripennis* (Uganda - swamp forest), *T. jardinei* (equator southwards), *T. melanops* (equator southwards) and *Vanellus spinosus* (Ethiopia to Kenya).

The principal species in the wetlands of the Nile Delta are *Alcedo atthis, Anas clypeata, A. crecca, A. penelope, A. querquedula, Ardea cinerea, Aythya ferina, A. nyroca, Calidris alba, C. alpina, C. minuta, Casmerodius albus, Charadrius alexandrinus, Chlidonias hybrida, C. leucoptera, Circus aeruginosus, Coturnix coturnix, Fulica atra, Larus genei, L. minutus, L. ridibundus, Luscinia svecica, Pelecanus crispus, Phalacrocorax carbo, Phoenicopterus ruber, Podiceps cristatus, P. nigricollis, Recurvirostra avosetta, Sterna sandvicensis, Tadorna tadorna* and *Tringa totanus.*

Species found at oases and in wadis include *Acrocephalus schoenobaenus, A. scirpaceus, A. palustris, Aquila clanga, A. pomarina, Ardea purpurea, Ardeola ralloides, Botarus stellaris, Buteo rufinus, Ciconia ciconia, C. nigra, Circaetus gallicus, Circus aeruginosus, C. macrourus, C. pygargus, Coracias garrulus, Coturnix coturnix, Crex crex, Egretta garzetta, Emberiza caesia, Ficedula parva, Fulica atra, Grus grus, Himantopus himantopus, Hippolais pallida, Ixobrychus minutus, Jynx torquilla, Lanius collurio, L. nubicus, Locustella luscinioides, Merops apiaster, Nycticorax nycticorax, Oriolus oriolus, Otus scops, Pandion haliaetus, Phylloscopus trochilus, Platalea leucorodia, Plegadis falcinellus, Streptopelia turtur, Sylvia corruca, S. rueppelli* and *Upupa epops.*

Inland along the lower Nile the more important species are *Anas acuta, A. crecca, Ardea cinerea, Casmerodius albus, Chlidonias leucopterus, C. niger, Ciconia ciconia, C. nigra, Circus aeruginosus, Falco naumanni, Gelochelidon nilotica, Larus ridibundus, Pandion haliaetus, Pelecanus onocrotalus, Platalea leucorodia, Plegadis falcinellus* and *Riparia riparia.*

Above the confluence of the White and Blue Nile Rivers, *Acrocephalus schoenobaenus, Anthus cervinus, Charadrius dubius, Chlidonias hybrida, C. leucoptera, Ciconia ciconia, C. nigra, Gelochelidon nilotica, Grus grus, Hieraaetus pennatus, Hippolais pallida, Lanius nubicus, Motacilla alba, Philomachus pugnax, Phylloscopus collybita, Platalea leucorodia, Streptopelia turtur, Sylvia corruca, Tringa glareola, T. ochropus* and *Upupa epops* are important species.

Birds found in the Sudd, in addition to many of those previously indicated as widespread south of the Sahara, or specifically present in southern Sudan, include *Anas acuta, A. clypeata, A. crecca, A. penelope, A. querquedula, Anthus cervinus, Circus macrourus, C. pygargus, Glareola nordmanni, Larus fuscus, Limosa limosa, Philomachus pugnax, Tringa glareola, T. nebularia, T. ochropus* and *T. stagnatilis.*

Mammals: The most fully aquatic of all mammals in the region is *Dugong dugon* which feeds mainly on seagrasses and often enters mangrove lined creeks, but does not move upstream into fresh water, by contrast with *Trichechus senegalensis* on West African coasts. It is distributed along the entire eastern coastline from Port Said to Mozambique. Other highly aquatic mammals, found in swamps, rivers and lakes, include *Aonyx capensis* (from Kenya southwards, including mangroves and the Rift Valley lakes), *Tragelaphus spekei* (Ethiopia southwards), *Hippopotamus amphibius* (Sudd south-

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wards), *Lutra maculicollis* (Sudan southwards) and *Micropotamogale ruwenzorii* (Lake Edward and Ruwenzori).

Large mammals which are comparatively closely tied to swamps include *Cephalophus nigrifrons* (Lake Victoria), *Kobus ellipsiprymnus* (Sudan southwards), *K. kob* (equatorial region and S Tanzania), *K. megaceros* (Sudd northwards), *Redunca arundinum* (Tanzania, including coasts), *Redunca redunca* (equatorial, not coastal), *Syncerus caffer* (Sudan southwards), *Tragelaphus buxtoni* (bogs, Ethiopian Highlands), *T. scriptus* (Uganda southwards) and *T. spekei* (central). *Potamochoerus porcus* may live in swamps, but is not dependent on them, while *Laxodonta africana* may visit swamps regularly, but also is not dependent on them.

Panthera pardus is the largest mammalian predator to frequent swamps, occasionally itself being taken by *Crocodylus niloticus*. It occurs throughout the region from Ethiopia southwards, including the Sudd. *Panthera leo* only rarely visits wetlands, from southern Sudan southwards, but has been known to attack in numbers and kill *Hippopotamus amphibius* and *Syncerus caffer*.

Among the smaller mammals closely associated with wetlands, or common in them, *Canis simensis* lives on the high plateaux of Ethiopia (3000-4500 m) and feeds mainly upon swamp rodents e.g. *Otomys* sp. *Felis chaus* occurs in the Nile delta and lower Nile, while *F. libyca* occurs throughout the region. Both species include fish and frogs in their diets. *Genetta tigrina* is locally common south of Ethiopia, while *Herpestes ichneumon* occurs throughout the region, and includes crabs, crayfish, fish and frogs in its diet. *Ichneumia albicauda* is widely distributed from Ethiopia and Sudan southwards; this species eats crabs, mussels and snails among other things. *Leptailurus serval* occurs in the Sudd and other wetlands to the south, where it then feeds chiefly upon swamp dwelling rodents and birds. Swamp rodents include *Dasymys incomtus* (Uganda southwards), *Malacomys edwardsi* (equatorial zone), *Otomys angoniensis* (Kenya southwards), *O. sloggetti* (mountain bogs), *Pelomys fallax* (Tanzania) and *Thryonomys swinderianus* (Sudan southwards).

Larger mammals which visit gallery forests and/or floodplains include *Aepyceros melampus* (Uganda southwards), *Cephalophus natalensis* (coastal forests, including mangroves), *C. monticola* (Kenya, Tanzania), *Erythrocebus patas* (Nile & tributaries, SE Lake Victoria), *Phacochoerus aethiopicus* (Ethiopia southwards), *Rapiceros melanotis* (Uganda, W Kenya, W Tanzania), *Tragelaphus equinus* (S Sudan, Uganda), *T. imberbis* (Ethiopia, Somalia, Kenya) and *T. strepticeros* (Ethiopia, Sudan, Somalia, Kenya, Tanzania).

Some small mammals also visit gallery forests or other wooded lands subject to seasonal inundation, or live on river banks or on the wet margins of swamps. Among these are *Acomys spinossimus* (Kenya southwards), *A. subspinosus* (Uganda south, discontinuous), *Aethomys chrysophilus* (Kenya, SW Tanzania), *Canis aureus* (Uganda southwards), *Cryptomys hottentotus* (Kenya southwards), *Dendromus mesomelas* (South-Kenya coastal highlands), *D. nyikae* (Lake Victoria southwards), *Felis caracal* (Sudd southwards), *Felis aurata* (N & NE Lake Victoria), *Herpestes sanguineus* (Sudan southwards), *Lycaon pictus* which may feed on cane rats on floodplains (Sudan southwards), *Mungos mungo* (Ethiopia southwards), *Mus minutoides* (Uganda northwards), *Papio cynocephalus* which sometimes eats crabs and mussels (Ethiopia southwards), *Praomys natalensis*

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(Uganda, Kenya southwards), *Steatomys pratensis* (Tanzania), *Thamnomys dolichurus* (Uganda southwards) and *Viverra civetta* which may eat frogs and toads (Sudd southwards).

In addition to several bats, arboreal mammals which frequent seasonally flooded forests or woodlands are *Anomalurus derbianus* (S Tanzania), *Cercocebus albigena* (Lake Victoria, W Tanzania), *C. galeritus* (Kenya, Tanzania), *Cercopithecus aethiops* (Ethiopia & Sudd southwards), *C. albogularis* (coasts, Kenya southwards), *C. ascanius* (Uganda, W Rift Valley, W Tanzania), *C. mitis* (Lake Victoria), *C. neglectus* (SW Ethiopia, S Sudan, Uganda, mid-Kenya) *Colobus badius rufomitratus* (Uganda, SE Kenya), *C. polykomos palliatus* (coastal regions of SE Kenya and Tanzania), *C. polykomos ruwenzorii* (Ruwenzori), Dendrohyrax arboreus (Uganda, Kenya, Tanzania - to coast), *Funisciurus pyrrhopus* (E Uganda, Rwanda, Burundi), *Galago demidovii* (Kenya, Tanzania), *Heliosciurus rufobrachium* (Lake Victoria to coast, including mangroves) and *Protoxerus stangeri* (Lake Victoria district).

Mammals which frequent periodically flooded sites in the deserts and semi-deserts, such as wadis, pans and dry river beds, are *Canis adustus* (Sudan, southwards), *Canis mesomelas* (Ethiopia, Somalia, Kenya, Tanzania), *Fennecus zerda* (Sahara), *Herpestes pulverulentus* (Ethiopia, Somalia), *Poecilictis libyca* (Sahara to Red Sea), *Saccostomus campestris* (Tanzania), *Vulpes rupellii*, (Egypt, Sudan, Somalia) and *V. vulpes* (Nile Delta).

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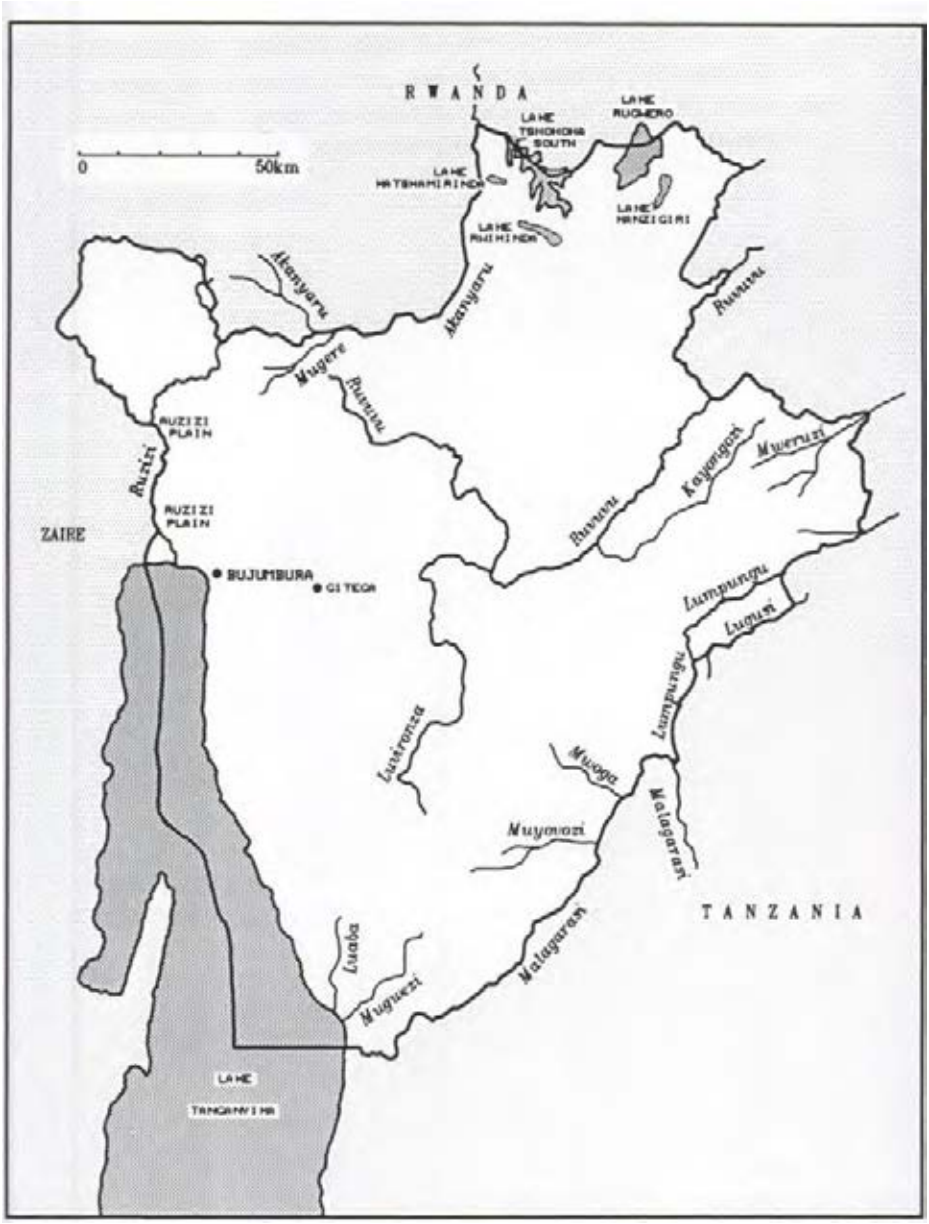

Map of Burundi

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2.1 BURUNDI

Introduction

Burundi has an area of 27 835 km^2, a population (1983) of 4 920 000, and thus a mean population density of 176.7 persons/km^2. It is therefore among the most densely populated of all African countries. It stretches 232 km from north to south between latitudes 1°19' and 4°27'S, and 203 km from west to east between longitudes 29°00' and 30°51'E. It is bounded by Tanzania in the east, by Rwanda in the north and by Zaire and Lake Tanganyika in the west. It is situated in the highlands along the eastern arm of the Western Rift Valley, and only along the shores of Lake Tanganyika (773 m asl) does the land surface fall below the 1000 m contour.

A mountain range, reaching 2670 m asl (3°36'S/29°30'E), runs roughly N-S along the western boundary, providing the highest land in the country, and from its watershed western streams descend steeply to the Ruzizi River and Lake Tanganyika. On the eastern side of the watershed, streams flow north to the Akanyaru River, or south to the Malagarasi River, or they collect, in central districts, into the Luvironza/Ruvuvu River. This latter river is the most important in Burundi in as much as it has the largest drainage basin. The Malagarasi and Ruzizi Rivers discharge to Lake Tanganyika and hence their waters flow to the Zaire River and the Atlantic Ocean, while the Luvironza/Ruvuvu and Akanyaru Rivers are affluents of the Kagera River. They are thus remote headwater tributaries of the Nile and their waters flow to the Mediterranean Sea. The source of the Luvironza is deemed to be the source of the Nile farthest from the sea.

Vegetation

The higher parts of Burundi are covered by evergreen Afro-montane vegetation, with transitional evergreen rain forest on the western slopes of the mountains, overlooking the Ruzizi Plain and Lake Tanganyika. The lower parts of Burundi, in the east and southeast, support a mosaic of evergreen bushland interspersed with a wetter type of *Acacia* savanna.

Climate

The climate is determined by altitude and the influences of three major wind systems, the SW Monsoon, and the SE and NE Trade Winds. The trade winds are dry. The SE Trades blow up from the Indian Ocean but lose most of their moisture over the rising series of scarps and plateaux that comprise East Africa, and are quite desiccating by the time they reach Burundi. The SW Monsoon which blows from Zaire brings most of the rain, especially to the high, west facing slopes. It prevails over the country between November and April. The NE Trades are even drier than the SE Trades and are the dominant winds in the northern winter, tending to push back the SW Monsoon. Mean annual rainfall at Bujumbura (3°22'S/29°20'E), on Lake Tanganyika, is close to 960 mm. About 820 mm falls during the six months November-April, but sometimes there is a short dry season in January if the NE Trade Winds become dominant. Very

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little rain falls in the May-October period, and June, July and August may be virtually rainless. Precipitation on the west facing mountain slopes reaches 1375 mm/yr, but is lower, c. 1100-1250 mm/yr, over the eastern plateaux. Rainfall may occasionally be irregular and droughts have been known.

Mean annual temperatures on the plateau are close to 21°C, with summer maxima in the region of 33°C. Below 2000 m, winter minima are about 6°C, but above this altitude winter minima are lower and frosts occur at the highest and most exposed points. The western facing mountain slopes are subject to higher cloud cover than the rest of the country, and in addition to being wetter, are also cooler than the eastern plateaux.

Wetlands

There are a number of small lakes in the mountains and four substantial lakes including Lake Tanganyika, about 8% of the surface of which is situated in Burundi. There are floodplains and permanent swamps along many of the rivers, especially in the headwater regions, and on the lower plateaux.

List of Wetlands Described

1. The Ruzizi Plain
2. Natural Lakes
   (a) Lake Tanganyika
   (b) Lake Tshohoha South
   (c) Lake Katshamirinda
   (d) Lake Rwihinda
   (e) Lake Rugwero
   (f) Lake Kanzigiri
3. Riverine Swamps & Floodplains
   (a) The Luvironza/Kayongozi/Ruvuvu System
   (b) The Akanyaru River
   (c) The Mugwezi & Luaba Rivers
   (d) The Malagarasi River System
   (e) Eastern Rivers

1. The Ruzizi Plain

Location: 2°32'-3°21'S/28°56'-29°35'E
Area: 181 000 ha (total lower plain - approximately 50% in Burundi)
Altitude: 773-810 m asl
Nearest Towns: Bujumbura (at S end); Gitega (62 km WSW)

General: The Ruzizi Plain occupies the floor of the Western Rift Valley at the northern end of Lake Tanganyika, and has been transgressed by lake water in the past. The

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lower plain slopes very gently southwards to the lake, and the Ruzizi River meanders across the centre of the plain, roughly from north to south, forming the national border with Zaire. On either side of the plain the land rises steeply into the mountains. Precipitation over the lower plain is 800-900 mm/yr, while on the slopes of the valley it is 1200-1300 mm/yr. April is the wettest month with mean falls of 140-160 mm on the plain and 180-200 mm in the hills, depending upon site. The dry season usually begins in the second half of May and persists until the end of September, but is longer in the south than the north. Winds are generally light in the morning, increasing to peak velocities at midday, when they may attain 20 km/hr in the wet season and 28 km/hr in the dry season. Mean monthly temperatures range from 22.5-25°C, while mean monthly maxima and minima are 30.5-32.5°C and 14.5-17°C respectively. There are extensive wetlands on the plain, chiefly associated with the Ruzizi River and its tributaries.

Flora & Fauna: *Phragmites mauritianus* swamps accompany the Ruzizi River, in a belt up to 3 km wide, along the lower half of its 135 km course between Lake Kivu and its delta in Lake Tanganyika. The swamps are wider in the south than the north, and also occur on the tributaries, but in much narrower strips. It is estimated that there are, or were, at least 12 000 ha of reed swamps on the Ruzizi Plain in Burundi. Where inundation is permanent the reeds reach 4 m in height, but where it is seasonal they are little more than 2 m high. The most important associate species are *Ipomoea fragrans*, *Panicum meyerianum*, *Paspalidium geminatum* and *Polygonum pulchrum*, the last three species being especially well represented where the surface waters are only superficial.

On the sides of lakes, on meander bends and around small islands in the river, one finds sandy beaches, subject to periodic inundation, but with groundwater always near the surface. These places are covered by a *Cyperus laevigatus-Pluchea bequaertii* association, 1.5-2 m high, with some *Pluchea dioscoridis* and *P. ovalis*, and a ground cover of *Cyperus laevigatus* and *Fimbristylis ferruginea* growing 35-125 cm high.

The country adjacent to the floodplain is covered by *Themeda-Bulbine* grassland, but throughout this there are small ponds which provide water-holes for domestic cattle. They are flooded to depths of over 1 m in the rainy season but are transformed into quagmires during the dry season. They support *Oryza barthii*, with *Asteracantha longifolia* and *Burnatia enneandra* on the fringes, and sometimes central patches of *Nymphaea lotus* and *Utricularia thonningii*. From place to place the *Themeda-Bulbine* association is interrupted by swards of *Sporobalus spicatus* in periodically inundated depressions. These are heavily grazed by local cattle in the dry season. This is the most halophilic association on the valley floor, under which the soil water contains salts to a total concentration of 8‰. Elsewhere, in large shallow depressions in the *Themeda-Bulbine* savanna, where the gradient is virtually zero, water collects semi-permanently. The ground surface is always muddy, particularly where trampled by cattle, but surface water is seldom more than a few centimetres deep. These areas support a cover of *Panicum ruziziense*, with some *Ammania senegalensis*, *Cyperus platycaulis*, *Desmodium hirtum*, *Ilysanthes parviflora*, *Lindernia boutiqueana* and *Ophioglossum costatum*.

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Another very local hydromorphic association in this large wide valley is that of *Setaria holstii* and *Bothriochloa insculpta*. This occupies depressions along the valley floor that were once the beds of lakes. They have clay floors and are inundated for most of the wet season, but dry completely during the dry season, when the clay hardens and cracks. Other species found here include *Digitaria scaetae*, *Glycine boriana* and *Paralmoxia ruziziensis*, together with vagrants from the surrounding savanna.

Where rivers traverse the metamorphic terrain at the feet of the mountains they flow in very steep-sided valleys, and throughout these regions the narrow banks carry gallery forest dominated by *Bophia descampsii* 10-12 m high, with *Cissus araliodes*, *Craibia grandiflora* and *Sterculia tragacantha* as typical associates.

Amphibians are abundant and some reptiles are present, including *Dromophis lineatus*, *Limnophis bicolor* and *Philothamnus irregularis*, together with varanid lizards and occasional crocodiles. Among the birds of the flood plain and permanent herb swamps one encounters *Acrocephalus schoenobaenus*, *A. scirpaceus*, *Actitis hypoleucas*, *Calidris ferruginea*, *C. minuta*, *Chlidonias leucoptera*, *Cuculus canorus*, *Delicon urbica*, *Falco subbuteo*, *Glareola nordmanni*, *Hippolais pallida*, *Hirundo rustica*, *Motacilla feldegg*, *M. flava*, *Pandion haliaetus*, *Phylloscopus trochilus*, *Porzana porzana*, *Riparia riparia*, *Tringa glareola* and *T. nebularia*. Mammalian wildlife has been largely displaced by domestic cattle. Only the small mammals, discussed in the regional introduction are present.

Human Impact & Utilisation: The Ruzizi Valley is intensively cultivated, and the wet areas are frequented by domestic cattle in the dry season when large areas of wetland are burned. Reeds are used for thatching and other domestic crafts.

Conservation Status: Unprotected.

2. Natural Lakes

(A) LAKE TANGANYIKA

Location: 3°21'-8°51'S/29°04'-31°12'E
Area: 3 290 000 ha (c. 263 200 ha in Burundi)
Altitude: 773 m asl
Nearest Towns: Bujumbura (at N end); Gitega (63 km W)

General: Lake Tanganyika is 659 km long with a maximum width of 85 km at the parallel 5°55'S. It is slightly brackish and the second deepest lake in the world (1470 m). It lies in the western arm of the Great Rift Valley and down most of its western side the escarpment plunges straight into the water, and in the south basin, it continues underwater to the maximum depth of 1470 m, which is reached just 4 km offshore. Only at the northern end in Burundi, and at the southern end in Zambia is the underwater slope moderate, and even in these places the 100 m contour is reached inside 10 km. In Burundi the adjacent mountain ranges reach 2670 m in altitude, while on the opposite, Zairean shore they exceed 3000 m. At the northern end the lake is fed by the Ruzizi River and by 31 torrential streams which flow down from the surrounding mountains of Burundi. Other rivers, and countless small streams

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enter all round its central, southern and eastern margins in Zambia, Tanzania and Zaire. The Ruzizi River, draining Lake Kivu, descends the Panzi Falls before entering Lake Tanganyika so that the two lakes are faunally isolated. The Ruzizi has formed a substantial delta at the north end of Lake Tanganyika, half of which is in Burundi. The other principal affluent is the Malagarasi River, which drains much swampy land to the south of Lake Victoria, and most of SE Burundi.

The lake drains from the middle western section via the Lukuga River to the Lualaba, but water levels fluctuate over long time periods, much as they do in Lake Malawi to the south, and these fluctuations are discussed by Camus (1965). The flora, fauna, hydrology, water chemistry and geological history of the lake proper are dealt with, in detail, in section 2.9 Tanzania. However, brief accounts of the fish fauna, and the lake and delta floras are given here.

Flora & Fauna: *Ceratophyllum demersum* is abundant in the vicinities of affluent river mouths, while in the deltas of several rivers, *Azolla pinnata* forms immense floating mats, green or red-brown in colour, and there are great submerged beds of *Myriophyllum spicatum*, *Najas marina*, *N. pectinata*, *Ottelia ulvifolia*, *Potamogeton pectinatus* and *P. schweinfurthii*. *Potamogeton* spp. are the predominant macrophytes around much of the shoreline, with occasional rafts of *Nymphaea caerulea* and *N. capensis* in shallow sheltered bays. *Cyperus papyrus*, *Phragmites mauritianus* and *Typha domingensis* dominate the delta swamps, with *Vossia cuspidata* as the principal low growing associate. The lake contains a large fish fauna comprising some 193 species from 13 families, an analysis of which suggests that the lake is ancient and has been isolated for a long time. Although 98% of the cichlids and 57% of the non-cichlid species are endemic, similar proportions to those found in the faunas of Lakes Malawi and Victoria, it is the degree of speciation here, which distinguishes Lake Tanganyika from the others. It contains no less than 8 endemic genera, and some endemic species reveal distinct subspecific forms between the north and south ends of the lake. In comparatively recent times Zaire Basin species have invaded the lake, presumably by way of the Lukuga River, the most recently established effluent. These include *Distichodus fasciatus*, *Hydrocynus goliath* and *Labeo lineatus*. Other interesting species include *Protopterus aethiopicus*, *Polypterus congicus* and *P. ornatipinnis*, which also occur in the Zaire Basin and, in the lake, inhabit lagoons and deltas, especially the Malagarasi Delta. These are ancient fish and their presence has probably been continuous from the time when the Malagarasi flowed directly into the Zaire Basin, before the faulting which led to the development of the Rift Valley and its lakes. There are two fully aquatic piscivorous snakes in the lake. *Boulengerina annulata* lies up in the rocks during the day and fishes nocturnally, while *Glypholycus bicolor* hunts pelagic fish, chiefly shoals of *Stolothrissa tanganicae*.

Human Impact & Utilisation: The lake is fished intensively from Bujumbura.

Conservation Status: Unprotected.

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(B) LAKE TSHOHOHA SOUTH

Location: 2°20'-2°32'S/29°59'-30°10'E
Area: c. 7000 ha (5000 ha in Burundi)
Altitude: c. 1750 m asl
Nearest Towns: Bujumbura (125 km SW); Gitega (100 km S)

General: Lake Tshohoha South (Lake Tshohoha North is in Rwanda) is 30 km long, oriented SE-NW, and is shallow with a highly indented perimeter. It reaches 5 km in width at the southeast, but is generally 1.5-2 km wide. It lies on the floor of a swampy forested basin between two low hill ridges. It is fed at the southeastern end and drains to the Akanyaru River from the northwestern end through 4 km of swamps. It is fringed by papyrus and *Miscanthidium* swamps, with patches of arborescent swamp forest containing *Bridelia micrantha*, *Ficus verruculosa*, *Myrica kandtiana* and *Phoenix reclinata*, while the submerged vegetation and fauna are typical of Equatorial East African Plateau lakes as described in the regional introduction. The surrounding basin contains some seasonally inundated savanna dominated by *Acacia polyacantha* var. *campylacantha* and *A. sieberana*. The lake is fished, some agriculture occurs higher in the basin, but it is not protected.

(C) LAKE KATSHAMIRINDA

Location: 2°27'S/30°01'E
Area: 400 ha
Altitude: c. 1450 m asl
Nearest Towns: Muhinga (57 km SE); Kitega (105 km S)

General: This little lake is oriented SE-NW. It is 4 km long and about 1 km wide, and is situated southwest of Lake Tshohoha South, in an adjacent and parallel basin. The southeastern end is set in forested country, but the northwestern end merges into papyrus swamps, through which it drains for 4 km to the Akanyaru River. Its flora and fauna are similar to those described for Lake Tshohoha South and it is unprotected.

(D) LAKE RWIHINDA

Location: 2°32'-2°34'S/30°03'-30°06'E
Area: 9200 ha (1200 ha open water + 8000 ha swamps)
Altitude: c. 1480 m asl
Nearest Towns: Muhinga (42 km SE); Kitega (95 km SSW)

General: Like the two previous lakes, this shallow waterbody is also oriented SE-NW. It is 6 km long and 2.5 km wide at the southeastern end. It is flanked by an extensive belt of permanent swamps on its southwestern shore, and drains to the Akanyaru River from its northwestern end through a tract of swampland 11 km long and 2 km wide. The swamps are dominated by *Cyperus papyrus* and *Miscanthidium violaceum* but with some *Phragmites mauritianus* and occasional *Dissotis incana*. *Phoenix reclinata* is common in substantial patches of low swamp forest dominated by *Ficus verruculosa* and *Myrica kandtiana*. The lake is unprotected. It is fished and there is some agriculture on the northeastern side.

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(E) LAKE RUGWERO

Location: 2°21'-2°28'S/30°16'-30°22'E
Area: c. 6000 ha (open water, excluding swamps)
Altitude: c. 1750 m asl
Nearest Towns: Bujumbura (143 km SW); Muyinga (43 km S)

General: The surface area of this lake varies considerably from wet to dry years. It is 15 km long, and up to 8 km wide at the north end at maximum. The lake is shallow, c. 2-4 m, and lies at the southern end of the Mugesera/Rugwero Lake/Swamp Complex, described in section 2.6.10. The northern part of the lake just intrudes into Rwanda. The southern and southwestern shores are forested, while the western, northern and northeastern shores abut extensive swamplands. The lake drains northeastwards, through a short swampy tract to the Nyawarungu River. Innumerable small circular or semi-circular papyrus islands float on the lake surface, and the shores are fringed by papyrus with *Vossia cuspidata* and other aquatic species along the outer faces. *Dryopteris gongylodes* forms an understorey in the papyrus, while to landward there are wide *Miscanthidium* swamps and occasional trees and *Phoenix reclinata* palms. The lake is fished, the hinterland is cultivated locally, and it is unprotected.

(F) LAKE KANZIGIRI

Location: 2°26'-2°29'S/30°21'-30°23'E
Area: 1600 ha (open water) + 3600 ha (swamps)
Altitude: c. 1490 m asl
Nearest Towns: Muhinga (38 km S); Kitega (113 km SW)

General: Lake Kanzigiri is situated 10 km SE of Lake Rugwero. It is 8 km long and 2 km wide, and aligned SW-NE. It is fed through a 6x3 km tract of swampland at the southern end by the Kabanga and Runombe Rivers, and drains from its northern end through swamps to Lake Rugwero. However, along most of its western shores it is separated from Lake Rugwero by forested land. It is fished and some cultivation occurs around its margins. It is unprotected.

3. Riverine Swamps & Floodplains

General: The climate is marked by a long dry season, which in many years may be virtually rainless, followed by a 6 month wet season when 2000 mm may fall in the highlands, and up to 1200 mm on the plateaux. Thus highland rivers are torrential at this time, deeply eroding the land, while in the flatter valleys much alluvium is deposited and floodplains have developed. Some of the lower valleys are characterised by permanent and semi-permanent swamps.

(A) THE LUVIRONZA/KAYONGOZI/RUVUVU SYSTEM

General: The Luvironza rises at a point 3°44'S/29°47'E at an elevation close to 1950 m asl on the high dorsale immediately east of Lake Tanganyika. It flows north over a boggy plateau, where *Sphagnum* sp. grows with *Drosera madagascariensis*, *Loudetia phragmitoides*, *Lycopodium carolinianum*, *Rhynchospora brownii*, *Utricularia appen-*

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diculata and *Xyris angularis*. Such bogs are common above 1700 m, but may also occur at the heads of valleys down to 1500 m. The Luvironza eventually turns NE and decends below 1500 m into a deep valley, in which it receives several tributaries, including the Karuzi River on the left bank, and after this becomes known as the Ruvuvu. Another major tributary, the Kayongozi River, rises in the far east of Burundi, close to the Tanzanian border, and flows southwestwards, anti-parallel with the Ruvuvu for 48 km, before turning abruptly northwards to a confluence with the Ruvuvu at 3°15'S/30°19'E, just below the 1500 m contour.

Extensive permanent swamps, dominated by papyrus, occur in the headwater basin of the Kayongozi (3°04'S/30°32'E-3°00'S/30°36'E) and its affluent the Mumizi (3°03'S/30°37'E). Many other deep high valleys above the Ruvuvu are blocked by *Cyperus papyrus* with, occasionally, some *Polygonum strigosum*. So dense are these swamps, and so variable the water levels, that agriculture is precluded, while the shallow valleys are largely given over to cultivation. These valleys tend to be flooded for half the year, but rather dry for the other half, and behind the papyrus along the thalwegs, they were once filled by swamp forests, dominated either by *Syzygium guineense* or *S. owariense*. The former is associated with *Ficus verruculosa* and *Myrica kandtiana* and occupies the drier sites. Little relict stands are still apparent, but the trees have mostly been cleared. *Syzygium owariense* forests occupy the wettest sites and the trees develop pneumatophores. They are associated with *Cyathea dregei*, *Lonchitis natalensis*, *Lygodium scandens*, *Osmunda regalis*, *Pteris intricata* and *Renealmia engleri*, but this type of forest has also been intensively cleared, and where there is no cultivation there are now secondary swamps of *Cyperus latifolius*. There is little *Phragmites* in the high valleys, but in some relatively undisturbed wet situations one meets *Cyperus nudicaulis* and *Pycreus mundtii* fringing standing water which supports floating mats of *Azolla pinnata* and *Lemna paucicosta*, over submerged beds of *Enhydra fluctuans*, *Hydrocotyle ranunculoides*, *Lemna paucicosto* and *Ludwigia adscendens*.

Gallery forest in the upper Ruvuvu system is confined to the narrow and often rocky valleys of tributaries. It is inundated only for short periods when the rivers are in spate, and is locally dominated by *Newtonia buchananii*, with *Albizzia gummifera*, *Bridelia micrantha*, *Cleistanthus polystachyus*, *Harungana madagascariensis*, *Magnistipula bangweolensis*, *Millettia dura*, *Sapium ellipticum* and *Xymalos monospora*.

The Ruvuvu River meanders along its lower valley at altitudes of 1400-1100 m asl, accompanied by a narrow, tree covered floodplain, 3-5 km wide. On this there are many pools, and the dominant trees are savanna species such as *Acacia seyal*. The river itself is densely fringed by *Cyperus papyrus* and *Phoenix reclinata*, with gallery forest behind. The pools on the floodplain support typical submerged and floating leaved aquatics including *Ceratophyllum demersum*, *Leersia hexandra*, *Ludwigia adscendens*, *Nymphaea caerulea*, *Potamogeton* spp. and *Vossia cuspidata*.

Large animals are comparatively common in the lower valley and include *Crocodylus niloticus*, *Hippapotamus amphibius*, *Hippotragus equinus*, *Kobus ellipsiprymnus*, *Phacochoerus aethiopicus*, *Syncerus caffer*, *Tragelaphus scriptus* and *T. spekei*. There is an abundance of water birds including *Mycteria ibis* and *Pelecanus onocrotalus*. Some 46 000 ha of the lower valley including much wetland, is protected in

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the Ruvuvu National Park. Otherwise, pressures on the land are great. Hunting and fishing take place everywhere, but the population is very centralised and agricultural pressure around towns and villages is enormous in view of the extremely high population density.

(B) THE AKANYARU RIVER

General: The river rises in Rwanda, about 2300 m asl, but the important headwater tributary, the Mugere, rises in Burundi with sources at 2°50'S/29°27'E and 2°52'S/29°29'E, both close to 2450 m asl. In its lower course the Akanyaru meanders through a shallow valley, flanked on both banks by permanent swamps, beyond which are seasonally inundated savannas. The swamps begin at a point 2°46'S/29°50'E, from where the river flows more or less due north forming the border between Rwanda and Burundi. The swamp belt is best developed on the Burundi side, especially at the confluences of tributaries, up the valleys of which it reaches 6-10 km. There are estimated to be 14 600 ha of permanent swamps on this river in Burundi in a strip 63 km long. Both these swamps, and those in the valleys of right bank tributaries, are dominated by papyrus, with strips of swamp forest parallel with the river on less deeply inundated sites. In these, *Bridelia micrantha*, *Ficus verruculosa*, *Myrica kandtiana* and *Phoenix reclinata* are dominant close to the river, but with *Acacia polyacantha* var. *campylacantha*, *A. sieberana* and *Albizia gummifera* locally common farther away. No part of the valley is protected. The river and swamps are fished by artisans, and much of the seasonally inundated land is cultivated.

(C) THE MUGWEZI & LUABA RIVERS

General: These short streams flow into Lake Tanganyika in the south of Burundi. Permanent swamps occur on the Mugwezi (4°22'S/29°38'E), which enters the lake south of the town of Nyanza (4°20'S/29°36'E), and on the Luaba (4°18'S/29°38'E) which enters the lake just north of the town. Each of these papyrus swamps covers about 400 ha, while another swamp occurs on the lakeshore immediately south of Nyanza, and yet another, immediately behind the town. The land between the swamps, some of which is inundated seasonally, is cultivated. The wetlands are not protected. The flora and fauna is typical for the western equatorial part of the region.

(D) THE MALAGARASI RIVER SYSTEM

General: The Malagarasi rises on the Burundi/Tanzania border (4°06'S/29°47'E) on a hill almost overlooking Lake Tanganyika. It then flows NE, away from the lake, along the border, receiving several tributaries from the highlands of Burundi on its left bank, until at a point 3°47'S/30°24'E it meets the Lumpungu River flowing SW along the border. This latter stream also receives tributaries from the highlands of Burundi, particularly from the region of Mt. Nyarwana (3°15'S/30°28'E), 1930 m asl. From the confluence the Malagarasi flows into Tanzania, later to turn full circle and enter Lake Tanganyika.

The river valley along the southern borders of Burundi is wide, shallow and savanna covered, with abundant *Isoberlinia* spp. A broad gallery of forest accompanies the river, and this is usually inundated after heavy rain in the Burundi catchments during

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November-December and again in March-April. There is much *Phoenix reclinata* at the water's edge, and in places, some *Cyperus papyrus*. In depressions the gallery forest is swampy containing species such as *Bridelia micrantha*, *Ficus verruculosa*, *Parkia filicoidea*, *Phoenix reclinata* and *Syzygium owariense*, but generally it is drier, inundated only for a few weeks at a time, and contains species such as *Albizzia gummifera*, *Diospyros mespiliformis*, *Ficus sycomorus*, *Khaya senegalensis* and *Syzygium cordatum*. The flora and fauna of the valley is as described in the regional introduction for this part of the region, but the river is of special interest because it contains several species of fish which occur in the Zaire Basin but not in Lake Tanganyika. This suggests that the river is ancient and once, in pre-rift times, crossed the area where Lake Tanganyika now is, to enter the Zaire River.

Strips of permanent swampland occur on both banks of the river, 1250 m asl between 4°21'S/29°55'E and 4°18'S/29°59'E, and again between 4°10'S/30°05'E and 3°53'S/30°15'E. These latter swamps lead into bamboo forests in the north and are situated about 1200 m asl. They attain 5 km in width at the mouths of two tributaries, the Muyovozi and Mwoga Rivers. Other permanent swamps occur on the Ndanga (3°36'S/30°17'E-3°18'S/30°17'E) and Motetma (3°32'S/30°22'E-3°34'S/30°26'E) tributaries, both about 1250 m asl. Farther east the Lugusi River forms the Burundi/ Tanzania border for a short distance, and here again there are swamps on both banks in both countries (3°34'S/30°30'E-3°28'S/30°35'E) at an altitude of 1220 m. Still farther east, swamps occur on the upper Lumpungu (3°23'S/30°35'E-3°18'S/30°41'E) between 1240 and 1260 m asl, and these also abut bamboo forests on the Burundi side of the river.

Hunting and fishing occur in the main valley which contains approximately 14 000 ha of permanent swampland and a further large area of seasonal wetland. There is some agriculture. No part of the system is protected.

(E) EASTERN RIVERS

General: Small areas of permanent swampland occur on the Kahumo (2°59'S/30°44'E) and Mwaruzi (3°03'S/30°43'E) Rivers in the far east of Burundi. The first of these swampy sections is on the Burundi/Tanzania border, and the second is just in Burundi, but both rivers flow into Tanzania, and both swamps are close to 1500 m asl. Neither area is protected.

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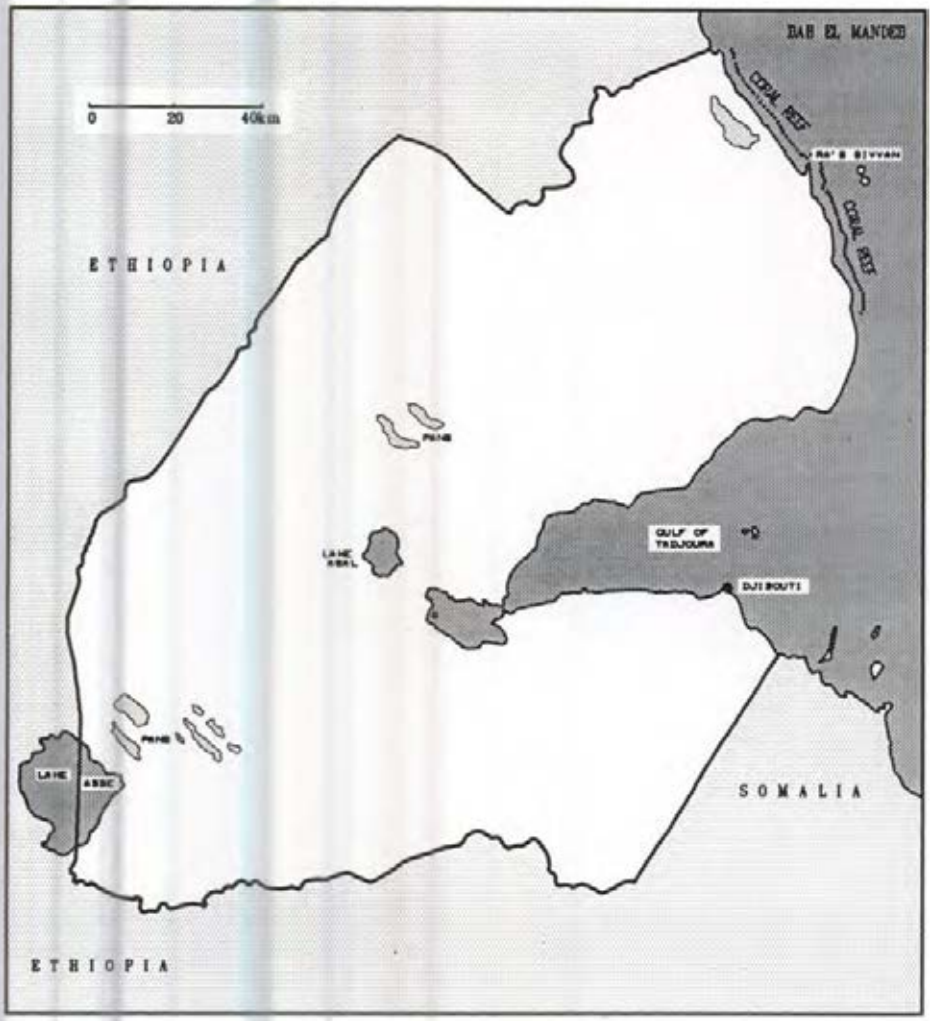

Map of Djibouti

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2.2 DJIBOUTI

Introduction

Djibouti has an area of 23 000 km^2, a population of 330 000 (1983) and therefore a mean population density of 14.3 persons/km^2. It stretches 200 km from north to south between latitudes 10°54' and 12°26'N, and 175 km from west to east between longitudes 41°46' and 43°26'E. It is bounded by Ethiopia in the north, west and south, but has a 66 km border with Somalia in the southeast, while in the east it has a frontage to the Gulf of Aden and the mouth of the Red Sea.

The coastline is 375 km long and includes the Gulf of Tadjoura which runs E-W and penetrates 120 km inland to the centre of the country. The coastal plain is 10-30 km wide, but in the bay (Ghoubet Kharab) at the head of the Gulf of Tadjoura, a low ridge, scarcely 3 km wide, separates the sea from a SE-NW depression which sinks to 155 m below sea level. On either side of the depression mountains rise steeply; to 1695 m in the west (11°50'N/42°15'E) and to 1783 m in the east (11°45'N/42°38'E). Indeed the western landscapes of Djibouti are dominated by a series of ridges oriented SE-NW, while the eastern half of the country, north of the gulf, is a dissected plateau some 600 m asl, but which rises southwards to hills of 1500 m along the gulf shore and northwards to 2029 m (12°28'N/42°24'E) on the Ethiopian border. Other hills, reaching 1289 m, lie along the border with Somalia in the far south.

Lake Abbé, at the southwestern extremity of Djibouti, receives drainage from Ethiopia via a branch of the Awash River, and from local wadis. North and east of this there is a series of pans, again oriented SE-NW, which receive the run-off from local hills. Otherwise drainage from the southwestern part of the country finds its way into wadis which lead to, but do not feed, Lake Asal. Drainage from the northeastern plateau is either to pans or to the coast.

Climate

Djibouti is hot and arid. The mean annual temperature at Djibouti Town (11°33'N/43°07'E) is 30°C and occasional temperatures of 48°C have been recorded near Lake Asal (155 m below sea level). It remains hot throughout the year but there is a cooler period from November to April. Mean annual rainfall is less than 200 mm in the southwest, 127 mm at Djibouti, and 300-500 mm on the mountains north of the Gulf of Tadjoura. Djibouti is in the rain-shadow of the Ethiopian Highlands, so far as the summer winds from the SW are concerned, however, rain has been recorded in all months. Humidity is always high at the coast but decreases dramatically in passing inland.

Wetlands

There are two important lakes, numerous pans, and some tidal wetlands.

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List of Wetlands Described

1. Natural Lakes
   (a) Lake Abbé
   (b) Lake Asal
2. Interior Pans
3. Tidal Wetlands

1. Natural Lakes

(A) LAKE ABBE

Location: 11°02'-11°17'N/41°38'-41°54'E
Area: 34 000 ha (11 000 in Djibouti)
Altitude: 243 m asl
Nearest Town: Djibouti (135 km ENE)

General: Lake Abbé is described more fully in section 2.4 Ethiopia. It is situated on the floor of a basin which once contained a much larger lake. It is 37 m deep, endorheic, and is fed principally by the Awash River, which with its tributaries drains a major part of the eastern slopes of the Ethiopian Highlands. Since 1954 an increasing volume of water has been removed from the upper Awash for irrigation and by 1984 the lake surface had shrunk to two thirds of what it was in the late 1940s. This shrinkage is evidenced by extensive flats now covering some 11 500 ha to the southwest of the lake. A small part of these flats extends into Djibouti.

Flora & Fauna: The biology of the lake is not known.

Human Impact & Utilisation: Apparently little used or disturbed in Djibouti.

Conservation Status: Unprotected.

(B) LAKE ASAL

Location: 11°40'N/42°25'E
Area: 10 800 ha (5200 ha open water + 5600 ha salt flats)
Altitude: 155 m bsl (lake surface)
Nearest Town: Djibouti (105 km ESE)

General: Lake Asal, which has maximum dimensions of 7x10 km, is situated on the floor of a depression leading NW from the head of the Gulf of Tadjoura. The land falls steeply, and in places precipitously, from sea level to a saline plain about 150 m below sea level which marks the floor of an older, larger lake. The present lake surface is set some 5 m below this, and is again ringed by steep banks. The saline plain is narrow to the south and east of the lake, but reaches nearly 2 km in width along the western shore, and 6 km in the northwest, having a total area of approximately 5600 ha. The lake surface is 4 km from the sea at the nearest point.

Hydrology & Water Quality: Lake Asal is fed by subterranean inflows which include infiltration of sea water, as well as by wadis which lead into the depression. Maximum depth is of the order of 20 m. Occasional rains in nearby catchments may lead to the

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wetting of the salt flats, but rain in more distant catchments, which includes an area south of the head of the Gulf of Tadjoura, does not nowadays reach the depression. Potential evaporation from the lake is very high, c. 5800 mm/yr, thus its waters are highly saline, the concentrations of the principal ions being sodium 104 340 mg/l; potassium 5104 mg/l; calcium 2640 mg/l; magnesium 12 366 mg/l; chloride 196 756 mg/l; sulphate 2554 mg/l; silicate 13 mg/l; and bicarbonate 4 mg/l, while the pH is generally close to 7.2. Surface water temperatures range from 28-32°C.

Flora & Fauna: The biology of the lake is not known, but the peripheral salt flats support patchy Red Sea coastal salt desert vegetation as described in the regional introduction.

Human Impact & Utilisation: Not utilised.

Conservation Status: Unprotected.

2. Interior Pans

General: A series of 20 saline pans is situated to the northeast and east of Lake Abbé in southwest Djibouti (11°06'-11°25'N/41°50'-42°15'E). A long hogsback slopes southeastwards from Gemeri Hauk (11°37'N/41°39'E-1358 m) in Ethiopia to a hill (11°12'N/42°05'E-684 m) in Djibouti, and these pans, also oriented SE-NW, are situated on it or on its southwestern side facing Lake Abbé. They have a total area of about 15 400 ha. The largest measures 14 km in length and reaches widths of 4 km; the smallest is barely 1 km long and 800 m wide. They are all fed by little wadis which may remain dry for several consecutive years, and when flooded, they seldom hold water more than 50 cm deep. They have sandy/clay or sandy/gravel floors and support tufts of *Cenchrus ciliaris* together with *Aeluropus lagopoides*, *Sporobolus spicatus*, *Suaeda monoica*, *Trianthema crystallina* and *Urochondra setulosa*. Bushes of *Acacia tortilis* and *Cadaba glandulosa* occur at the sides of some wadis.

Another series of SE-NW oriented pans is situated north and east of Lake Asal (11°52'-12°26'N/42°15'-42°46'E). They lie between 300 and 600 m asl and are fed by wadis leading northwards from the hills along the north shore of the Gulf of Tadjoura, and south from the highlands along the Ethiopian border. The largest pan is 19 km long and 6 km wide at its southern end and their total area approaches 20 000 ha. They support scant vegetation.

Yet other pans and shallow wadis are found at the foot of the coastal hills. These are floored by sandy alluvium which in places extends down to the sea and covers the raised Quarternary reefs which line parts of the coast. The largest pan is 50 - 100 m asl, covers some 32 000 ha (12°23'-12°40'N/42°55'-43°10'E) and is 32 km long and up to 20 km in width. All these latter pans support some saltmarsh/salt-desert vegetation, including such species as *Aeluropus lagopoides*, *Aerva persica*, *Calotropis procera*, *Cenchrus ciliaris*, *Cyperus conglomeratus*, *Eleusine compressa*, *Halopeplis perfoliata*, *Heliotropum pterocarpum*, *Panicum turgidum*, *Salsola forskalii*, *Sporobolus spicatus*, *Urochondra setulosa*, and at the edges of wadis, bushes of *Cadaba glandulosa*. Occasional trees of *Acacia tortilis* and *Balanites aegyptiaca* are to be found. These pans and wadis are not utilised and are unprotected.

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3. Tidal Wetlands

General: Coral reefs occur offshore and extend southwards from the Djibouti/Ethiopia border to a latitude of 12°16'N. South of this the beaches are sandy, but often the sand overlies old reefs, and in places alluvium from wadis has washed out over these reefs. Other reefs occur east of Djibouti Town on the southern shore of the Gulf of Tadjoura and near the mouth of the gulf. In places small mangrove stands occur in little bays, e.g. behind the northward pointing peninsula of Ra's Siyyan (12°29'N/43°19'E). Tidal amplitudes here are little more than 1 m, but some saltmarshes occur on the beach behind mangroves and behind low narrow dune ridges. *Avicennia marina* is the dominant mangrove and the saltmarsh vegetation is as described in the regional introduction. These coastal wetlands are not utilised and are unprotected.

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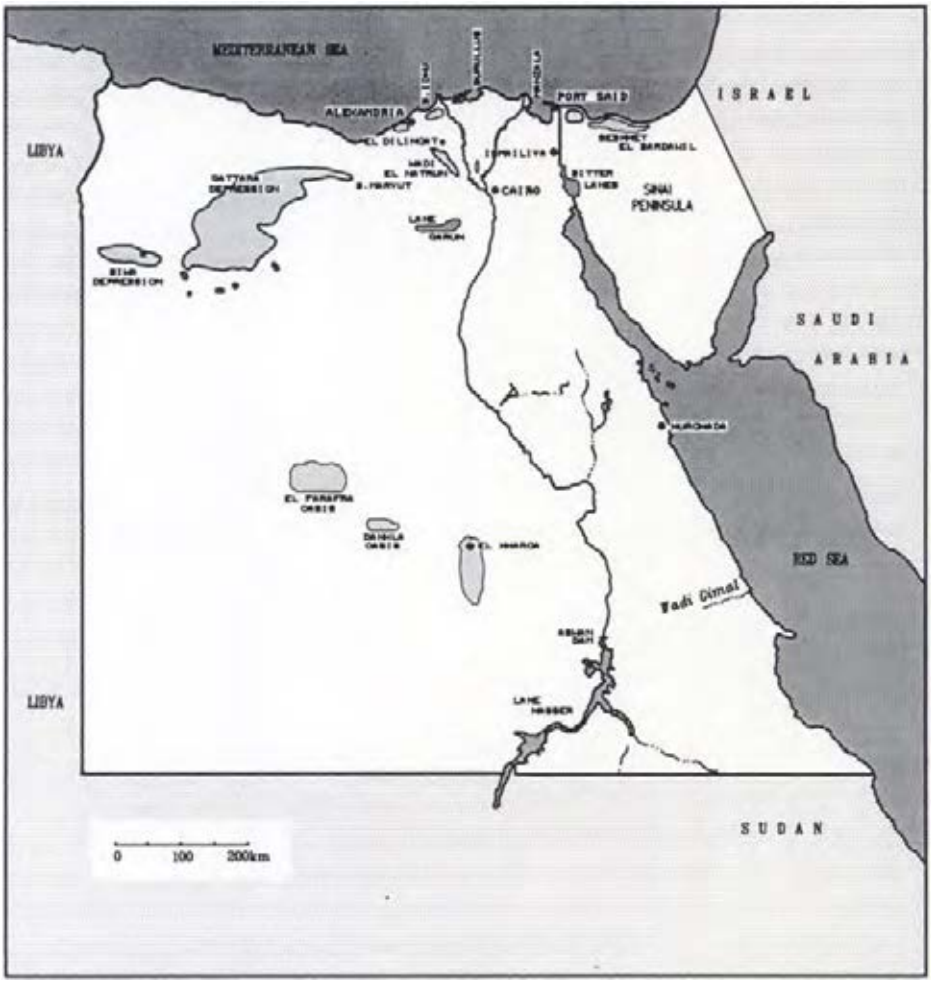

Map of Egypt

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2.3 EGYPT

Introduction

Egypt has an area of 1 000 250 km^2, a population of 46 000 000 (1984), and thus a mean population density of 46 persons/km^2. This however is very misleading, since some 70% of the people live in Cairo and the Nile Delta, and most of the remaining 30% in the Nile Valley. Population densities exceed 20 100/km^2 in some urban areas. Egypt is bounded by Libya in the west, Sudan in the south, and Israel in the east. The Mediterranean coast is almost 1100 km long, and the east coast, which includes the west coast of the Gulf of Aqaba, both coasts of the Gulf of Suez, and a length of Red Sea coast, is some 1780 km long. The country stretches 1095 km from north to south between latitudes 21°47' and 31°38'N, and about 1140 km from west to east between longitudes 24°42'E on the Libya/Egypt border and 35°47'E at Ras Bânas on the Red Sea.

The Nile divides the plateau across which it flows into two regions, the Western Desert and the Eastern Desert. The Western Desert, between Libya and the Nile, is arid and without wadis. In the west it comprises a great sea of blown sand, but nearer to the Nile it is rocky. It sinks to a number of large depressions in which there are oases, and rises to heights of over 1000 m in the extreme SW on the Gilf Kebir Plateau. This towers over the surrounding desert from which it ascends by cliffs and scarps.

The lower Nile Valley is a verdant strip across the desert, demarked by steep valley sides, except on the west bank above Cairo, where land, after rising a little, slopes down to the depression and lake of Qârûn, 45 m below sea level. Below Cairo the valley flattens out and the river enters the delta which is criss-crossed by canals and distributaries. The delta is 300 km wide, 175 km deep, and covers 26 000 km^2. A number of swampy lakes and large lagoons line its seaward face.

A discontinuous range of mountains in the Eastern Desert, oriented NNW-SSE, separates the Nile Valley from the Gulf of Suez and the Red Sea, and reaches a high point of 2187 m at Gebel Shâyib el Bânat (26°59'N/33°29'E). The Eastern Desert is extensively dissected by deep wadis which run down from these gullied mountains to the Nile, while to the east, other wadis lead to the sea across a narrow coastal plain. Parallel to the shore there is an almost continuous line of coral reefs.

Sinai is another desert. The hills along its two gulf coasts rise and converge southwards to form a sharply serrated range of a mountains near the tip of the peninsula. Here, Gebel Katherina (28°30'N/33°57'E) is the highest point in Egypt (2637 m asl). All of Sinai is gullied, with wadis leading directly to the gulfs on either side, or into the centre, to the anastomosing system of the Wadi el Arish which runs north to reach the Mediterranean Sea (31°08'N/33°52'E) near the town of El Arish.

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Climate

The Tropic of Cancer runs through southern Egypt, 94.6% of which is true desert. Precipitation over the Western Desert is minimal and many consecutive years may be completely rainless. Mean annual rainfall at Cairo is only 25 mm. However, the Mediterranean coast and the mountains along the Red Sea attract some winter rain. Alexandria (31°12'N/29°58'E) on the Nile Delta has a mean annual rainfall of 147 mm, but Hurghada (27°18'N/33°47'E) on the Red Sea coast receives only 3 mm/yr. Precipitation in the hills of the Eastern Desert and Sinai is very variable. In these places a stream may flow as a torrent for a day or so after a storm, during which over 100 mm of rain may fall, but it may thereafter remain dry for several years.

There are two seasons. Winter lasts from November to March, and summer from April to October. Winters are cool and mild, but summers are hot and dry. Then, in the deserts, daytime temperatures may reach 48°C but may fall to 10°C at night. Temperatures may also reach 48°C along the Red Sea, but seldom fall below 14°C at night. NE winds predominate in winter, but it is the occasional westerly winds that bring rain. In summer, winds are from the SW, off the Sahara. January is the coolest month throughout the country, when mean monthly minima and maxima are 9.3 and 18°C at Alexandria, 8.6 and 19.1°C at Cairo, 11.3 and 18°C at Port Said and 8 and 23.8°C at Aswan. August is generally the hottest month, and at this time mean monthly minima and maxima are 22.9 and 30.4°C at Alexandria, 21.6 and 34.8°C at Cairo, 24.9 and 30.9°C at Port Said and 24.7 and 41.3°C at Aswan.

Wetlands

There are some important wetlands on the Mediterranean coast, and others of lesser size and importance on the eastern coasts. In Sinai, and on the Red Sea, some small swamps exist in the lower valleys of intermittent watercourses and there are extensive saltmarshes along the littoral. Mangroves have a discontinuous distribution from the tip of Sinai southwards. There are lakes in some depressions of the Western Desert. The Nile has a floodplain and a delta, and it is impounded at Aswan to form Lake Nasser.

List of Wetlands Described

1. Wetlands of the Nile Delta
   a) The Delta Proper
   b) Bahra el Maryut
   c) Bahra el Idku
   d) Bahra el Burullus
   e) Bahra el Manzala
   f) Sabkhet el Bardawil
2. The Lower Nile Valley
3. The Suez Canal & Associated Lakes

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4. The Gulfs of Aqaba & Suez, & the Red Sea
5. Oases
   (a) The Siwa Depression
   (b) The Qattara Depression
   (c) Wadi el Natrun
   (d) Lake Qârûn
   (e) The 'New Valley' Oases
6. Lake Nasser/Nubia

1. Wetlands of the Nile Delta

(A) THE DELTA PROPER

Location: 30°07'-31°36'N/29°53'-32°31'E
Area: 2 292 500 ha (total delta)
Altitude: 0-30 m asl
Nearest Towns: Alexandria (at W edge); Port Said (at E edge)

General: The delta is symmetrical. It is 175 km from apex to base, i.e. from Cairo to the sea, and some 263 km wide at the sea. Since the construction of the Aswan High Dam the delta is no longer subject to annual flooding, and much of the marshland has been reclaimed for agriculture. Of the persisting marshland, most is associated with the lakes and lagoons along the seaward face and is discussed in the succeeding sections. However, coastal erosion is increasing now that the Aswan Dam impounds most of the silt coming down river, and the integrity of the delta lakes is threatened. Below Cairo the Nile divides into the Rosetta (western) and Damietta (eastern) branches which reach the sea at places of these names. Several major canals and numerous distributary streams branch off from these main rivers. A number of small lakes occur in the delta, many representing sections of abandoned river channel. To the west of the Rosetta channel, just below Cairo, there are the two El Mallah Lakes (30°05'-30°07'N/31°03'-31°04'E) and Lake el Qatta (30°12'N/30°59'E), and farther north a cluster of 15 small lakes (30°48'-30°57'N/30°16'-30°39'E) near El Dilingât. Between the Rosetta and Damietta branches, shortly below the bifurcation, there is Lake Faraontya (30°21'-30°28'N/30°56'-31°03'E) which is a section of abandoned channel. To the east of the Damietta branch there are Lakes Sinnéra and Sanel Hagar (31°05'N/31°55'E), just south of the large coastal lagoon of Manzala, and the Mineishar Lakes (30°44'N/31°53'-32°04'E).

Flora & Fauna: The delta wetlands have coastal fresh water floras and faunas as discussed in the regional introduction. *Phragmites australis*, *Typha capensis* and *Juncus maritimus* are common here, together with some small sedges. Papyrus is now virtually absent from the delta. Some marine fishes enter the delta, e.g. *Anguilla* spp., *Mugil cephalus* and *Solea vulgaris*. Several European animals are present including *Lutra lutra* and *Vulpes vulpes* and there is an abundant avifauna.

Human Impact & Utilisation: Most of the delta wetlands have been reclaimed for agriculture, but since the construction of the High Dam at Aswan the upper delta has tended to become progressively more saline. This is due in part to the intrusion of sea

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water, but also to the use of artificial fertilisers in the lower Nile Valley to compensate for the loss of silt which used to be deposited by the flood each year. By contrast the delta lakes have become less saline due to increased drainage from irrigation schemes.

Conservation Status: Unprotected.

(B) BAHRA EL MARYUT

Location: 31°07'N/29°53'E
Area: 2700 ha (lake proper)
Altitude: 3 m bsl (water surface)
Nearest Town: Alexandria (2 km SW)

General: This lake fills a depression below sea level and is separated from the sea by a limestone ridge. The water surface is now 3 m bsl. The lake used to have an area of about 11 000 ha, but most of this was reclaimed between 1950 and 1980. The Nozha Hydrodome was isolated from Lake Maryut in 1939 and is now enclosed by a 9 km concrete embankment and is used as a fish farm.

Hydrology & Water Quality: Water depths vary between 90-150 cm and the bottom is covered by silt, clay and shells. It is fed chiefly by the Qalaa Drain and water from the lake is pumped to the sea. Water temperatures range from 13-30°C and Secchi depths of 10-100 cm are obtained. pH ranges from 7.0-9.7 and is lowest near industrial inputs. Total dissolved solids range from 1750-11 400 mg/l. Chloride ion concentrations range from 3-9 mg/l and silicate from 8-17 mg/l. High nitrate and nitrite concentrations have been recorded but these are not permanent. The lake may become deoxygenated when levels of organic matter are high. The lake is unstratified because of wind action. Pesticides such as DDT and Lindane have been detected in the water in comparatively high concentrations.

Flora & Fauna: The southern shores are covered by dense reedbeds (*Phragmites australis*), together with *Cyperus* and *Juncus* spp. *Ceratophyllum demersum* and *Najas pectinata* occur in the centre of the lake. The lake is eutrophic and primary production is high. Most of the Nile delta birds and mammals are found here.

Human Impact & Utilisation: A fishery on the lake is highly productive yielding some 17 000 tonnes/yr, i.e. 6200 kg/ha/yr. Currently *Oreochromis* spp. comprise 77% of the catch and *Clarias* spp. 17%. The lake is polluted by industrial and agricultural effluents and there is evidence of both heavy metal and pesticide accumulation in the fish.

Conservation Status: Unprotected.

(C) BAHRA EL IDKU

Location: 31°12'-31°16'N/30°08'-30°18'E
Area: 10 400 ha
Altitude: sea level
Nearest Towns: Alexandria (17 km W); Cairo (162 km SE)

General: This shallow brackish lake contains a number of islands and is situated 15 km SW of the mouth of the Rosetta branch of the Nile. It is 16 km long, has a maximum

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width of 10 km, and is separated from the sea by a narrow sand barrier. An extensive reed swamp at the eastern side has been partially reclaimed in recent years.

Hydrology & Water Quality: Water is received by drainage of the surrounding delta lands and exchange with the sea occurs through the Bougaz el Maadiah, with inflow from the sea occurring principally in winter. The lake is usually well oxygenated and water temperatures range from 15-29°C. Chloride ion concentrations range from 0.5-23 mg/l, and total dissolved solids from 1000-45 000 mg/l.

Flora & Fauna: The flora and fauna are much as described in the regional introduction. The lake supports *Ceratophyllum demersum* and dense mats of *Eichhornia crassipes*, with *Potamogeton crispus* and *P. pectinatus* in the most saline areas. It is eutrophic and highly productive. The eastern marshes are dominated by *Phragmites australis*. European animals such as *Lutra lutra* occur here.

Human Impact & Utilisation: There is a flourishing fishery in which *Oreochromis* spp. account for 82% of the catch, *Anguilla anguilla* for 10% and *Mugil* spp. for 6%.

Conservation Status: Unprotected.

(D) BAHRA EL BURULLUS

Location: 31°22'-31°35'N/31°31'-32°08'E
Area: 71 000 ha
Altitude: sea level
Nearest Towns: Alexandria (57 km SW); Cairo (154 km S)

General: This is a shallow brackish lagoon with numerous small islands. It is open to the sea through a narrow mouth at the northern extremity near the town of El Burg. Depths vary from 0.7-2.4 m, and changes in water level expose large areas of shoreline. The northern shore is separated from the sea by a long dune covered spit. The bottom is muddy along the southern shore, but sandy on the northern side.

Hydrology & Water Quality: Inflows from the land occur from 7 major drains along the southern shore, and discharges from these, together with rainfall and seepage from the Rosetta branch of the Nile, cause the lake level to rise and induce a net discharge to the sea in summer. However, seawater may enter in winter. Water temperatures range from 11°C in winter to 30°C in summer. The water is well mixed and well oxygenated, although turbid, with Secchi depths of only 8-37 cm. Chloride ion concentrations range from 0.3-14 mg/l, while silicate levels may reach 400 mg/l.

Flora & Fauna: This is essentially as described in the regional introduction. There are extensive reed beds dominated by *Phragmites australis*, with *Potamogeton* spp. dominant in the lake. *Ceratophyllum demersum*, *Eichhornia crassipes* and *Lemna gibba* are also present; *Lemna* forms scums on stagnant backwaters while *Eichhornia* is dominant in the drains. About 30 different fishes have been recorded from the lake including species of *Anguilla*, *Mugil* and *Solea*.

Human Impact & Utilisation: There is a fishery on the lake.

Conservation Status: Unprotected.

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(E) BAHRA EL MANZALA

Location: 30°51'-31°33'N/31°45'-32°35'E (total system)
Area: 90 000 ha (open water) + 68 800 ha salt- marsh
Altitude: sea level (saltmarsh partly below sea level)
Nearest Towns: Port Said (at E end); Cairo (135 km SW)

General: This is the largest of the delta lagoons. It is situated between the Damietta Branch of the Nile and the Suez Canal, while the El Manzala Canal, which traverses the lagoon, connects Port Said with Damietta. The lagoon is shallow, with a mean depth of 1 m, and salt-marshes extend southwards and eastwards from the SE corner. Some 48 800 ha of the salt-marsh, east of the Suez Canal, are below mean sea level. Because of reclamation the open water area has been decreasing steadily, from 170 000 ha at the turn of the century, to 90 000 ha in 1983. The present lagoon is 64 km long with a maximum width of 49 km and contains numerous islands.

Hydrology & Water Quality: There are several connections with the sea, the largest being at El Gamil. A number of drains enter on the southeastern shore, the largest of these being the Bahr el Bagar Drain and the Hadous Drain which between them discharge 5 billion m^3/yr. The lake is moderately well oxygenated, but concentrations may fall to 4-5 mg/l or less in the south at night. Salinity has fallen over the last 50 years due to increased fresh water inputs from irrigation schemes and decreased connection with the sea. In 1926 mean salinity was in the region of 17‰, but this had decreased to a value of 3‰ by 1982. Salinity is now lowest in September-October and highest in March-April.

Flora & Fauna: Marshlands on the periphery are dominated by *Phragmites australis* and *Typha capensis*. The southern part of the lake supports beds of *Ceratophyllum demersum*, *Potamogeton crispus* and *P. pectinatus* and there is a dense phytoplankton. The lake is eutrophic and highly productive. *Eichhornia crassipes* is present and has been fought by aerial spraying. The fauna of peripheral wetlands is as described in the regional introduction.

Human Impact & Utilisation: The lagoon is the site of important capture fisheries and fish farms, the yields from which have increased with eutrophication. The total catch from open water fisheries in 1979-80 was 40 000 tonnes, while fish farms produced an additional 20 000 tonnes. *Oreochromis niloticus* is the most important species landed, closely followed by *O. aureus*, *O. galilaeus* and *Tilapia zillii*. *Liza ramada* used to be the most important species taken, but its proportion in the annual catch has declined to 2%. Other components of the catch include the marine species *Anguilla anguilla*, *Dicentrarchus labrax*, *D. punctatus*, *Liza saliens*, *Mugil cephalus*, *Sciena aquila*, *Sparus aurata* and the shrimp *Palaemon elegans*, together with the freshwater species *Bagrus bayad*, *Clarias lazera*, *Labeo niloticus* and *Lates niloticus*, the latter now very scarce. Some 17 000 fishermen work the lagoon using 4000 boats. In addition some 14 300 ha of hosha (fish-farm) enclosures are in operation, employing a further 9000 people. Part of the discharge of the El Bagar Drain, which is rich in Cairo sewage water, is being diverted to the Um el Rish Lake where a similar program of intensive exploitation is starting.

Conservation Status: Unprotected. A general danger to all the delta lakes is that of erosion which has increased since the building of the High Dam and the consequent lack of silting.

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(F) SABKHET EL BARDAWIL

Location: 31°02'-31°14'N/32°41'-33°36'E
Area: 68 100 ha (open water)
Altitude: sea level
Nearest Towns: Port Said (38 km W); El Arish (19 km W)

General: The Sabkhet el Bardawîl is a salt water lagoon, 90 km long and up to 24 km wide, on the Mediterranean coast of Sinai. It is bounded on the seaward side by a long narrow spit, and on the landward side by a sandy coastal plain 15-20 km wide. It is open to the sea, through a narrow mouth, towards the eastern end. The lagoon is not presently exploited, but there are plans for the development of a fishing port. Rainfall over the lagoon is about 125 mm/yr, evaporation is about 2000 mm/yr, and some fresh water enters along the southern shore after rain.

2. The Lower Nile Valley

General: The Nile Valley below Aswan varies between 20-30 km in width and is confined by steep sides, particularly on the east. Since the closure of the High Dam at Aswan the valley is no longer flooded each year. It is however, irrigated and traversed by a number of streams and canals on the western side. The longest of these, flowing in parallel with the Nile is the Bahr Yûsef. This receives water from the Nile at various points and terminates in the vicinity of El Faiyûm, from where, ultimately, its waters drain to Lake Qârûn. A number of small lakes also occur along the western side of the valley. A succession of deep wadis run down from the eastern hills to the right bank of the river, and comparatively little agriculture occurs on this side of the valley. The valley is becoming progressively more saline as a consequence of the use of artificial fertilisers. These are now used to compensate for the silt which is no longer deposited by the annual floods.

3. The Suez Canal & Associated Lakes

General: The Canal runs from Port Said (31°17'N/32°18'E) on the Mediterranean Sea to Suez (29°59'N/32°33'E) at the head of the Gulf of Suez, a distance of 160 km. It traverses en route, the eastern end of Manzala Lagoon, Lake Timsâh (30°31'-30°35'N/32°16'-32°20'E) near Ismâ'iliya, and the Bitter Lakes (30°10'-30°25'N/32°18'-32°35'E). Lake Timsâh occupies about 2500 ha while the two Bitter Lakes, actually one water body, are 35 km long, up to 12.5 km wide, and have an open water surface of 31 250 ha. The canal and lakes are tidal. In the north the canal traverses the saltmarshes at the eastern end of Manzala Lagoon, and yet other saltmarshes between El Qantara (30°52'N/32°19'E) and El Firdan (30°41'N/32°19'E). The flora and fauna of these marshes is as described in the regional introduction.

4. The Gulfs of Aqaba & Suez, & the Red Sea

General: Mangrove vegetation is absent from the Gulf of Suez where in places the coastal plain is absent and the mountains rise straight from the sea, e.g. at Kashm el

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Galala some 60 km south of Suez, at Ras Zeit at the entrance to the Red Sea, and around Abu Durba (28°28'N/33°20'E) on the Sinai shore. The shores of the Gulf of Aqaba are even steeper and less hospitable, but the most northerly stand of mangroves on the East African coast occurs here, near the tip of the peninsula, in the shallow Marsa Lagoon (27°47'N/34°15'E). Only *Avicennia marina* is present, with sponges and algae growing on the pneumatophores in clear water. On the Egyptian Red Sea coast *Avicennia* makes its appearance at Myos Hormos Bay (27°25'N/33°39'E), 22 km north of Hurghada. From here, southwards to the Egyptian border at latitude 23°N, mangrove vegetation characterises the littoral. *Avicennia marina* grows in monospecific stands, either as clumps of isolated trees or as dense belts several kilometres long. It also grows densely on Abu Minqar Island (27°15'N/32°51'E) off Hurghada, and on Safaga Island (26°44'N/33°57'E). *Rhizophora mucronata* joins the mangrove association near the Tropic of Cancer growing as a co-dominant with *Avicennia marina*. The Red Sea coasts are fringed by raised Quarternary coral reefs, into which many small bays have been cut, and these provide sheltered habitats for mangroves with floors of sandy mud. Soil reactions are generally alkaline with a pH range of 7.5-8.5. In places *Avicennia* occurs above the tidal zone, apparently having survived the silting of the shoreline, e.g. in the delta of the Wadi Gimal (24°40'N/35°04'E). This Wadi Gimal drains the northern end of the Gebel Hamada Range (1977 m asl) and reaches the sea in a bay, the mouth of which is sheltered by Wadi Gimal Island. The stream, like several others along this coast, flows torrentially after storms in the mountains. Various marine angiosperms occur to seaward of the mangrove trees, principally *Cymodocea ciliata*, *C. rotundata*, *Diplanthera uninervis*, *Halophila ovalis* and *H. stipulacea*.

Reed swamps occur at the mouths of some wadis, as described in the regional introduction and saltmarshes extend along much of the Egyptian littoral. Often it is difficult to determine the limit of tidal inundation as the saltmarsh vegetation grades into salt desert vegetation. Common species are given in the regional introduction.

5. Oases

(A) THE SIWA DEPRESSION

Location: 29°02'-29°28'N/25°12'-26°06'E
Area: c. 7000 ha open water + 10 000 ha marshland.
Altitude: 17 m bsl (lowest lake surface)
Nearest Towns: Cairo (525 km ENE); Siwa (at W end)

General: The lowest point of the Siwa Depression, which is underwater, is about 25 m below sea level. The depression has developed in limestones of Eocene and Miocene age, and is bounded by steep slopes on the northern side, reaching about 120-160 m asl, but by much gentler slopes to the south and southeast. Here, slopes rise into the plateau of the Western Desert which comprises limestone covered by wind blown sands. The depression occupies 108 800 ha. It is 82 km long and has a maximum width of 28 km, but narrows in places to 2 km. A number of small basins on the floor of the depression hold little lakes, about a dozen in total, mostly surrounded by marshes. These are the remnants of larger Pleistocene lakes, and fossil shorelines can be seen at altitudes of 8-12 m below sea level. The levels of the present lakes fluctuate seasonally and some

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dry up in summer. The principal lakes, some of which are not named, are situated at 29°20'N/25°09'E (Shiyata -250 ha); 29°13'N/25°18'E (el Maraqi -900 ha); 29°13'N/25°28'E (Siwa -3200 ha); 29°14'N/25°35'E; 29°11'N/25°39'E; 29°12'N/25°40'E; 29°11'N/25°43'E (el Zaytûn -1600 ha); 29°21'N/25°55'E; 29°18'N/25°59'E; 29°17'N/25°59'E; 29°17'N/26°01'E (el Ma'asir -400 ha); and 29°14'N/26°04'E. All the lakes are saline but are supplied with fresh water from springs. Mean annual precipitation in the depression is 8 mm, but many years are rainless. Temperatures may exceed 48°C in summer, while frosts are not uncommon on the surrounding limestone plateau in winter. Potential evaporation (Class A Pan) exceeds 2300 mm. Relative humidity is generally very low 15-30%, but this may increase to 50% at night, and may fall to 1% when the hot dry Khamsin wind blows in summer.

Flora & Fauna: The lakes contain *Chara*, and both unicellular and filamentous algae occur in the springs. Reeds and sedges grow in the saline marshes, as discussed in the regional introduction. Among fish, *Aphanius dispar* is indigenous and *Tilapia zillii* has been introduced. Water birds, including ducks and ibises are often abundant while *Felis caracal*, *F. lybica* and *Vulpes rupellii* are resident mammals.

Human Impact & Utilisation: The depression has long been inhabited and stone tombs are present at the western end. Subsistence agriculture is practised using water from the springs and from wells which have been dug.

Conservation Status: Unprotected.

(B) THE QATTARA DEPRESSION

Location: 28°35'-30°25'N/26°20'-29°04'E
Area: 1 700 000 ha (below sea level)
Altitude: 133 m bsl to 300 m asl
Nearest Towns: Cairo (220 km E); Alexandria (150 km NE)

General: This depression, oriented SW-NE, is 285 km long and reaches a maximum width of 135 km. It is bounded by a steep, and in places precipitous, escarpment, along the northwestern and northern sides, which rises to heights of over 300 m, and a few kilometres away from the escarpment edge, to over 500 m. By contrast the southern and eastern sides of the depression rise more gradually to the plateau of the Western Desert. Saline marshes/deserts, up to 30 km wide and over 150 km long, are situated under the escarpment along the northern side of the depression, and other marshes extend out into the southern central part of the basin, occupying a total of about 300 000 ha. Wind blown sands have intruded into the depression along the southern margins and are encroaching upon the marshes in the central and extreme southern areas. Elsewhere on the south side, the floor of the depression comprises black gravels or bare broken rock, or there are rock/salt plateaux, and in the far south there is a hard clay pan. There are four semi-permanent saline lakes, one, Lake el Maghra (30°14'N/28°53'E), at the extreme northeastern end of the depression, and three along the most southerly margin, on a gravel plain at the edge of the sand sea. These are situated at 28°39'N/26°41'E; 28°40'N/26°27'E (Lake el Bahrein); and 28°43'N/26°56'E (Lake Sitra). Each covers several hundred hectares. Lakes el Maghra and Sitra (the largest) are below sea level, while the other two are just above it. There are springs at Ain Tibaghbagh (29°05'N/26°23'E), el Araq (28°57'N/ 26°30'E) and el Watya (28°51'N/26°43'E) along the southern edge.

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Flora & Fauna: *Chara* occurs in the lakes, and the saltmarshes contain species listed in the regional introduction. A number of invertebrate species have been recorded from the lakes and there is an abundant birdlife. Mammals present include *Felis caracal*, *F. lybica*, some rodents and *Vulpes rupellii*.

Human Impact & Utilisation: Not permanently inhabited and at present virtually unutilised. However, consideration is currently being given to a proposal to flood the depression with sea water, thus creating the world's largest manmade lake. This would raise the water table in the surrounding desert and water evaporated from the lake might condense over the Western Desert with beneficial effects for projected agriculture.

Conservation Status: Unprotected.

(C) WADI EL NATRUN

Location: 30°19'-30°30'N/30°02'-30°30'E
Area: 30 000 ha (total depression)
Altitude: 10 m bsl
Nearest Towns: Cairo (75 km ESE); Alexandria (80 km N)

General: The wadi is situated in an area of undulating sand with sparse scrub vegetation 47 km west of the Nile Delta, but there are hard packed gravel soils along the northern wadi margin. The lowest part of the Wadi is a depression below sea level, 50 km long and up to 8.5 km wide, oriented NW-SE, which contains a string of small saline lakes surrounded by saline desert marsh vegetation. The principal lakes are, from NW-SE, el Ga'âr, el Beida, el Hamrah, el Rumnya, um Risha and el Fâsoa. There are deposits of salt and soda crystals on parts of the wadi floor, which may occasionally be inundated by discharges from the dozen temporary watercourses that enter the depression along its southern margin.

Flora & Fauna: Flora and fauna as described in the regional introduction. There are however, comparatively few birds.

Human Impact & Utilisation: Little used.

Conservation Status: Unprotected.

(D) LAKE QARUN

Location: 29°24'-29°32'N/30°24'-30°49'E
Area: 23 500 ha
Altitude: 44 m bsl (lake surface)
Nearest Towns: Cairo (65 km NE); El Faiyûm (13 km S)

General: Lake Qârûn is situated in a depression 71 km long and 20 km wide, which descends to 44 m below sea level at the mean surface level of the lake. The lake has a mean depth of 4.2 m and a maximum depth of 8.5 m in the western basin. A cluster of small natural lakes is situated near El Gharaq el Sultâni (29°08'N/30°42'E), some 13 km south of the Qârûn Depression, and some artificial lakes have been created in the Wadi Ruwayan, 12 km southwest of the depression.

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Hydrology & Water Quality: Lake Qârûn is endorheic and was in the past artificially fed by water from the Nile, but now, with modern agricultural practices, it receives only the run-off from the irrigated peripheral lands. This enters the lake via two canals at the eastern end, and the mean annual influx is estimated at 390 million m^3. Mean annual precipitation over the lake is estimated at 9 mm, relative humidity ranges from 49% in June to 75% in December, and Class A Pan evaporation is estimated at 1750-1900 mm. The lake is becoming increasingly saline. At the turn of the century salinity was measured as 13‰, but this had risen to over 34‰ in some parts of the lake by 1976. Salinity is highest in the western basin and lowest in the vicinity of the influx canals. Secchi depths of 2-3 m are obtained in the western basin, but only 60 cm near the mouths of the canals.

Flora & Fauna: There is a rich plankton and an invertebrate benthos dominated by the mollusc *Cerastoderma glaucum* which produces an average standing crop of 288.5g dry weight/m^2, and comprises 70% of the total benthic biomass. The benthic fauna is characterised by the presence of several euryhaline marine species, e.g. *Nereis diversicolor*, and there are marine elements in the plankton, believed to be imported with fish fry with which the lake is stocked each year. The most important species of fish are *Mugil capita*, *M. cephalus*, *Solea vulgaris* and *Tilapia zillii*. All of these were first introduced in 1928 and are now restocked annually. The lake supports large numbers of water birds among which *Anas clypeata* (11 000), *Aythya fuligula* (6000), *Fulica atra* (19 000+), *Podiceps cristatus* (4000) and *P. nigricollis* (11 000) are the most abundant.

Human Impact & Utilisation: The rate of salification has increased since the closure of the high dam at Aswan. Artificial fertilisers are used to replace the nutrients formerly provided by the sediment deposited during the annual flood, and these raise the concentration of salts in the waters entering the lake. There is a flourishing fishery on the lake.

Conservation Status: Unprotected.

(E) THE 'NEW VALLEY' OASES

In the days of the Pharaohs the oases west of Luxor (25°41'N/32°24'E) were among the most fertile areas of Egypt and are believed to have supported a population of 8 million people. Today the oasis at El Farafra (26°55'-27°30'N/27°50'-28°20'E) has no surface water, while there are now only springs and wells at Dakhla (25°10'-25°50'N/28°50-29°25'E) and at the Great Oasis of El Khârga (24°32'-25°49'N/30°23'-30°43'E). However, artesian water is available at these places and vast irrigation projects are underway to 'reclaim' these oases. At Dakhla, a depression, less than 200 m asl, lies in a NW-SE oriented trough in the plateau at 500 m. On the southwestern side, the plateau slopes gradually down to the floor of the trough, but on the northeastern side it rises abruptly from the depression in a 300 m escarpment. A series of wells and springs occurs several kilometres out into the depression below the foot of this escarpment. At El Khârga there is a depression, less then 100 m asl, oriented roughly N-S and parallel with the Nile. It is 135 km long and up to 40 km wide.

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6. Lake Nasser/Nubia

Location: 20°27'-23°58'N/30°07'-33°15'E
Area: 685 000 ha (581 000 ha in Egypt)
Altitude: 183 m asl (at capacity)
Nearest Towns: Aswan (at dam); Cairo (700 km NNW)

General: In the past the Nile flooded its lower valley and delta each year, depositing a fertile layer of silt on which crops could be grown. The highest flood on record was in 1879 and the lowest in 1913. During successive dry years, water for irrigation was in very short supply and agricultural production was greatly reduced. Each year water flowed into the Mediterranean without having been used for irrigation or power generation. However, since the construction of the High Dam at Aswan, 7 km below the old Aswan Dam, the Nile no longer overtops its banks in Egypt and river flow is controlled to provide water for hydroelectric power and year round irrigation. The dam is rock-filled, 111 m high at its crest, 980 m wide at its base and 40 m wide at the top. It has an impervious core, a grout curtain extending 180 m under the core to meet the bedrock, and a horizontal upstream impervious blanket. It is 3600 m long, 520 m lying between the banks of the Nile with the remaining 3080 m stretching outward in the form of two wings on both sides of the river. The irregular shoreline of the lake is approximately 7900 km long, and is presently unprotected.

The lake can be divided into three sectors. The northern sector is fully lacustrine and extends south from the dam to Tushka. The middle sector is semi-riverine and comprises the southern part of Lake Nasser and the northern part of Lake Nubia, up to Daweishat. It is characterised by riverine properties during the flood season but by lacustrine properties during the rest of the year. The southern sector has riverine characteristics all year round. The irregular shoreline is some 7900 km long.

Hydrology & Water Quality: The dam holds back 161 billion m^3 of water at capacity, comprising a dead volume of 31 billion m^3, below which the generators will not operate, a live capacity of 90 billion m^3, and a flood control capacity of 41 billion m^3. Maximum depth is 98 m. It is anticipated that it will take 500 years for the dead capacity to be filled by silt. There is a diversion system on the east bank, used during dam construction, which can accommodate the full flood capacity of the river, while on the west bank there is a tunnel which can accomodate the passage of surplus water when the lake is full. This has a carrying capacity of 9400 m^3/sec. In the case of successive high flood years occurring, water can be sent 40 km from Aswan to the Toshka Dam, constructed across a depression in the Western Desert.

When the annual flood enters the southern part of the lake it destroys stratification in the lake and the turbid floods push lake water, with relatively high conductivity, ahead of them. Secchi depths at the high dam range from 3.4 m in winter to 1.5 m in summer, and from 2.3 m in winter to 80 cm in summer at Tushka. It is estimated that 134 million tonnes of suspended matter enter the lake each year. Chloride ion concentrations have increased since impoundment and are now 8.83-9.83 mg/l, while sulphates range from 5-10 mg/l, the highest concentrations being in bottom water. Sulphide ion concentration increases sharply close to the bottom, sometimes exceeding 400 mg/l at depths below 90 m. The principal cation concentrations are 8.2-27.8 mg/l for sodium, 2-8 mg/l for

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potassium, 14-27.5 mg/l for calcium and 4.5-12.5 mg/l for magnesium. Carbonate and bicarbonate concentrations have fallen since the lake was first filled and carbonate concentrations at the surface are now in the range of 0 - 1 mg/l. The waters have become more alkaline since impoundment and current pH values are 8-8.85, with some seasonal variations, increasing in winter.

The highest surface water temperatures are recorded in August and range from 29.3-31.8°C, while the lowest surface water temperature of 16°C was recorded during winter 1970/71. In winter the water column is oxygenated from top to bottom with concentrations of 6.7-11 mg/l at the surface and 5.4-8.7 mg/l at the bottom, but in the summer bottom water may become deoxygenated. Surface water oxygen concentrations in summer range from 5.2-10.1 mg/l.

Flora & Fauna: The lake is set in the desert. It has a bluish-green colour due to the presence of blue-green algae which are particularly abundant in early summer. *Volvox* comprises the bulk of the phytoplankton, while cladocerans (*Daphnia*) and copepods (*Cyclops*) provide the bulk of the zooplankton. Primary production ranged from 10.7-16.4 g carbon/m^2/day in 1979. Most of the Nile fishes, referred to in the regional introduction, have been recorded from the lake, but the lacustrine and riverine sectors have these species in different proportions so that their fish faunas are distinct. For example, *Eutropius niloticus*, *Schilbe mystus* and *S. uranoscopus* thrive where riverine conditions predominate and are most common at the southern end of Lake Nubia, while *Alestes nurse* and *Hydrocynus forskalii* are most common in the clear waters of northern Lake Nasser under lacustrine conditions. The importance of the lake to birds has not yet been properly ascertained.

Human Impact & Utilisation: The power station has a generating capacity of 2.1 MW, producing 10 billion KW/hours/yr. Annual catches from the fishery which has developed on the lake have increased from 645 tonnes in 1966 to 33 933 tonnes in 1981. The principal species landed are *Bagrus bayad*, *B. docmac*, *Clarias* spp., *Eutropius niloticus*, *Labeo* spp., *Lates niloticus*, *Oreochromis galilaeus*, *O. niloticus* and *Synodontis* spp. The two cichlids are by far the most important species, having formed 27% of the catch in 1968 but 90% in 1981. Gill and trammel nets are commonly used for fishing in the lake. Gill nets are about 2 m deep and mainly catch *Alestes* and *Hydrocynus*. The other species are generally caught in trammel nets. Fish are usually iced, and then frozen or processed in some other way. A small proportion of the catch, say 6%, is salted. Some 8960 fishermen operate on the lake, using mainly two-man canoes or traditional Nile boats manned by 4-5 men. Few of the craft are motorised. Signs of fishing stress, seen in decreasing fish sizes, have begun to appear at certain centres in recent years. References and a good introductory account of the fishery are given by Latif (1984).

The high dam has had a deleterious effect upon the Nile below it, in that the number of species of fish in the river has decreased from 71 to 31. Despite this the annual production of the lower Nile fishery has increased since the dam, but chiefly because of intensified effort. The coastal fishery, and in particular the sardine fishery, has however, declined. The Egyptian catch from the Mediterranean fell from 38 000 tonnes in 1962 to 7000 tonnes in 1969, but recovered to 20 000 tonnes in 1979. Sardines, which once formed 37% of the annual catch now constitutes only 9%.

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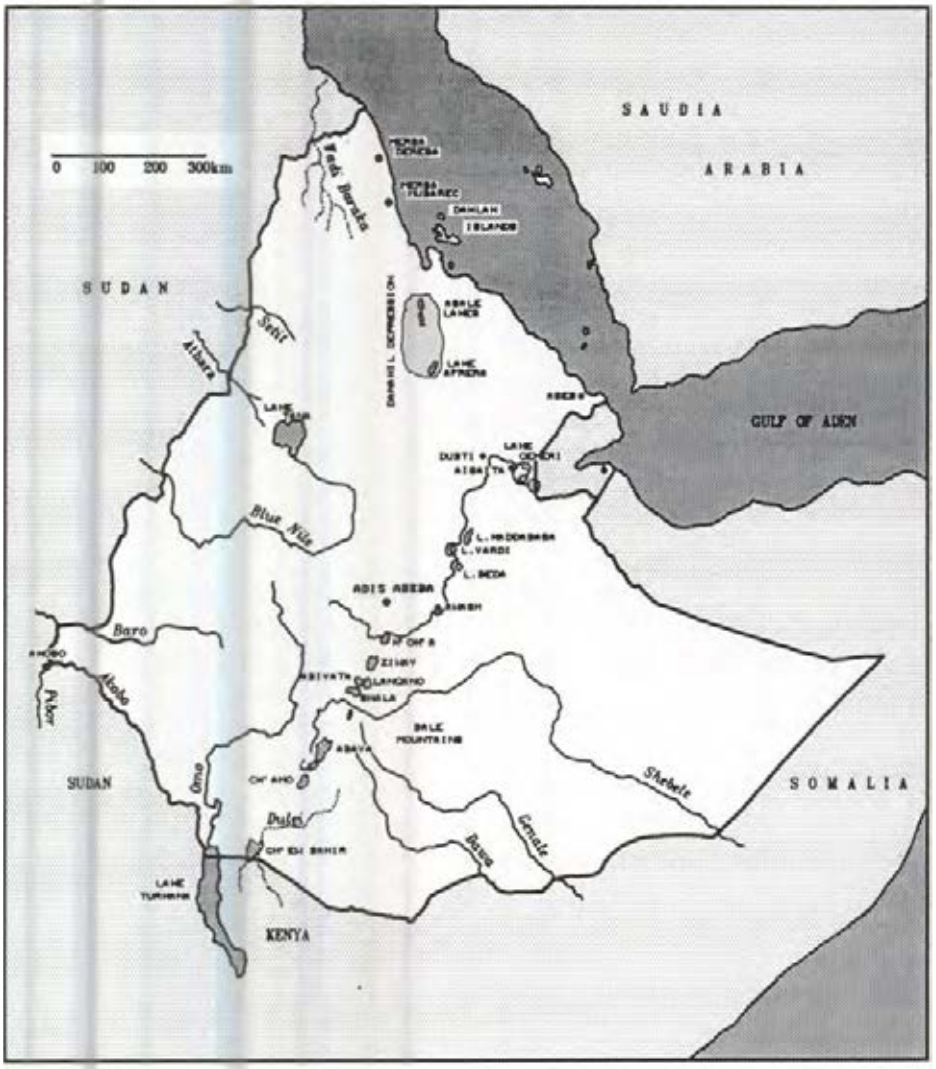

Map of Ethiopia

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2.4 ETHIOPIA

Introduction

Ethiopia is a mountainous country bounded by Sudan in the north and west, by Kenya and Somalia in the south, and by Somalia, Djibouti and the Red Sea in the east and northeast. It has an area of 1 023 050 km^2, a population of 33 680 000 (1983), and thus a mean population density of 32.9 persons/km^2. It stretches approximately 1645 km from north to south between latitudes 3°25' and 18°00'N, and 1615 km from west to east between longitudes 33°03' and 48°00'E.

The western half of the country, to longitude 40°E, is almost completely occupied by the Ethiopian Massif. The southern part of the massif is split by the Eastern Rift Valley which, running SW-NE, divides it into a large northwestern block and a small southeastern block. Active volcanoes occur in the rift valley, right through to the Djibouti border. In the northwestern highlands, Mt. Ras Dashen (13°12'N/38°25'E) rises to 4620 m asl, and there are five other peaks above 4000 m, while in the southeastern highlands Mt. Batu (6°56'N/39°47'E) rises to 4307 m asl and two other peaks exceed 4000 m.

The eastern half of the country is a plateau, 500-1000 m asl, divided into southern and northern halves at a latitude of 9°N, by an E-W oriented extension of the great massif. Mountains along the southern arm of the Eastern Rift Valley provide this extension, and in this range, 7 peaks exceed 3000 m asl. The southeastern quadrant of the country slopes into Somalia and Kenya, while the northeastern quadrant slopes towards the Red Sea. However, at its northern end it descends to more than 116 m below sea level in the Afar Depression, separated from the Red Sea by the Eritrean Mountains which are aligned parallel to the coast. Active volcanoes occur on the floor of the depression and to the south of it.

The western slopes of the Ethiopian Massif drain to the Nile, while the southern and southeastern slopes drain to the Indian Ocean by rivers which cross Somalia and Kenya. The slopes facing the Rift Valley drain to a series of endorheic lakes on the valley floor, and both the northeastern slopes of the massif and the western slopes of the Eritrean Mountains drain to lakes in the Afar Depression. The Eastern slopes of the Eritrean Mountains drain to the Red Sea.

Climate

In winter, the Ethiopian coast is in a zone of convergence between dry NW winds and moist SE winds, and some rain falls. This is greatest at Mits'iwa (15°38'N/39°25'E) where mean annual precipitation is 165 mm, but this decreases northwards to 100 mm/yr at the Sudanian border, and southwards to 104 mm/yr at T'i'o (14°41'N/40°55'E) and 27 mm/yr at Aseb (13°02'N/42°47'E). Rain may fall over coastal districts at any time of the year but it is always concentrated in the October-February period. For example, Mits'iwa has an average receipt of 120 mm for these five months, i.e. 72% of the mean annual total. Annual variations along the coast may be very great, for example, Karora (17°42'N/38°22'E), 34 km inland at an altitude of 244 m, once had an annual receipt of 321 mm, but it normally receives less than a third of this. Further, there are regional

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vagaries, thus Damas (15°28'N/39°13'E) which lies 26 km inland of Mits'iwa, had a mean annual rainfall of 645 mm/yr between 1926 and 1948.

In summer the intertropical convergence between the SW Monsoon and the NW Trade Winds lies over the Ethiopian Massif, reaching its most northerly position, about 19°N in Sudan, during July-August. While the monsoon brings heavy rain to the western mountains it does not usually extend far east of the mountains, so that the eastern half of the country remains dry. Falls on the high mountains reach 2000 mm/yr locally, but are lower in the valleys and plateaux, and tend to decrease from SW to NE. Thus mean annual receipts are 1302 mm at Adis Abeba (9°03'N/38°42'E), 1118 mm at Dese (11°05'N/39°40'E) and 730 mm at Adi Ugri (14°47'N/38°50'E), all between 2000 and 2440 m asl. The floor of the Rift Valley, in rainshadow, is very dry, while falls along the western foothills range from 800-1100 mm/yr.

At Mits'iwa the mean annual temperature is close to 30°C, occasioned more by warm winters than by exceptionally hot summers. July and August are the warmest months when the mean temperature is 34.7°C, while February is the coldest month with a mean temperature of 25°C, and the average diurnal range is 7°C throughout the year. Extremes of temperature occur inland in the east of the country, with colder winters and warmer summers, during which recordings above 50°C have been made in the Danakil Depression. The climate of western Ethiopia is moderated by altitude, as indicated by the mean temperatures at Adis Abeba (16°C - 2440 m), Dese (18.6°C - 2220 m) and Adi Ugri (19.3°C - 2022 m).

Vegetation

The Ethiopian Massif supports Afro-montane vegetation at the highest levels, giving way below to evergreen bush and woodland, and this in its turn to Ethiopian savannas along the western flanks of the massif. The Rift Valley supports deciduous bushland, the eastern plateaux semi-desert scrub, while an area of Red Sea coastal desert occupies the southern half of the Eritrean coastal plain. The Danakil (Afar) Depression is largely barren, being covered in part by lava flows, and having vegetation almost confined to wadis.

Wetlands

Tidal wetlands occur along the coast including isolated mangrove stands, reed swamps at the mouths of wadis, and extensive saltmarshes. Most rivers draining the mountains have seasonal floodplains because of the seasonality of rainfall over their catchments, and many valley floors are covered by deep fertile alluvia. Some rivers traverse lakes and permanent swamps on the plateaux. There are a number of endorheic lakes in the Rift Valley, in the Danakil (Afar) Depression, on the Danakil Plateau, and in the mountains. Montane lakes range from large deep lakes like Lake Tana, through small but deep crater lakes, to myriad alpine tarns. In addition some rivers have been impounded to create artificial lakes in the mountains.

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List of Wetlands Described

1. Tidal & Coastal Wetlands
2. Lake Tana
3. Wetlands of the Bale Mountains
4. Lakes of Bishoftu
5. Lakes of the SW Rift Valley
    (a) Lake Ziway (Zwai)
    (b) Lake Langano
    (c) Lake Abiyata
    (d) Lake Shala
    (e) Lake Awasa
    (f) Lake Abaya (Margherita)
    (g) Lake Ch'amo
    (h) Lake Ch'ew Bahir
    (i) Lake Turkana (Rudolph)
6. Lakes & Swamps of the Awash River System
    (a) The Upper Awash Valley
    (b) Lakes & Pans of Southern Wadis
    (c) The Lake Beda Sector
    (d) The Gewane Lake/Swamp Complex
    (e) The Dubti Swamps
    (f) The Gemeri Lake/Swamp Complex
    (g) Lake Abbé
7. Lakes of the Danakil (Afar) Depression
    (a) Lake Afrera
    (b) The Asale Lakes
8. River Floodplains
9. Artificial Impoundments
10. Other Wetlands

1. Tidal & Coastal Wetlands

General: In the north the coast consists of raised coral reefs which end abruptly with a low shelf about 1.5 m above high tide mark. Generally these are overlaid either by coralline or quartz sands, and at wadi mouths by pale brown alluvium. In the south the fossil reefs are lower and sand beaches reach the sea. Living reefs line the coast almost continuously, being especially well developed in the island studded bay at Aseb. In places small bays have been eroded into the fossil reefs, often where the discharges from wadis have facilitated erosion, and these bays are the sites of small mangrove stands,

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with *Avicennia marina* dominant. Many gnarled old trees are present, some 8-10 m high. Mangroves also occur on the islands of the Dahlak Archipelago, where *Ceriops tagal* and *Rhizophora mucronata* have been reported in addition to *Avicennia marina*. A Marine National Park has been proposed for this area which will protect some mangrove stands. Mangroves also occur on infrequently flooded areas, separated from the sea by low dune ridges, e.g. at 17°40'N/38°44'E some 13 km south of Lake Mandalum. Other prominent mangrove stands occur at Mersa Deresa (17°55'N/38°35'E) and Mersa Mubarek (16°31'N/39°08'E) in the north, and in Aseb Bay in the south.

Salt-marshes, many of which are only irregularly tidal, are often found adjacent to mangroves, and are dominated by *Arthrocnemum glaucum*, *Halopeplis perfoliata* and *Suaeda monoica*, grading inland into areas of *Aeluropus lagopoides*, *Cenchrus ciliaris* and *Sporobolus spicatus*. Maximum tidal amplitudes vary between 1-1.5 m along this coast.

The coastal plain is narrow, 10-30 km in width, and from it hills rise to heights of 800-2100 m over distances of 5-15 km. These hills are deeply gullied, but many rivers divide on reaching the coastal plain, into a network of streams which periodically flood substantial areas. Most wadis flow only for a few hours after storms in the hills, and do not extend to the sea, their waters always being absorbed by the soils of the coastal plain. However, a few larger wadis do reach the sea and regularly flow throughout their courses, e.g. Wadi Falcat which drains the northern end of the Ethiopian Massif. It has a mouth in the far north of the country (17°36'N/38°47'E) and has deposited alluvium over a raised beach which supports large bushes of *Suaeda monoica*. In favourable years these flooded lands (inland deltas) on the coastal plain are cultivated for bulrush-millet (*Pennisetum typhoideum*) and cotton. Inland many wadis are dammed with sand, both to contain flood water, and to direct it and the alluvium it carries onto the banks for the cultivation of crops, but all floods eventually breach these dams.

In some places, near the mouths of large wadis, drainage to the sea is impeded by dunes, and in these areas pans develop, supporting the grasses *Aeluropus lagopoides*, *Eleusine compressa* and *Sporobolus spicatus*, together with *Pulicaria schimperi* and *Tavernieria lappacea*. In these sites vegetational cover may be nearly complete, but vegetation in the wadis is scant. *Tamarix orientalis*, often reaching 10 m in height, occurs on the banks of wadis and on islands in the wadi beds, often with *Salvadora persica* and sometimes with *Calotropis procera* or *Ziziphus spinachristi*. In the hills these species may be joined by *Acacia tortilis* and *Delonix elata*. *Acacia nubica* often covers depressions in backwaters along wadis which are subject to periodic flooding but not to heavy scouring. No coastal wetlands are currently protected.

2. Lake Tana

Location: 11°35'-12°18'N/37°01'-37°35'E
Area: 315 600 ha
Altitude: 1829 m asl
Nearest Towns: Adis Abeba (310 km SE); Gonder (37 km N)

General: The lake is 73 km long with a maximum width of 67.7 km and contains several minor and two major islands. These latter, Daga and Dek Islands in the southern part of

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the lake, are volcanic cones. Small swampy and seasonally flooded alluvial plains border the lake to the north, east and west and in these regions the lakeshore is flat; elsewhere it is steep and rocky. The lake area enjoys some 2660 hours of sunshine each year, with a mean maximum of 288 hours in January and a mean minimum of 114 hours in July. Winds are generally light.

Hydrology & Water Quality: The lake is fed by 61 small streams, all very seasonal in the volume of water they carry. They drain a basin of 16 500 km^2 and the longest of them, the Abbai, is considered to be the source of the Blue Nile. This river carries the overspill of the lake from its southern extremity. Maximum outflow is of the order of 400 m^3/sec in September and the annual overspill is estimated at 3.9 billion m^3. Precipitation averages 1320 mm/yr over the lake, with a monthly maximum of 475 mm in July, but by contrast the December-April period is virtually rainless. Rainfall over the upper catchments may reach 2000 mm/yr while evaporation from the lake margins has been determined as 1836 mm/yr. The lake has a maximum known depth of 14.1 m, a mean depth of 8.5 m and an estimated capacity of 28 billion m^3. The surface level has varied by nearly 2 m during the past 20 years.

Mean annual surface water temperatures are beteen 21.5 and 22.0°C depending upon locality, and the waters are generally well mixed and well oxygenated. Total dissolved solids range from 151-174 mg/l and the pH range is 7.5-8.4. Calcium is the most abundant cation, and bicarbonate the most common anion.

Flora & Fauna: Emergent macrophytes fringe the flat swampy parts of the shoreline, the dominant species being *Cyperus papyrus*, with *Echinochloa pyramidalis*, *E. stagnina*, *Polygonum barbatum*, *P. senegalense* and *Typha domingensis*. Floating leaved aquatics include *Nymphaea caerulea*, *N. lotus* and *Pistia stratiotes*, while the most important submerged species are *Ceratophyllum demersum* and *Vallisneria spiralis*. Among the fishes, cyprinids are best represented, with 14 species of *Barbus* (of which *B. affinis* and *B. intermedius* are the most numerous), *Discognathus quadrimaculatus* and *Varicorhinus beso*. There are three clariids, *Clarias anguillaris*, *C. mossambicus* and the endemic *C. tsanensis*. *Oreochromis niloticus* is the only cichlid. The lake is not very productive and the fish biomass is comparatively low. A wide spectrum of aquatic birds is found here with *Alopochen aegyptiaca*, *Bubulcus ibis*, *Egretta intermedia*, *Larus ichthyaetus*, *Plectropterus gambensis*, *Sarkidiornis melanota* and *Threskiornis aethiopica* among the most numerous. Small mammals include otters and rodents.

Human Impact & Utilisation: There are artisanal fisheries on the lake, with *Barbus* and *Clarias* spp. contributing 90% of the catch. Parts of the lakeshore are cultivated, but the lake is little interfered with. There is an hotel at Bahr Dar on the lakeshore and the lake is used for recreational purposes.

Conservation Status: Unprotected.

3. Wetlands of the Bale Mountains

Location: 6°30'-7°20'N/39°00'-41°00'E
Area: c. 10 500 ha (500 ha permanent open water)
Altitude: 4000-4200 m asl
Nearest Towns: Adis Abeba (275 km NNW); Yirga'Alem (75 km W)

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General: About 100 small lakes, each a few hectares in area, and many bogs are set in the Quaternary basalt of the Goba Plateau well above tree line in the Monts Bale. This is a glaciated area and most lakes occupy depressions carved out by ice. Others have been filled in, but retain water permanently and support wetland vegetation. There tend to be two wet seasons here, the principal summer one, when the SW Monsoon blows, and a minor winter one, when SE winds reach the eastern edge of the Ethiopian Massif from the Indian Ocean. Precipitation exceeds 2000 mm/yr, and there are frequent frosts. The mean temperature is in the vicinity of 2°C. Ultimately these tarns drain either to the Shebele or Genale Rivers.

The Garba Guraatch and Hora Orgona lakes are the best known. The former is situated 15 km south of Goba (7°01'N/39°59'E) and covers about 12 ha and has a maximum depth of 5 m, while water levels fluctuate by some 40 cm/yr. There is an outflow, to an affluent of the Genale River, and the water is clear, with a Secchi depth of 5 m. Water temperatures range from 11-12°C in summer and the pH is close to 7.5. The concentrations of the commonest ions are sodium 0.38 mg/l, calcium 0.23 mg/l, sulphate 0.15 mg/l and chloride 0.1 mg/l. The Hora Orgona is larger, but variable in area, less deep, more turbid, more alkaline (pH 8.4) and has higher concentrations of dissolved solids (sodium 3 mg/l; calcium 4 mg/l; magnesium 3.5 mg/l; chloride 4 mg/l and sulphate 1 mg/l). It is situated a few kilometres southwest of Garba Guraatch and does not have a perennial effluent.

The biology of these lakes is not known in any detail, but the plankton includes palearctic species. The benthic fauna includes cladocerans, copepods and ostracods, but neither amphibians nor fish have been recorded. The avifauna is comparatively rich, with *Bostrychia carunculata*, *Cyanochen cyanoptera*, *Pallus rougetii* and *Tadorna ferruginea* the most numerous species. *Canis simensis* and a species of *Otomys* occur in these wetlands. The lakes are little used and are, ostensibly at least, protected in the Bale Mountain National Park, proclaimed in 1970, but not yet gazetted.

4. Lakes of Bishoftu

General: A chain of volcanoes, containing 5 crater lakes, runs roughly SW-NE near Debre Zeyit (8°47'N/39°01'E) some 45 km SE of Adis Abeba. Lake Biete Mengest is 1850 m asl, while the others are all higher, Bishoftu (1870 m), Pawlo (1870 m), Aranguadi (1900 m) and Kilotes (2000 m). The maximum recorded depths and mean depths of these lakes are Bishoftu 87 m and 55 m, Pawlo 65 m and 38 m, Biete Mengest 38 m and 17 m, Aranguadi 32 m and 19 m, while Kilote is only 6.5 m deep with a mean depth of just 2.6 m. The crater walls around Lake Kilotes have been heavily eroded, accounting for much infill and the shallow depth of this lake, but those around the other lakes are well preserved. The lakes are all about 7000 years old. Lake Biete Mengest covers 103 ha, while the others are smaller; Bishoftu (93 ha); Kilotes (77 ha); Pawlo (58 ha) and Aranguadi (54 ha). Mean annual temperatures in the area are 17-18°C, precipitation is 800-900 mm/yr, and maximum wind speeds range from 11 km/hr in the summer wet season to 30 km/hr in the winter dry season.

The lakes are fed by direct precipitation and local run-off and are apparently endorheic, although some may have underground effluents. Mean surface water temperatures range

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from 25°C in Lake Kiloti to 19°C in Lake Aranguadi. All lakes are alkaline; Bishoftu, Pawlo and Biele Mengest have mean pH values of 9.2, while Kilotes has a mean value of 9.6 and Aranguadi 10.3, but there are seasonal variations. In all lakes sodium is the most abundant cation and bicarbonate and silicate the most abundant anions.

Productivity is generally high, especially in the most alkaline lakes, Aranguadi and Kilotes. *Microcystis aeruginosa* is the dominant species in the phytoplankton of all lakes and occasionally forms blooms, while *Spirulina platensis* may also reach very high densities in the two highly alkaline lakes. The fauna of the lakes has not been studied. The lakes are fished but are not protected. The area is an important recreation area for citizens of Adis Abeba and there are several hotels.

5. Lakes of the SW Rift Valley

General: The Ethiopian Rift Valley, aligned SW-NE, is an extension of the Eastern Rift Valley of Equatorial Africa. It is a trench limited by faulting and its development has been characterised by predominantly acid volcanism. Much of the floor is covered by recent, still barren lavas, and by deposits of pumice. Since the development of the major escarpments 1.8-1.6 million years ago, volcanic activity has been confined to the Wonj Fault Belt, a zone of normal faults 5-15 km wide, oriented NNE-SSW, and arranged in stepped fashion along the rift. In the southwestern part of the rift four topographic basins have developed, separated by volcanic sills and these now contain, from N-S, Lakes Ziway, Abiyata, Langano and Shala. Lake Shala occupies a deep caldera of Pliocene age, while the others are set in younger shallow depressions. Lakes Ziway and Langano have surface drainage towards Lake Abiyata, which is endorheic. Lake Shala does not presently overflow, although it clearly did in the past. During past pluvial periods of the Quaternary these four lakes were continuous, at an altitude of 1670 m, and then overflowed northwards to the Awash River.

Farther to the southwest is the basin of Lake Awasa, separated from the Shala-Ziway complex by Caldera Corbetti. Yet farther, and some 400 m lower, is another basin containing Lakes Abaya and Ch'amo. They are linked by a watercourse and they too formed a single lake in the past. In the far southwest, close to the Kenyan border is Lake Bahir, within the giant pan of Ch'ew Bahir, which is most often dry but is sometimes flooded over very large areas.

The Ethiopian Rift Valey is arid, with mean annual rainfalls in the vicinity of 600 mm, and with annual variations in the range 400-900 mm. At least 50% of the rain falls in the three months from July to September, and this is comparatively reliable, but the remainder which falls between October and January is very unreliable. February-June are generally rainless months. The dry season may thus persist for 9 months in some years. Wind speeds do not vary much throughout the year, with mean velocities in the vicinity of 4 km/hr. Mean annual evaporation reaches or exceeds 2000 mm throughout the valley. Mean annual temperatures range from 19-20°C, but in winter temperatures as low as 4°C have been recorded near Lake Ziway.

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(A) LAKE ZIWAY (ZWAI)

Location: 7°51'-8°07'N/38°43'-38°56'E
Area: 65 400 ha
Altitude: 1636 m asl
Nearest Towns: Adis Abeba (105 km N); Yirga'Alem (135 km SSW)

General: The lake has flat swampy margins on all sides except the south and southeast. It is fed by a number of streams, the most important of which are the Katar River, which drains the Arsi Mountains to the east, and the Me'ki River, which drains part of the Western Highlands. The lake has a catchment of 7025 km^2 and its overspill is carried to Lake Abiyata by the Bulbula River. Seasonal variations in the surface level are within the range 50-120 cm, with high water in September and low water from February-May, while annual variations are equally great. Exceptionally high levels in 1969-70 were followed by unusually low levels in 1973-74. The lake is almost 29 km long and 20 km wide. It has a maximum depth of 8 m at high water and a mean depth of 2.5 m, and is estimated to contain 1.1 billion m^3 of water. Water temperatures range from 21-27°C and pH from 7.9-8.7. Mean dissolved oxygen concentration is 6 mg/l, while that of total dissolved solids is 350 mg/l. Sodium, magnesium and calcium are the principal cations, in that order of abundance, and bicarbonate the principal anion.

Flora & Fauna: Primary production is moderately high and the phytoplankton is seasonally dense, being dominated by *Microcystis flos-aquae* and species of *Aphanotheca, Chroococcus, Gloeotrichia, Mesrimopedia*, and *Spirulina*. The distribution of emergent vegetation along the banks are determined by fluctuations in lake level and the distribution of plants may alter substantially over a period of a few years. *Cyperus papyrus, Phragmites mauritianus* and *Typha domingensis* are the dominant species, with *Aeschynomene elaphroxylon* on areas inundated only periodically and along the banks of the Bulbula River. There are dense beds of submerged macrophytes. The zooplankton is dominated by rotifers, with species of *Brachionus* most numerous and molluscs are abundant amongst the vegetation. Among gastropods, *Anisus natalensis, Biomphalaria sudanica, Bulinus forskali, B. truncatus, Lymnea natalensis* and *Melanoides tuberculata* are most common. Only 8 species of fish are known, belonging either to Cichlidae or Cyprinidae. These include *Oreochromis niloticus, Discognathus* sp. and several barbels, one of which, *Barbus zwaicus*, is probably endemic. Remarkably, *Clarias* is absent.

There are several species of snake, but crocodiles are reputedly absent. The avifauna is quite rich. *Anas crecca, Anhinga rufa, Bubulcus ibis, Egretta garzetta, Larus fuscus, Pelecanus onocrotalus, Phalacrocorax carbo, Plegadis falcinellus* and *Threskiornis aethiopicus* are common species and *Merops nubicus* is abundant along the River Bulbula. *Hippopotamus amphibius* is present, as are several small semi-aquatic mammals.

Human Impact & Utilisation: There is a commercial fishery currently producing about 1500 tonnes/yr, but with an estimated sustainable yield of 3000 tonnes/yr. The catch is exported to Adis Abeba by refrigerated trucks. Dense vegetation along the shore makes access to the lake difficult and most fishing is carried out from canoes. It is planned that an area of 5500 ha near the lake will be cultivated, using water pumped from the lake for irrigation. This scheme will involve the construction of sluice-gates on the Bulbula River where it leaves the lake.

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Conservation Status: Unprotected.

(B) LAKE LANGANO

Location: 7°32'-7°43'N/38°42'-38°50'E
Area: 24 000 ha
Altitude: 1582 m asl
Nearest Towns: Yirga 'Alem (95 km SSW); Adis Abeba (150 km N)

General: This lake receives drainage from the Arsi Mountains at the southern end and discharges from the northern end via the River Hora Kallo to Lake Abiyata. It has a catchment of approximately 1600 km^2. Direct precipitation accounts for about 20% of the annual input. The lake is 23 km long and has a maximum width of 16 km. It has a maximum depth of 46 m and a mean depth of 20 m and is estimated to contain 3.8 billion m^3 of water. The shores are rocky in places, particularly on the eastern side, but there are a number of swampy bays in the south. The water is usually a reddish-brown colour. Water temperatures range from 22-26.5°C and pH is generally close to 9.1. The principal ions are sodium and bicarbonate. The concentrations of total dissolved solids ranges from 1250-1650 mg/l, while mean dissolved oxygen concentration is 4 mg/l. The level of the lake surface has varied by 1.7 m over the past 25 years, with a maximum level in 1969 and a minimum in 1974. Seasonal variations in level are generally less than 1 m.

Flora & Fauna: Species of *Juncus* and *Scirpus* fringe some of the lake and form extensive swards in the small swampy bays, but much of the shoreline is a rock or pebble beach largely devoid of vegetation. *Ceratophyllum demersum* and *Potamogeton* spp. are important submerged aquatics. The phytoplankton is quite diverse and the diatomaceous flora is characteristic of East African alkaline lakes. Primary production is moderate. Crustaceans dominate the zooplankton, and a number of molluscs are present including *Corbicula pusilla*, *C. saharica* and *Melanoides tuberculata*. The lake is rich in cichlid and cyprinid fish. There are a number of amphibians, reputedly no crocodiles, but an abundance of birds, including *Alopochen aegyptiacus*, *Anhinga rufa* and *Phalacrocorax carbo*.

Human Impact & Utilisation: There is an artisanal fishery, mainly exploiting *Oreochromis niloticus*, and an hotel which largely serves the adjacent Rift Valley National Park.

Conservation Status: Unprotected.

(C) LAKE ABIYATA

Location: 7°33'-7°43'N/38°27'-38°40'E
Area: 17 500 ha
Altitude: 1578 m asl
Nearest Towns: Yirga 'Alem (95 km S); Adis Abeba (150 km N)

General: Lake Abiyata is an endorheic alkaline lake set in flat *Acacia* savanna country, with large areas of seasonally or periodically flooded alkaline mudflats. It is a shallow lake covering some 20 000 ha with a maximum recorded depth of 14 m and a mean depth of 7.6 m. Seasonal variations in water level are of the order of 50-100 cm, but interannual variations may be greater than this. Over the past 25 years the lake surface has varied by

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5 m, and the area has correspondingly changed from 14 200 ha to 18 100 ha. Surface water temperatures may approach 27°C in April and the pH range is 9.3-9.5. Mean oxygen concentration is 5.8 mg/l, and total dissolved solids amount to some 8200 mg/l. In addition to direct precipitation, which accounts for some 21% of of the annual influx, inputs are from Lake Ziway via the Bulbula River, from Lake Langano via the Hora Kolla River, and from the Gogesa River. The lake is estimated to contain 1.6 billion m^3 of water.

Flora & Fauna: The mudflats support little more than clumps of *Juncus* and occasional sedges, usually *Scirpus littoralis*. There is a dense submerged vegetation in places and productivity is relatively high. The diatom flora is typical of East African alkaline lakes with species such as *Navicula elkab*, *Nitzschia* spp., and *Thalassiosira rudolfi*. Both rotifers and crustaceans are important in the zooplankton, with species of *Brachionus* and *Cyclops* dominant. The benthic fauna is very scant, save for chironomid larvae and a few molluscs, e.g. *Bellamya unicolor* and *Helicarion ruppellianum*. Cichlids are numerous but *Barbus gregorii* is the dominant fish. The abundance of piscivorous birds suggests that fish production is high, and it has been estimated that the resident population of white pelicans consume some 3000-5000 tonnes fish/yr. The avifauna includes *Anas crecca*, *Anhinga rufa*, *Ephippiorrhynchus senegalensis*, *Pelecanus onocrotalus*, *Phalacrocorax carbo* and *Phoeniconaias minor*. There are no crocodiles and no large aquatic mammals, but otters and rodents are present.

Human Impact & Utilisation: Virtually none as the area is protected.

Conservation Status: Entirely situated within the Abiyata-Shala National Park, otherwise known as the Rift Valley National Park. This includes plains and two hills between the lakes and six rivers which flow into the lakes.

(D) LAKE SHALA

Location: 7°24'-7°33'N/38°23'-38°39'E
Area: c. 32 900 ha
Altitude: 1558 m asl
Nearest Towns: Yirga 'Alem (75 km S); Adis Abeba (370 km N)

General: Lake Shala is set with its long axis (27 km) across the rift valley and reaches a maximum width of 17 km. It has a maximum depth of 266 m and a mean depth of 86 m and is estimated to contain 37 billion m^3 of water. Surface water temperatures range from 21-27°C and pH from 9.7-10.1, while mean oxygen concentration is 6.4 mg/l. Sodium is the principal cation and bicarbonate the chief anion, and the concentration of total dissolved solids is frequently in excess of 16 500 mg/l. For the most part the banks are steep, but locally there are mudflats, and hot springs on the lakeshore.

Flora & Fauna: Little known. Both phytoplankton and zooplankton are poorly developed and productivity is low. *Oreochromis niloticus* occurs in the lake, but fish production is low and it is therefore surprising that it supports a rich avifauna, including a large breeding colony of *Pelecanus onocrotalus* on a volcanic island.

Human Impact & Utilisation: There used to be a commercial fishery but this has ceased. Some artisanal fishing still occurs.

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Conservation Status: Entirely protected, together with an area of peripheral land, in the Abiyata-Shala National Park.

(E) LAKE AWASA

Location: 6°58'-7°07'N/38°22'-38°29'E
Area: c. 12 000 ha
Altitude: 1680 m asl
Nearest Towns: Yirga 'Alem (25 km S); Adis Abeba (220 km N)

General: The lake is apparently endorheic, 17 km long, and up to 11 km wide with a perimeter of 53 km. It has a maximum recorded depth of 21.6 m and a mean depth of 10.7 m. It has a catchment of 52.5 km^2 and is estimated to contain 1.3 billion m^3/water. Sodium and bicarbonate are the dominant ions and total dissoved solids amount to some 650 mg/l. The water temperature ranges from 21-26°C and has a pH close to 8.4. It is fed by a river which drains the highlands to the east of the Rift Valley, with a total catchment of 1250 km^2. The affluent stream flows through an extensive area of swampland, containing papyrus and *Phragmites*, and also swamp forest en route to the lake which has extensive fringing marshes and areas of wet grassland. The possibility that the lake loses water underground is not ruled out. A dormant volcano is situated in Caldera Corbetti immediately to the north of the lake.

Flora & Fauna: There are dense beds of submerged aquatics in the lake and the peripheral vegetation includes *Cyperus papyrus*, *Nymphaea caerulea*, *Phragmites mauritianus*, *Polygonum senegalense*, *Scirpus littoralis* and *Typha domingensis*. It is an important habitat for birds and supports comparatively large numbers of *Actophilornis africana*, *Ardea melanocephala*, *Ardeola ralloides*, *Bubulcus ibis*, *Chlidonias leucoptera*, *Dendrocygna viduata*, *Larus ridibundus*, *Leptoptilos crumeniferus*, *Pelecanus onocrotalus*, *P. rufescens*, *Scopus umbretta*, *Threskiornis aethiopica*, and is visited by the normal spectrum of small mammals.

Human Impact & Utilisation: There is an artisanal fishery and a fish market on the lakeshore, and concentrations of tame piscivorous birds, including pelicans, are a tourist attraction. The area is beginning to be important for recreation and tourism and there is an hotel between this lake and Lake Ch'amo.

Conservation Status: Mostly unprotected, but the southern end of the lake is included in the Nechisar National Forest, a game reserve.

(F) LAKE ABAYA (MARGHERITA)

Location: 6°02'-6°37'N/37°40'-38°06'E
Area: 107 100 ha
Altitude: 1285 m asl
Nearest Towns: Yirga 'Alem (50 km NE); Adis Abeba (275 km NNE)

General: This lake is 70 km long, 29 km wide at maximum, and is oriented SW-NE along the axis of the Rift Valley. It has a maximum recorded depth of 13.1 m and an estimated mean depth of 7 m. Surface water temperatures range from 22-28°C, mean oxygen concentration is 5.7 mg/l, and pH is close to 8.0. Sodium and bicarbonate are the principal ions and the concentration of total dissolved solids is 515 mg/l. The lake is fed

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by 5 major rivers, the most important of which is the Bilate, and a number of small streams which drain a catchment of 17 300 km^2. Overspill is carried by the Ualo River to Lake Ch'amo, with which it was united during pluvial phases of the Pleistocene. Lake Abaya is estimated to contain 8.2 billion m^3/water. The large islands of Sacchi and Bottego are situated in the northeastern part of the lake and there are many small islands. Great areas of the shores are flat with swampy woodlands and extensive marshes, especially in the northeast, but there are a number of rocky promontories. Luxuriant riverine woodland occurs between this lake and Lake Ch'amo in the south.

Flora & Fauna: Areas of swampy savanna forest occur on the lake margins, containing species of *Acacia* and *Ficus*, while *Aeschynomene elaphroxylon*, *Juncus* sp., *Phragmites mauritianus* and *Typha domingensis* are present in places along the lake shores together with the pendent *Ipomoea fragrans*. *Juncellus* sp., *Leersia hexandra*, *Ludwigia adscendens*, *Oenanthe* sp., *Paspalidium geminatum*, *Panicum* spp. and *Sphaeranthus* sp. are common on the lake margins. In the lake, *Ceratophyllum demersum*, *Hydrocotyle* sp., and *Potamogeton* spp. are important submerged aquatics, while *Azolla nilotica*, *Lemna gibba*, *Nymphaea* spp., *Ottelia ulvifolia* and *Pistia stratiotes* are floating plants. The phytoplankton is dominated by cyanophytes but the diatoms are very diverse. Papyrus is reputedly absent.

In the zooplankton rotifers are abundant, notably *Brachionus militaris* and *Keratella quadrata*. In addition there are numerous cladocerans, copepods and chironomids. Among molluscs, *Anisus natalensis*, *Biomphalaria sudanica*, *Bulinus forskali*, *B. truncatus*, *B. ugandae* and *Lymnea natalensis* are the most numerous.

28 species of fish have so far been identified including Bagridae (*Bagrus docmac*), Centropomidae (*Lates niloticus*), Characidae, Cichlidae (*Oreochromis niloticus*, *Tilapia zillii*), Clariidae, Cyprinidae (10 species of *Barbus* and 3 species of *Labeo*), Mormyridae (3 species), Schilbidae (*Schilbe mystus*) and Synodontidae (4 species). The most numerous species are *Barbus gregorii*, *Clarias mossambicus* and *Oreochromis niloticus*.

Amphibians and reptiles are present, including crocodiles, monitors, snakes and terrapins. There is a diverse avifauna which includes *Anhinga rufa*, *Bubulcus ibis*, *Casmerodius albus*, *Egretta garzetta*, *Haliaeetus vocifer* and *Scotopelia peli*. The spectrum of mammals includes *Hippopotamus amphibius* together with many others listed in the regional introduction.

Human Impact & Utilisation: There are artisanal fisheries, which take mainly *Lates niloticus*, but it is anticipated that a commercial fishery will soon be started with a production of some 7000 tonnes/yr, comprising about 3000 tonnes of *Lates* and 4000 tonnes of other fish. Some cultivation occurs on the lake shores.

Conservation Status: Unprotected.

(G) LAKE CH'AMO

Location: 5°43'-5°59'N/37°32'-37°45'E
Area: c. 45 000 ha
Altitude: 1233 m asl
Nearest Towns: Gidole (19 km SW); Adis Abeba (350 km N)

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General: This is a large lake with fringing beds of *Typha* in places and some extensive lakeshore marshes, swampy woodlands and wet grasslands. The lake is 36 km long and nearly 23 km wide at maximum. It has a maximum known depth of 12.7 m and the surface water temperature range is 22-28°C. Mean oxygen concentration is 4 mg/l. Sodium and bicarbonate are the dominant ions in solution and pH is always close to 8.6. The concentration of total dissolved solids is 651 mg/l. The lake receives drainage from several small streams with a catchment of approximately 2220 km^2, and receives the overflow from Lake Abaya (with which it was once united) via the Uaio River. It has no outlet at the surface but there appears to be a substantial loss of salts by infiltration.

Flora & Fauna: There are extensive beds of submerged aquatics and productivity is moderately high. The phytoplankton is dominated by cyanophytes and the zooplankton by rotifers and crustaceans. *Aetheria elliptica*, *Aspatharia rubens*, *Corbicula pusilla*, *Limicolaria barderensis* and *Planorbis herbini* are molluscs. Among fishes, *Bagrus docmac* and *Lates niloticus* are most numerous. There are large populations of *Crocodylus niloticus* and some *Hippopotamus amphibius*, together with a large proportion of the small mammals cited in the regional introduction as being associated with East African wetlands. There is a rich avifauna.

Human Impact & Utilisation: There is an important local fishery and tourism and recreation are developing in the area. There is an hotel between this lake and Lake Abaya.

Conservation Status: Unprotected.

(H) LAKE CH'EW BAHIR

Location: 4°27'-4°59'N/36°41'-37°00'E
Area: 112 500 ha
Altitude: 520 m asl
Nearest Towns: Gidole (100 km NNE); Adis Abeba (485 km NNE)

General: This is a temporary endorheic saline lake situated in the far south of Ethiopia, indeed the tip of the lake crosses the border into Kenya. It is 45 km long and 30 km wide at maximum. The lake is often dry, but the lowest part in the northeast is always moist. The lake is fed by the Dulei River from the north and by two temporary rivers from Kenya which enter the southern end. It is set in *Acacia-Combretum* scrub country with a mean annual rainfall over the lake of 500-600 mm/yr, while evaporation exceeds 2000 mm/yr. Sodium and chloride are the most abundant ions in solution when there is water in the lake and there is a sparse halophytic flora over most of the basin, with reeds, sedges and rushes in the more permanently moist sites. Only in very wet years is the basin deeply flooded. The detailed biology of the lake is not known, however, in wet years it is visited by large numbers of flamingoes and it is important to many large mammal species. The entire lake is situated within the Ch'ew Bahir Wildlife Reserve.

(I) LAKE TURKANA (RUDOLPH)

General: The northern edge of Lake Turkana intrudes a few kilometres into Ethiopia, but is dealt with in section 2.5 Kenya. The Ethiopian shoreline is 52 km long, and the Omo River enters the lake from Ethiopia in a large swampy delta which includes two lakes. Upstream of this there is an extensive floodplain. The combined wetland (4°28'- 5°13'N/

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35°44'-36°13'E) covers 120 000 ha, and the river discharges 18.6 billion m^3 of water into Lake Turkana each year. The river carries levée forest and the delta was forested in comparatively recent times. The lake level has fluctuated by 20 m over the past 75 years and the delta forest, remains of which are still apparent, was drowned when the level was higher. Fishing and hunting take place in the delta and no part of the system is protected. Papyrus is absent.

6. Lakes & Swamps of the Awash River System

General: The Awash drains the highlands on either side of the northeastern part of the Ethiopian Rift Valley and then flows out into the Danakil Desert. The temperate headwater basin receives between 1600-2000 mm of rain/yr, but the Rift Valley is warm and arid. Mean annual rainfall at the feet of the escarpments is 500-900 mm, and on the plain of Danakil it is generally less than 200 mm. Rain in the Rift Valley is a summer phenomenon, but in central and southern Danakil there are two 'rainy' seasons, one in April, the other in July/August. Potential evaporation along the course of the Awash increases with the thermal gradient, generally from west to east, rising from 2000 mm/yr to over 4500 mm/yr.

(A) THE UPPER AWASH VALLEY

General: The river has a drainage basin of some 76 000 km^2 and is approximately 1200 km long. It has four sources (8°29'N/38°12'E; 8°47'N/38°04'E; 9°01'N/38°06'E and 9°10'N/38°28'E) high above the Rift Valley on the western side, at altitudes close to 3000 m. These, and their several tributaries, traverse a broad headwater valley, 100 x 60 km, containing large areas of permanent swamp and floodplain before a final confluence at about 2100 m asl. From this point the combined stream flows SE, entering a deep valley in which it descends to the floor of the Rift Valley where it is impounded to form Lake K'ok'a (dealt with in section 2.4.9). This lake is also fed by other rivers, principally from the western highlands, and one of which enters the northern end of the lake over Menelik Falls.

The Awash then descends the Rift Valley, at first flowing northeastwards past Lake Beseka (8°53'N/39°52'E) near the village of Metehara. This lake has an area of about 600 ha and is a volcanic lake containing highly mineralised water. It is fed by thermal sources, at least in part, and is nearly 10 km distant from the Awash and not strictly a part of the Awash system. Downstream of this the Awash skirts another small lake with a swampy marginal floodplain (8°51'N/39°52'E) about 5 km above the town of Awash (8°59'N/40°09'E). The lake has a mean open water surface of about 400 ha and the floodplain, with its swamps, extends to an additional 2800 ha and appears to have tenuous connection with the Awash.

(B) LAKES & PANS OF SOUTHERN WADIS

General: Below the town of Awash the river flows northwards onto the plains of Danakil (Afar). On its eastern side a number of wadis descend from the Ahmar Mountains, an extension of the southern margin of the Rift Valley, and on reaching the plain they flow roughly northwards, parallel with the Awash. These are not effectively part of the Awash

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system, since their waters seldom reach that river, being absorbed or evaporated on minor floodplains tens of kilometres distant. One stream forms a temporary lake at a point 9°28'N/40°25'E, which may cover 3000 ha in a wet year when it may have a maximum length of 11 km and a width of up to 3 km. The stream often continues below this shallow 'lake' to a confluence with the Mi'eso Stream on which another floodplain and temporary lake forms at a point 9°51'N/40°42'E, again covering 3000 ha in a wet year. Still farther north (9°55'N/40°47'E) another small floodplain (1000 ha) is inundated by an unnamed stream which flows to the east of the Mi'eso, and parallel to it.

(C) THE LAKE BEDA SECTOR

Location: 9°52'-9°55'N/40°22'-40°24'E (Lake Beda)
Area: 1800 ha
Altitude: 609 m asl
Nearest Towns: Adis Abeba (200 km SW); Harer (205 km ESE)

General: The Awash skirts the eastern side of a barren lava field between latitudes 9°30'-9°41'N, and this contains two small crater lakes (9°31'N/40°12'E and 9°33'N/40°12'E) fed by subterranean waters. Below this the Awash receives a number of tributary streams on the right bank, all rising on the eastern flanks of the Western Highlands. Perhaps the most important of these is the Hawadi River which has a confluence with the Awash at a point 9°51'N/40°15'E. The river then skirts the northern tip of another vast lava field at 9°55'N, and receives below this, the overspill from Lake Beda, which lies at an altitude of 609 m under the northern face of the lava and 5 km distant from the river. This lake also has highly mineralised water and its pH rises above 11.0. It is fed by subterranean sources but is connected to the Awash via swamps, through which its overspill drains.

(D) THE GEWANE LAKE/SWAMP COMPLEX

Location: 9°57'-10°35'N/40°25'-40°38'E
Area: 70 000 ha (total wetland area)
Altitude: 600-608 m asl
Nearest Towns: Adis Abeba (220 km SW); Harer (190 km ESE)

General: At the southern extremity of the system the Awash divides into three streams, one of which traverses the swamps while the others skirt them on either side. At first the rivers cross a seasonal floodplain, but a permanent swamp soon appears along the central channel, beginning at 11°04'N and quickly reaching 6 km in width. At a latitude of 11°10'N this swamp becomes permanently flooded and gives way to Lake Yardi, now enlarged behind a barrage at 10°14'N/40°33'E to give an open water area of 6600 ha. The permanent swamp above the lake covers 5200 ha, and the floodplain about 30 000 ha. Another swampy tract occurs below the barrage. It is studded with little lakes and covers at least 20 000 ha in a strip 4 km wide on either side of the river which flows in a single channel below Lake Yardi. The largest of these lakes is Lake Kaddabasa. These swamps contain papyrus, *Phragmites* and *Typha* together with a spectrum of aquatic and floodplain grasses, and submerged and floating aquatics.

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Farther north the river cuts through another lava field between latitudes 10°47' and 11°02'N and then flows through a small swamp/lake system (11°17'-11°21'N/40°53'-40°57'E) of some 3000 ha, above and below which it receives tributary wadis on the the right bank. Then, at Dubti (11°44'N/41°04'E), it swings SE and enters the Dubti Swamps.

(E) THE DUBTI SWAMPS

Location: 11°35'-11°43'N/41°08'-41°25'E
Area: 23 500 ha
Altitude: c. 400 m asl
Nearest Towns: Adis Abeba (380 km SW); Harer (295 km SE)

General: This swampy tract is 34 km long and up to 12 km wide, and comprises at least 23 500 ha of semi-permanent wetland. An irrigation scheme at Dubti, just north of the swamps, covers about 7000 ha and withdraws water from the river. Much of the peripheral area of the swamps has been converted for cultivation in recent years, with cotton the principal crop. Towards the end of these swamps the Awash branches into eastern and western channels. Natural vegetation is dominated by *Phragmites mauritianus*, but a wide spectrum of the East African wetland species associated with herb swamps is also present (see regional introduction).

(F) THE GEMERI LAKE/SWAMP COMPLEX

Location: 11°20'-11°41'N/41°27'-41°42'E
Area: c. 76 000 ha
Altitude: 260-339 m asl
Nearest Towns: Adis Abeba (400 km SW); Harer (240 km SSE)

General: Immediately below Aisaita (11°33'N/41°27'E) the eastern channel of the Awash enters the Lake Gemeri swamp complex where it breaks into two channels. One (now the central channel) skirts the western margin of the swamps, the other (eastern channel) crosses them eastwards to Lake Gemeri. The swamps measure 40 km from N-S and 28 km from E-W and cover some 72 000 ha at high water. They have developed where the river, flowing eastwards, meets a N-S escarpment and spreads its waters both north and south along its foot. At the southern end of the escarpment the waters encounter the lava fields of a young volcano (Dama Alé) which further deflect the flow back to the SW, before it finally clears the obstruction and continues south.

The swamps begin 26 km upstream from the escarpment, and Lake Gemeri with its surface at 339 m, lies immediately beneath it. The eastern shore of the lake rises very steeply, to 1358 m asl within 2 km of the lake near the northern end. The lake is oriented roughly N-S, is 15 km long and 5 km wide (11°29'-11°37'N/41°37'-41°42'E), and covers 6000 ha. South of Gemeri, Lake Afambo (11°21'-11°28'N/41°40'-41°42'E) is separated from the rest of the wetland having developed down the eastern margin of the lava field. This lake is 13 km long and up to 2 km wide, with an open water surface of 1760 ha. To the west of this are two small lakes in the lava, and Lake Bario (11°21'-11°24'N/41°34'-41°37'E) which is set in the swamps abutting the northwestern face of the lava field. The eastern channel of the Awash flows from Lake Gemeri, southwards through the swamps to Lake Bario, leaving the latter lake from its southwestern corner to flow

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SW along the edge of the lava to rejoin (11°19'N/41°31'E) both the western branch of the river, which flows west of the swamp, and the central branch, which skirts its western boundary. From here the combined stream flows in a single channel down the western side of the lava field to enter Lake Abbé (243 m asl) south of the volcanic massif.

The swamp vegetation is dominated by *Phragmites mauritianus*, although both *Cyperus papyrus* and *Typha domingensis* are present. The lakes are fringed by aquatic grasses and contain the typical spectrum of submerged and floating aquatics. *Crocodylus niloticus*, *Hippopotamus amphibius* and *Phacochoerus aethiopicus* are common in the swamps, together with snakes, small mammals and an abundance of water birds. The fish and amphibian faunas are however, not well known.

(G) LAKE ABBE

Location: 11°01'-11°16'N/41°37'-41°54'E
Area: 45 000 ha (34 000 ha open water + 11 000 ha salt-flat)
Altitude: 243 m asl
Nearest Towns: Adis Abeba (380 km SW); Harer (200 km SSE)

General: The volcanic peak of Dama Alé (1069 m asl) dominates the northwestern shoreline of the lake, while vast saltflats, locally 10 km wide, extend around the southwestern and southern shores. The lake is set in an endorheic basin, which during pluvial phases of the Pleistocene, was once the site of a very much larger lake. The present open water area of the lake is close to 34 000 ha, but in recent years successive droughts and the extraction of water for irrigation has greatly reduced this area, and the saltflats bear testimony to this. It is believed that the water level has fallen by 5 m since 1954. The Awash enters the northwestern corner of the lake and other watercourses, notably the Oleldere and Abana Merekes Wadis, enter from the west and south, crossing the saltflats. The lake has a maximum depth of 36 m. Its biology is poorly understood, but stromatolites occur along the eastern margins and the banks support large colonies of *Phoenicopterus ruber*.

7. Lakes of the Danakil (Afar) Depression

General: The Danakil Plains lie between the Ethiopian Highlands and the Red Sea/Gulf of Aden. The Danakil Depression is an actively widening rift valley oriented NW-SE, parallel with the Red Sea coast. At its southern end it impinges at right angles upon the Ethiopian Rift Valley, aligned SW-NE. This structure runs across the southern edge of the Danakil Plain and continues through Djibouti as the Gulf of Tadjoura and then the Gulf of Aden. Both rift systems are marked by lines of active volcanoes along their axes. Mt. Dama Alé, immediately NW of Lake Abbé, is one of those on the Ethiopian Rift.

The Danakil Depression *per se* is 260 km long and 70 km wide and descends to depths exceeding 125 m below sea level. The central part of the depression is covered by a vast diamond shaped lava field, 200 km from NW-SE, and 100 km wide in the centre. Several volcanic cones rise above this lava field, the highest to 1501 m asl (12°53'N/40°35'E), but on either side of the volcanic ridge the land surface sinks below sea level, with a maximum depth being attained on the axis of the depression immediately north of the ridge. Here the surface of Lake Asale, now split into two basins, is 125 m below sea

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level. In the east centre of the lava field the surface of Lake Afrera is 102 m below sea level. Both these lakes are fed by subterranean waters.

The depression is separated from the Red Sea along its eastern boundary by hills which rise to 2218 m asl (13°23'N/41°43'E) and which drain from their drier western slopes into the depression by deep wadis which peter out in a series of narrow pans, aligned in parallel SW-NE along the eastern side of the floor of the depression just above and below sea level. A similar series of wadis and pans, with similar parallel alignment is present on the opposite side of the depression but is far less well developed, no doubt as a consequence of the greater aridity on that side.

The depression is very hot and arid. Rainfall is unreliable, less than 100 mm/yr, while temperatures of 50°C have been recorded and potential evaporation reaches 5000 mm/yr locally.

(A) LAKE AFRERA

Location: 13°12'-13°24'N/40°52'-40°59'E
Area: 12 500 ha
Altitude: 102 m bsl
Nearest Towns: Adis Abeba (520 km SW); Harer (460 km SSE)

General: Lake Afrera is set in a barren lava landscape in the south central part of the depression and has a mean surface level of 102 m below sea level. It is reputedly 160 m deep, but we cannot confirm this. It is saline with a mean pH of 7.9, and is fed by subterranean thermal water. Sodium and chloride are the principal ions. Its biology is not known, it appears to be little utilised and is unprotected.

(B) THE ASALE LAKES

Location: 13°56'-14°06'N/40°22'-40°32'E
Area: 7000 ha
Altitude: 125 m bsl
Nearest Towns: Mits'iwa (200 km NW); Adis Abeba (575 km NNE)

General: There are two lakes, separated by about 2.5 km. The northern lake (4500 ha) has a mean surface level of 125 m below sea level, but the surface level of the southern lake (2500 ha) appears not to have been published. However, it is certainly close to that of the northern lake. A long salt-flat, 10 km wide and 45 km long, covers 30 000 ha, and extends northwestwards away from the northern lake along the axis of the depression. It represents the floor of a much larger fossil lake, present some 7-10 000 years ago. The Asale Lakes are clearly fed by underground water, but run off from the coastal hills may occasional reach them. One wadi enters tha northern lake on its eastern shore and 8 wadis discharge onto the fossil lake bed. Very little is known of the biology of the Asale Lakes, which are little utilised and unprotected.

8. River Floodplains

General: Because of the intensity of rainfall over the Ethiopian Highlands for a few months each year, rivers rise rapidly and most overtop their banks locally. Thus

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floodplains with deep alluvium tend to occur wherever the slopes of river valleys flatten out, and this is especially true of the torrential rivers draining the Ethiopian Massif.

The Shebele and Oenale Rivers drain the Bale Mountains on the southeastern side of the Rift Valley, and floodplains occur on both watercourses where they flow SE across the plains into Somalia. Flooding also occurs on the Omo River which drains the SW part of the massif north of the Rift Valley. Farther west, floodplains and extensive permanent swamps occur on the Akobo River along the border with Sudan. Swamps are best developed between the village of Neum (7°23'N/34°03'E) and the confluence with the Pibor River at Akobo Town (7°49'N/33°05'E). In parallel, to the north, other permanent swamps including two substantial lakes, are situated on the Gilo River (7°33'-7°43'N/34°11'-34°25'E) and there is a floodplain along the Baro or Sobat River. These latter rivers carry broad galleries of forest right across the floodplains, and there are areas of swamp forest in depressions. Seasonally inundated savannas occur behind the galleries. The flora and fauna of these sondanian wetland types is discussed in the regional introduction. In the far north, small wetlands occur in the headwater valleys of several tributaries of the Atbara River, and also in the great Wadi Baraka which reaches the Red Sea in Sudan.

9. Artificial Impoundments

K'ok'a Lake (8°17'-8°29'N/38°55'-39°07'E) was created in 1960, by closure of a dam on the Awash River in the Rift Valley 70 km SE of Adis Abeba. It is situated 1500 m asl, and, with an open water area in excess of 25 000 ha at capacity, it is currently the 20th largest artificial lake in Africa in terms of surface area. It is a multipurpose reservoir and supports a small fishery. Fincha'a Lake is situated behind a dam (9°33'N/37°24'E), 2000 m asl, in a broad swampy valley in the western highlands. It impounds a left bank tributary of the Blue Nile. Permanent herb swamps are scattered over an area of 70 000 ha (9°15'-9°39'N/37°15'-37°29'E) on either side of the lake, at altitudes of 2100- 2400 m asl. Zula Lake (15°16'N/39°38'E), 57 m asl on the Haddas River, was also created in 1960. It is situated in the Red Sea coastal region, 75 km WSW of Asmera (15°19'N/38°56'E).

10. Other Wetlands

The Tufta Swamps are situated near Butajira (8°08'N/38°24'E) high in the Western Highlands above Lake Ziway in the Rift Valley, to which they drain via the Me'ki River. The swamps are in the headwater valley of the river and its tributaries, which rise above Butajira at altitudes close to or above 3000 m.

There is a floodplain on the Akaki River near Adis Abeba. We have no biological information on these wetlands.

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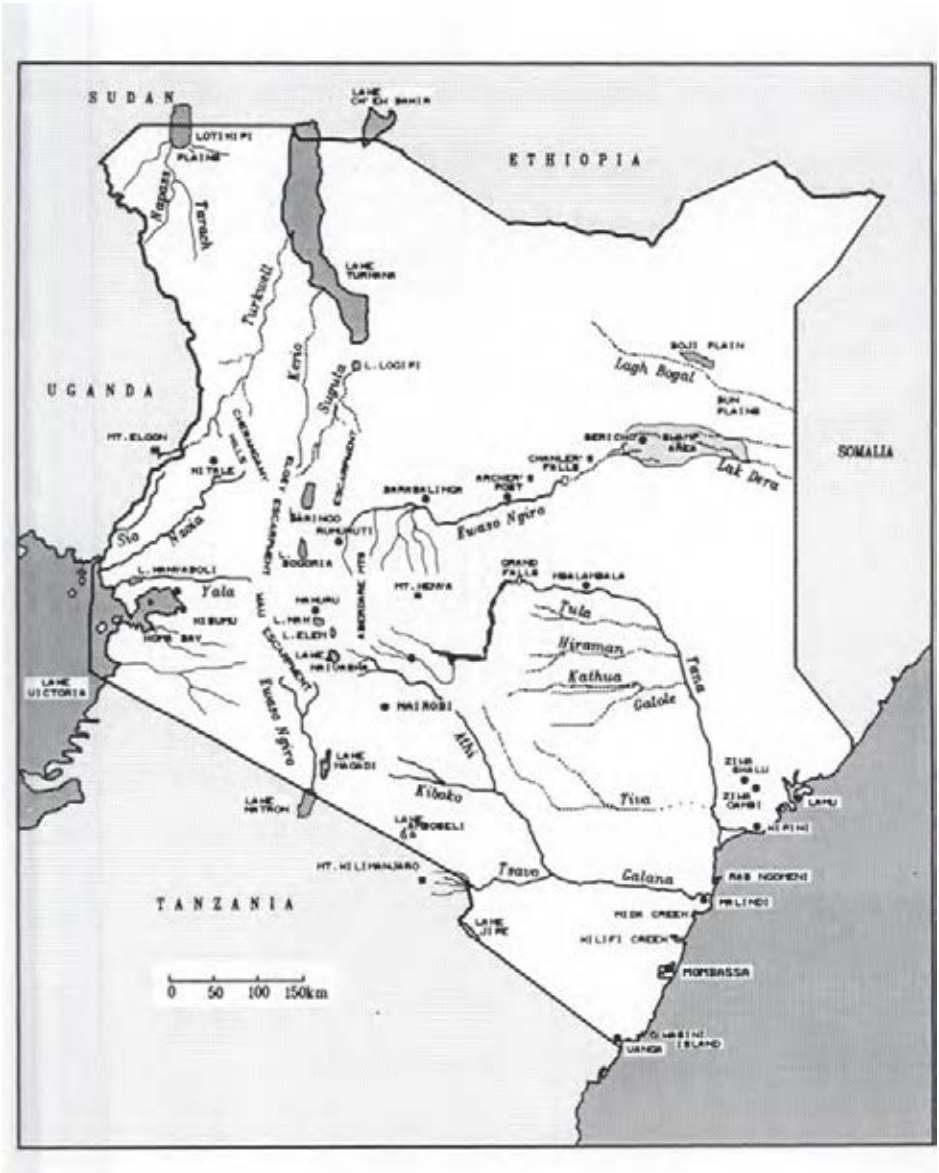

Map of Kenya

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2.5 KENYA

Introduction

Kenya has an area of 582 645 km^2, a population of 18 750 000 (1983) and thus a mean population density of 32.2 persons/km^2. It is bounded by Tanzania in the south, Uganda in the west, Sudan and Ethiopia in the north and the Indian Ocean in the east, and has a shoreline of approximately 810 km. In the west there is a further shoreline of 550 km on Lake Victoria. The country exhibits greater extremes of altitude than any other African country except Tanzania, rising from sea level to 5200 m at Mt. Kenya (0°09'S/37°19'E), the highest point in the country. It stretches 1062 km from north to south, between latitudes 5°00'N and 4°40'S, and 891 km from west to east between longitudes 33°58' and 40°55'E.

Along the shores of the Indian Ocean the coastal plain, below 200 m, widens from south to north. It reaches a minimum width of 21 km just north of Mombasa (4°03'S/39°41'E) and a maximum width of 240 km at Kiamboni on the Somalian border. In passing westwards the land surface rises to a plateau 500-1000 m asl in the north, and 1000-1500 m asl in central and southern districts. Numerous hilly ranges rise above the plateau in the north, the most important being the Huri (1252 m asl), Katigithigira (986 m asl), Lapurr (1481 m asl), Loichangamatak (1175 m asl), Marsabit (1702 m asl), Mogila (1694 m asl), Murua Lokwana (1701 m asl), Pelekech (1585 m asl) and Songot (1752 m asl) Ranges. In the south, the Wundanyi Hills rise to 2209 m asl (3°23'S/38°18'E). In central districts mountains rise much higher above the plateau, among them the isolated volcanic massif of Mt. Kenya.

The Eastern or Gregory Rift Valley crosses the country sinuously, from Lake Natron in the south to Lake Turkana in the north, bisecting the interior plateau. Mountains occur along the valley margins, and several important lakes lie on its floor in central Kenya. On the eastern side of the valley the Aberdare Mountains rise to 3999 m asl at Mt. Lesatima (0°18'S/36°37'E), while on the western side, peaks reach 3098 m asl (0°45'S/36°06'E) on the Mau Escarpment and 3370 m asl (1°15'N/35°26'E) in the Cherangany Hills. West of the Rift Valley land slopes down to Lake Victoria with a water surface at 1133 m asl. Mt. Elgon, 4321 m asl, is another isolated volcanic massif, situated in central western Kenya on the Kenya/Uganda border (1°07'N/34°32'E).

Drainage

Drainage of the far northwest is by very seasonal rivers to the Lotikipi Plain where the Lotikipi Swamp extends into Sudan. Here the Kotome River flows SW from Sudan, and the Nanam Tarach and Narengmor Rivers flow NE from the Kenya/Uganda border, dissipating their waters in the endorheic system. To the south of this the eastern slopes of Mt. Elgon, and the Cherangany and Cherapokot Hills, drain to Lake Turkana in the Rift Valley, by the Kerio, Kalabata, Lokichar and Turkwel Rivers. The eastern slopes of the interior plateau however, drain to the Indian Ocean. In the north a number of seasonal rivers, but most importantly the Laghs Bogal, Bor and Dera, flow into Somalia, and the swamps on their lower courses are described in section 2.7 Somalia. The higher central part of the interior plateau, including Mt. Kenya, is drained by the Tana River and its tributaries. This, the largest river of Kenya, enters the sea through a delta at

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Formosa Bay on the central Kenyan coast. Another large perennial river, the Galana, drains the southernmost part of the interior plateau. A series of endorheic soda lakes occupies the central part of the Kenyan Rift Valley, receiving the run-off from the opposing valley sides, but in the south Lake Natron also receives drainage from the western side of the Mau Escarpment via the Ngiro River. This stream, having first flowed SW, cuts back through the more southerly Nikuruman Escarpment into the Rift Valley.

Climate

Rainfall increases from north to south along the coast, and also becomes less seasonal in this direction. Lamu (2°16'S/40°54'E) receives a mean annual total of 889 mm, but 80% of this falls in the three months from April to June, with 345 mm in May. The other 9 months bring less than 50 mm each. Malindi (3°14'S/40°07'E) receives 1022 mm/yr, while Mombasa receives 1040 mm, with an average of 240 mm in May, and more than 50 mm in every month except January and February. There are only 45 rainy days a year on the Somalian border, but 90 such days at Lamu and 140 at Mombasa. At Vanga (4°40'S/39°13'E) on the Tanzanian border it is wet from May to December with scarcely a break.

The eastern slopes of the interior plateau are dry, and this part of Kenya is semi-desert. Here in the north, Moyale (3°30'N/39°04'E), 1113 m asl, on the southern edge of the Ethiopian plateau, receives an average of 687 mm rain/yr. April is the wettest month with 186 mm, and more than 50 mm is received in both March and May, but there is a second rainy season in October-November, during which a further 185 mm is received. In the far northwest, Lodwar (3°07'N/35°35'E) is very dry. This centre is 506 m asl, 51 km west of Lake Turkana, and receives 166 mm rain/yr, with a single peak in April when 45 mm may fall. In central districts, in the valley of the Tana River, 128 m asl, Garissa (0°27'S/39°39'E) receives 301 mm rain/yr. Monthly falls in excess of 50 mm are recorded only in April, November and December. In the far south Voi (3°24'S/38°35'E), 560 m asl, receives 538 mm/yr. December is the wettest month, with an average receipt of 125 mm. March, April and November receive over 50 mm, but June, July and August are virtually rainless. Thus the eastern and northwestern interior is semi-desert.

In the highlands, Meru (0°03'N/37°40'E), on the northeastern slopes of Mt. Kenya, 1570 m asl, receives 1370 mm rain/yr. There are two distinct wet periods, peaking in April (275 mm) and November (320 mm), while no month between June and September receives more than 25 mm. The upper slopes of Mt. Kenya receive just over 2000 mm rain/yr and constitute the wettest part of the country. Nairobi (1°17'S/36°49'E), 1661 m asl, receives 907 mm/yr, with 200 mm in April, 140 mm in May and close to 100 mm in both October and November. Farther north, equidistant from the Aberdare Mountains and Mt. Kenya, Nyeri (0°25'S/36°57'E), 1829 m asl, receives 932 mm rain/yr with a very similar distribution, but Nanyuki (0°01'N/37°05'E), 1945 m asl, receives only 743 mm/yr but over 50 mm falls in all months except January and February. It is shielded from the influence of the SE winds by Mt. Kenya.

In the southern Rift Valley, Magadi (1°54'S/36°18'E), 619 m asl, receives only 411 mm rain/yr. There is a reduced two peak pattern. March-April-May is the wettest period, each of these months receiving over 50 mm, with a minor wet season in November-December.

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Farther north and higher up, Nakuru (0°17'S/36°05'E), 1850 m asl, receives 862 mm/yr, but here a rainy season extends from the beginning of April to the end of August.

In the highlands west of the Rift Valley, Narok (1°07'S/35°52'E) is situated below the Mau Escarpment, 1890 m asl. It records an average of 729 mm rain/yr, with a single wet season between January and May. April is the wettest month with a mean receipt of 147 mm. Farther north, Eldoret (0°30'N/35°16'E), 2085 m asl, receives 1085 mm rain/yr, with a single wet season from April to August, with August the wettest month with a mean receipt of 175 mm.

Precipitation over the northern part of the Lake Victoria basin is comparatively high at lake level, and increases up the slopes towards the highlands along the western side of the Kenyan Rift Valley. There is no really dry season in the basin since all months receive more than 50 mm, but January and February are the driest months at all stations, while April and May are the wettest ones. Kisumu (0°04'S/34°45'E), 1157 m asl on the lakeshore, has a mean annual rainfall of 1295 mm with 200 mm in April. Kisii (0°40'S/ 34°45'E), at an altitude of 1768 m, receives 1767 mm rain/yr; Kericho (0°23'S/35°16'E) at 1981 m asl receives 1848 mm rain/yr; Kakamega (0°18'S/34°45'E), 1554 m asl, receives a mean annual total of 1923 mm. In these last three stations over 250 mm are received in April.

Temperatures are moderated by altitude inland, and by sea breezes at the coast. Thus the hottest parts of the country are the eastern slopes of the plateau along the Somalian border and the low northwestern part of the plateau around Lodwar. The mean annual temperature at Mombasa, on the coast, is 26.3°C, with a mean maximum of 30.3°C and a mean minimum of 22.4°C. Annual absolute maxima and minima for this place average 37.3 and 14.1°C. Corresponding figures for Garissa, at low altitude and away from the sea, are 28.4, 34.3 and 22.5°C, with absolute recordings of 46.1 and 13.9°C. At Lodwar in the NW the figures are 29.3, 34.8 and 23.7°C; at Magadi in the southern Rift Valley they are 29.0, 34.9 and 23.1°C. In the Highlands, the figures are 18.2, 26.4 and 10.0°C at Nakuru, and 16.6, 23.6 and 9.5°C at Eldoret. Frosts are seldom experienced below 2000 m, but occur regularly above 2500 m, and there is permanent snow on Mt. Kenya. Kisumu, on Lake Victoria, has a mean temperature of 23.2°C, with mean maxima and minima of 29.4 and 17°C and average annual absolute recordings of 36.9 and 11.0°C.

Mombasa experiences some 2900 hours of sunshine a year, while highland areas are cloudier and Lodwar in the northwest has close to 3600 hours sunshine/yr. Potential evaporation is about 1250 mm/yr at altitudes over 3000 m, but rises to a figure often well in excess of 2500 mm/yr below 300 m.

Vegetation

There is a strip of evergreen coastal forest, occupying the coastal plain in the south, and part of it in central districts. Otherwise the interior of the plain, the eastern slopes of the plateau and the northwestern interior are semi-desert areas, supporting deciduous scrub vegetation dominated by species of *Acacia* and *Commiphora*. Above this, around the eastern slopes of the highlands, there is savanna country, while the highest areas support Afro-montane evergreen vegetation and Afro-alpine vegetation. The Rift Valley and shores of Lake Victoria support evergreen bushland, with a drier type of rain forest on the slopes leading up eastwards and northeastwards, from Lake Victoria to the rim of the Rift Valley.

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Wetlands

Offshore the coast is fringed by coral reefs, and mangrove forests occur at several sites, notably in sheltered bays and estuaries. Many contain barren mudflat areas, often with peripheral salt-marsh vegetation. Floodplains occur on many rivers, and there are permanent swamps on the shores of lakes, and in numerous depressions along rivers. There are several lakes, including the endorheic soda lakes of the Rift Valley and the part of Lake Victoria situated in Kenya. High altitude bogs occur in the mountains.

List of Wetlands Described

1. Tidal Wetlands
2. The Lotikipi Plain
3. Riverine Swamps & Floodplains
   (a) The Tana River
   (b) The Athi/Tsavo/Galana System
   (c) The Ewaso Ngiro North
   (d) The Ewaso Ngiro South
   (e) Southwestern Rivers
4. Natural Lakes
   (a) Lake Victoria
   (b) Lake Amboseli
   (c) Lake Magadi
   (d) Lake Naivasha
   (e) Lake Elmenteita
   (f) Lake Nakuru
   (g) Lake Bogoria
   (h) Lake Baringo
   (i) Lake Turkana
5. Isolated Swamps & Pans
6. Minor Lakes
7. Artificial Impoundments

1. Tidal Wetlands

General: Mangrove swamps, containing almost the full spectrum of Equatorial East African species, are present in all sheltered sites, but are best developed in estuaries where fresh water influence is pronounced. The coast comprises Pleistocene deposits, raised coral reefs and associated lagoonal deposits, at altitudes below 30 m. North of the Galana River mouth and south of the Tana River mouth there are dunes, but they are limited in extent. The gradients of most rivers are very gentle over the lower coastal plain and tides penetrate the estuaries for tens of kilometres, although many small rivers reach the sea only in the rainy season.

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The most northerly stretch of coast is aligned NE-SW and is protected by a series of islands, on the lee shores of which there are mangrove swamps and salt-marshes. Immediately south of this several seasonal rivers reach the sea at Lamu, and here mangroves are well developed in Dodori and Mongoni Creeks, along Siyu Channel between Pate Island and the mainland, along Kipungani and Mto Wa Channels, and on the shores of Lamu and Manda Islands. The coast continues southwesterly from here, and is generally exposed and devoid of mangroves, until the Tana Delta is reached in Formosa Bay. The delta face has been moulded by strong longshore currents, but bays have developed at the northeastern end, near Kipini (2°32'S/40°32'E), where the main Tana River mouth is situated, and in the southwest, near Karawa (2°39'S/40°12'E), where two distributaries reach the sea. Both these bays support mangroves, which grade into fresh water swamp forests inland. Small mangrove stands then occur, with salt-marshes, in the series of bays leading southwards, and are moderately well developed in the bay at Ngomeni (3°00'S/40°11'E) sheltered by the Ngomeni Peninsula. Thereafter, in passing farther south, mangroves occur at the mouth of the Galana River just north of Malindi, and southwest of this in the large shallow bay at Mida Creek (3°19'-3°23'S/39°40'-39°51'E). Mangroves then occur in Kilifi Creek (3°35'-3°39'S/39°46'-39°51'E), Takaunga Creek (3°41'S/39°51'E), Shimo la Tewa Creek (3°54'-3°58'S/39°41'-39°46'E), Mombasa Harbour (3°58'-4°08'S/39°32'-39°40'E), Maftaha Bay (4°26'S/39°31'E), Funzi Bay (4°31'-4°35'S/39°23'-39°27'E), and finally along the embayed stretch between Wasini and Vanga (4°33'-4°40'S/39°14'-39°17'E) where the Mwena and Umba Rivers reach the sea. In this latter sector the coast is protected by an almost continuous line of reefs and small offshore islands.

Flora & Fauna: The flora and fauna of the tidal swamps is described in the regional introduction. Sea grass beds are well developed in front of the mangroves in places, with species such as *Cymodocea ciliata, C. rotundata, Halodule wrightii, Syringodium isoetifolium* and *Thalassia hemprichii. Chelonia mydas, Eretmochelys imbricata* and *Lepidochelys olivacea* are found along the coasts and may visit mangroves. *Dugong dugon* forages in mangrove creeks, and birds of the sand and mudflats backing the mangroves include *Calidris alba, C. ferruginea, Charadrius leschenaultii, Larus hemprichii, Pluvialis squatarola, Sterna saundersii* and *Thalasseus bengalensis. Damaliscus lunatus* and *Tragelaphus imberbis* occasionally venture onto the mangrove fringes.

Human Impact & Utilisation: Mangroves have been extensively utilised for firewood during this century, and for poles and masts for Arab dhows for many centuries. *Rhizophora mucronata* is the preferred species for poles, and large quantities were once shipped to Arabia for house construction, while *Heritiera littoralis* is used for masts. The latter species was once in great demand and has been almost completely cut out from many sites. In places mangrove swamps have been cleared for urban development and port facilities.

Conservation Status: Tidal swamps are protected in Lamu District, in the Dodori Coastal Reserve, NE of Lamu, and in the contiguous Kiunga National Marine Reserve, which includes both coastal and offshore island sectors. The coast between Malindi and Mida Creek is reef-fringed and is protected in the Malindi/Watamu Marine National Parks and National Marine Reserves. These include mangrove swamps and salt-marsh vegetation, best developed in Mida Creek. A further tidal area is protected in the Ras

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Tenewi Coastal Zone National Park, between the Tana River Delta and Lamu. In the south, an area from Kaya Kinondo to Chale Island, is to be protected in the proposed Diani Marine National Park.

2. The Lotikipi Plain

Location: 3°52'-5°04'N/34°18'-35°27'E
Area: c. 720 000 ha (c. 500 000 ha in Kenya)
Altitude: c. 490-500 m asl
Nearest Towns: Eldoret (390 km S); Nairobi (630 km SSE)

General: The Lotikipi Plain, 90 km west of Lake Turkana, is a flat endorheic basin which slopes almost imperceptibly northwards into Sudan. It is situated in a semi-desert zone, with direct annual precipitation close to 250-500 mm. It receives water from several seasonal rivers, notably the Kotome, Narengor, Tarach, Napass, Natira and Nanam Rivers. The Kotome enters about half way along the eastern side of the plain, and drains the Murua Lokwana and Lorionetom Ranges to the northeast on the Sudan border. The Narengor drains the Pelekech Range in the south, and enters the southern end of the plain, as does the Tarach River which drains the Murua Nigithigerr and Mersuk Hills. The Napass, Natira and Nanam Rivers drain the highlands along the Uganda border in the west. These rivers overtop their banks after heavy rains and, in concert, may inundate an area of the plain 120 km long, and up to 120 km wide at the northern end in Sudan, with a total area of 720 000 ha. However, the rivers do not always flood together, and indeed may not flood at all in dry years. Thus the area of the plain that is inundated is usually far less than the maximum given. However, the Narengor and Tarach Rivers have definite courses across the plain from south to north as far as the Sudan border, anastomosing and diverging again before that point, and a zone of permanent swamps accompanies them across the lowest part of the plain. While the Kotome River is a tributary of the Narengor River, the western streams do not extend laterally across the plain to a discrete confluence with the Narengor/Tarach system.

Hydrology & Water Quality: The swamp is flooded during the rains to depths in excess of 1 m. The 9 rivers feeding it are seasonal but some retain pools of water in their beds during the dry season.

Flora & Fauna: Essentially it is a grassy floodplain with reeds and papyrus in the wettest sites, and scattered *Acacia* and *Balanites* trees. See regional introduction.

Human Impact & Utilisation: Apparently little utilised, but there is some hunting.

Conservation Status: Unprotected.

3. Riverine Swamps & Floodplains

(A) THE TANA RIVER

General: The Tana is the most important river of Kenya, with a mean annual discharge of 5.6 billion m^3/yr, i.e. it has a mean annual flow rate of 178 m^3/sec, but annual variations are large and total discharges in recent years have ranged from 2.7-10.2 billion m^3. Evaporation over the delta is said to account for a loss of 700 million m^3 (Haskoning,

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1983). The river has three principal sources over 3000 m asl, on the eastern slopes of Mt. Ilkinangop (0°37'S/36°42'E), which rises to 3906 m in the Aberdare Range. The three headwater tributaries join east of Fort Hall and below this the Tana receives the Thika on the right bank and the Thiba, which rises on Mt. Kenya, on the left, above Seven Forks Falls. Thereafter the river receives two right and two left bank tributaries above Grand Falls, and in this section is impounded to produce reservoirs at Kambuvu, Kindaruma, Gtaru and Masinga. Then flowing northeast and east, it receives several more tributaries. It descends below the 500 m contour at Usneni (0°09'S/38°12'E), and below the 200 m contour 160 km farther on at Mbalambala (0°03'S/39°03'E).

Below this point the Tana flows SE and then S and develops a floodplain which becomes broader towards the coast. In this sector the river supports a wide gallery forest backed by floodplain forest, and permanent swamps become more common downstream. The Tula, Hiraman, Galole, Kokani and Buna Rivers are seasonal streams which drain the lower eastern slopes of the interior plateau. They reach the Tana on its right bank when in flood, but in dry years, some, e.g. the Kokani, may dissipate their waters before they reach the Tana. Floodplains are well developed on the Kathua/Galole system (1°15'-1°25'S/38°55'-39°32'E) and on the Tiva/Kokani system (2°03'-2°25'S/38°38'-39°30'E). The Galole floodplain is 70 km long, and with widths of 7 km, occupies about 25 000 ha, while the Kokani floodplain is 112 km long, beginning just above Hidilathi Wells (2°25'S/38°38'E), and up to 10 km wide. It has a high water area of 55 000 ha and includes the Ndarapo Swamp, centred 2°07'S/39°18'E.

Direct precipitation increases downstream on the Tana, from about 250 mm/yr at Mbalambala (0°02'S/39°03'E) to about 1000 mm/yr over the delta. A flood plain extends 300 km downstream, from Mbalambala to the delta, varying in width from 1-9 km, with an area exceeding 150 000 ha. The river bifurcates (2°00'S/40°09'E) immediately below Mnazini, and from here, for 25 km, the two streams are accompanied by strips of high riverine forest backed by a broad floodplain forest with patches of swamp forest and numerous small lakes. At Hewani (2°14'S/40°12'E) another distributary leaves the main channel on the left bank and flanks the northern side of the delta to the sea. Below Lake Bilisa (2°13'S/40°08'E), at the head of the delta, the floodplain widens on the north-eastern (left bank) side. There are extensive permanent swamps along the channels and around the lakes, among which Lake Shakabebo (2°17'S/40°11'E) is the largest. In the delta proper the floodplain soils are heavy clays, with numerous shallow depressions, while the prominent forested levées are sandy. The deposition of silt raises the delta surface by some 2 cm each year. As the sea is approached the swamp forests along channels merge into tidal forests on the open creeks. A triangular area, 42 km wide along the coast, and extending 33 km upstream, covering 69 000 ha, is subject to regular inundation. However, the area of the full delta has been estimated at 130 000 ha by Drijver & Marchand (1985), who say that as much as 90 000 ha may be inundated at the peak of the flood. The flood regime in the delta is bimodal, with a major flood in April-June, following rains over the catchments in March-May, and a minor flood in November to December.

Flora & Fauna: Galleries along the upper river and its tributaries contain *Acacia elatior, Apodytes dimidiata, Aspilia mossambicensis, Canthium schimperanum, Elaeodendron buchananii, Ficus eriocarpa, Hyphaene coriacea, Newtonia* sp., *Populus ilicifolia* and

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Rhus natalensis among others. In places papyrus and *Phragmites mauritianus* occur beside the river. The flora and fauna of the lower Tana floodplain and its associated swamps, lakes and forests are essentially as described in the regional introduction. The floor of the delta floodplain supports grasses such as *Digitaria adscendens, Echinochloa haploclada* and *Sporobolus confinis*. The delta lakes contain dense aquatic vegetation, dominated by *Ceratophyllum demersum, Nymphaea caerulea* and *Pistia stratiotes*. Typical riverine swamp forest occurs in permanently wet, but less deeply inundated spots, and this is backed by floodplain forest.

Fish migrate upstream from the sea to spawn, and river fish leave the river to spawn in the swamps and pools of the floodplain in the wet season. *Chelania mydas* occurs in the delta together with aquatic snakes and varanid lizards. 429 species of birds have been recorded from the delta, of which about 100 are aquatic birds (Ecosystems, 1983), many breeding in the delta. A rather different avifauna occurs in the galleries of the upper river, where among others, *Tockus erythrorhynchus* and *T. flavirostris* occur. *Crocodylus niloticus* and *Varanus niloticus* are common on the upper river, where also, the rare *Malacochersus tornieri* is found on the river banks. Most of the typical gallery forest snakes and mammals referred to in the regional introduction are present here. In the delta and on the lower river there is a rich primate fauna including the endemic subspecies *Cercocebus galeritus galeritus*, and *Cercopithecus aethiops johnstoni, C. albogularis, Colobus badius rufomitratus, Galago crassicaudatus, G. senegalensis* and *Papio cynocephalus cynocephalus*. Other mammals include *Canis aureus* (at the southern limit of its range), *Cephalophus natalensis, Damaliscus lunatus* (the most numerous large mammal on the floodplain), *Dugong dugon, Hippopotamus amphibius, Kobus ellipsiprymnus, Leptailurus serval, Loxodonta africana, Otocyon megalotis* and *Syncerus caffer*.

Human Impact & Utilisation: At present there are 4 reservoirs on the upper Tana, at Masinga, Kamburu, Gitaru and Kindaruma, with a total capacity of 1.743 billion m^3, and a fifth is under construction at Kiambere. This will have a capacity of 350 million m^3. A further 6 reservoirs are planned, to be built at Karura, Mutonga, Grand Falls, Usueni, Adamson's Falls and Kora Hills. It is believed that the upstream reservoirs will store sufficient water to irrigate large areas, and that further land can be converted for agriculture between Bura (1°05'S/39°58'E) and Galole (1°29'S/40°01'E). However, present development in the latter area is much smaller and includes the cultivation of some 6700 ha of cotton. Recently, small scale irrigation farming has been encouraged by the government in the 'Lower Tana Village Irrigation Program'. Major stock routes lead along the western side of the river from Garissa to Karawa, and thence down the coast to Mombasa. East of the river they run from Garissa to Bura, and then across country to Lamu, from where cattle are shipped to Mombasa. Cattle are grazed on the delta floodplains which are free from tsetse flies, and numbers treble during the dry seasons. Malaria is prevalent along the lower Tana River, with a six month transmission period and an incidence as high as that around Lake Victoria. Thus DDT has entered the floodplain foodchains. The river is fished by artisans, all the way to its delta, where freshwater prawns and typical floodplain genera (*Clarias, Protopterus*) contribute to the catch. The annual yield has not been reliably reported, but that from the delta is probably in the order of 2000 tonnes. Fish are an important source of protein for the 25 000 people who live in the delta. Whitehead (1960) gives an account of the lower Tana River fisheries, including names of the most important species. An extensive empoldering

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scheme for the delta was proposed by consultants from the Netherlands in the early 1980's, details of which are given by Drijver & Marchand (1985).

The present impoundments reduce flooding at Garissa by 50% of what they were, but permit high floods to pass. This means that while the moderate floods, which were extremely beneficial to the people of the delta and lower river, are now suppressed, the damaging high floods still occur. Complete flood control, as envisaged, will prevent floodplain disasters but will alter the entire economy and ecology of the floodplain district. It is likely that savanna species of plants and animals, including tsetse flies, will invade the riverine area and possibly the delta. To date no clear picture has emerged of the new hydrological regime after all upstream projects are completed, but certainly irrigation schemes and impoundments will reduce the available discharge to the delta to about 30% of the current mean annual volume. Clearly this will have a drastic detrimental effect upon the floodplain ecology.

Conservation Status: The northern bank of the Kamburu Reservoir, a drowned section of the Tana, forms the boundary of the Mwea National Reserve. Part of the left bank of the river in its upper course is protected in Meru National Park, while the right bank forms the boundary of the contiguous North Kitui National Reserve. A further 80 km section of the right bank is protected in another contiguous reserve, the Kora National Reserve, 125 km east of Mt. Kenya. The southern boundary of this latter reserve is the Mwitamisyi River, a tributary of the Tana. Part of the floodplain with sandy river courses, but not the main river, is protected in the Arawale National Reserve, NE of the river in Garissa County. However, the most important reserve is the Tana River Primate Reserve, on the river north of Garsen between latitudes 1°45'-1°54'S. Here 50 km of the river channel with its sandy levées, adjacent black cotton soil floodplain, and numerous oxbows and sections of abandoned channel are protected. The delta is unprotected.

(B) THE ATHI/TSAVO/GALANA SYSTEM

General: The Athi has sources on the eastern rim of the Kenyan Rift Valley both north and south of Nairobi. The most southerly of these, the Sinya River, drains the Athi Plains and flows NE for 95 km, receiving headwater tributaries from the dip slopes of the Aberdare Mountains on its left bank, and others from the Kaputei Plains on its right bank, before rounding the flanks of Ol Doinyo Sapuk (2146 m asl). From here it flows SE for 250 km along the southwestern flank of the Yatta Plateau, a long flat-topped ridge aligned NW-SE. In this sector it receives many seasonal streams on its right bank, draining the slopes below Machakos, before reaching a confluence with the Kiboko River (2°09'S/37°54'E). Below this the river continues southeastwards to a confluence (2°59'S/38°31'E) with its principal tributary, the Tsavo River, near the town of that name. The river, then known as the Galana, veers east and after some 30 km, descends Lugard's Falls. It descends to the coastal lowlands some 45 km farther on, and crosses them with an ever decreasing gradient, to reach the sea through a swampy floodplain with numerous ox-bows und other small lakes, north of Malindi. In its lower course it is often referred to as the Sabaki River.

The Kiboko also has sources on the plateau along the eastern rim of the Rift Valley, the most important draining country to the north and south of Mt. Ile Melepu which rises to 2146 m asl (2°00'S/36°45'E). These several streams unite to form the Ol Keju Ado

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which, with other tributaries, develops a more or less continuous floodplain of 25 000 ha above Mtiweshi, between longitudes 36°57' and 37°30'E.

The Tsavo has sources on the northern and eastern slopes of Mt. Kilimanjaro (5898 m asl) in Tanzania. Many streams descend the mountain and feed endorheic swamps in the trough between Kilimanjaro and the NW-SE oriented Chiule Range (2174 m asl), 50 km distant in Kenya. Here the Namalog Swamps (2°41'-2°44'S/37°23'-37°34'E) are situated immediately west of the several sources of the Kikanet River. These swamps are part of the Lengerruahange Swamp Complex dealt with in section 2.5.4b, Lake Amboseli. At the confluence with its tributary from the Chiule Range, the Kikanet River has a floodplain (2°36'-2°44'S/37°38'-37°43'E) merging into an extensive permanent swamp zone (2°38'-2°46'S/37°40'-37°44'E), below which the river is called the Lolterish River. This receives the other tributaries from Mt. Kilimanjaro in another floodplain zone (2°51'-2°59'S/37°46'-37°53'E) before joining the Tsavo proper (3°01'S/38°00'E) below Kitane Lodge. In flowing east from here, to its confluence with the Athi, the Tsavo receives numerous seasonal affluents from the Serengeti Plains and Taita Hills in the south.

Flora & Fauna: The river and its tributaries support galleries of forest, stretches of which are subject to varying degrees of inundation. The permanent swamps in the upper reaches are predominantly papyrus swamps, but swamp forest occurs on the coastal plain. Very many of the species cited in the regional introduction for forested floodplains on equatorial rivers are present, but *Acacia elatior* and *A. xanthophloea* also occur on the riverside and at Mzima Springs. Copley (1958) and Whitehead (1960) give some account of the fishes and fisheries of the lower reaches of the river. Important species include *Clarias* spp., *Clarotes* sp., *Labeo gregori* and *Oreochromis spirulus*. Freshwater prawns are common in the Sabaki, notably *Macrobrachium lepidactylus* (which grows to 40 g), *M. rude* and *M. scabriusculum*, while *Caradina africana* and *C. nilotica* occur in the lakes of the floodplain. *Crocodylus niloticus* occurs in many pools and *Varanus niloticus* is common. Among birds, *Anastomus lamelligerus, Dendrocygna viduata, Egretta ardesiaca, Halcyon leucocephalus, Haliaeetus vocifer, Ispidina picta, Pandion haliaetus, Rynchops flavirostris* and *Threskiornis aethiopicus* occur here. Among large mammals, *Hippopotamus amphibius, Kobus ellipsiprymnus, Loxodonta africana, Panthera pardus* and *Syncerus caffer* occur in the wetlands.

Human Impact & Utilization: Artisanal fisheries occur on the system, and much of the floodplain outside the protected areas is cultivated in the dry season. Water is carried by pipeline from Mzima Springs at the SE end of the Chiulu Range to Mombasa. The springs used to discharge southwards to the Tsavo River.

Conservation Status: A section of the upper Athi River is protected, where it flows through Nairobi National Park. About 120 km of the Tsavo and 230 km of the Athi/Galana Rivers are protected in the Tsavo East and West National Parks, but this does not include any of the important wetlands. Rather more than half (13 500 ha) of the floodplain on the Kibolo River is situated in the Amboseli National Park.

(C) THE ENASO NGIRO NORTH

General: This river has 4 major sources on the western slopes of Mt. Kenya which unite with the Sugurol and Enaso Narok Rivers from the Aberdare Mountains, on the high

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plateau east of the Rift Valley. The Ewaso Narok descends steeply northeastwards to the high plateau and then spreads its waters over the 50 000 ha expanse of the Ewaso Narok Swamp below Rumuruti (0°15'-0°23'N/36°33'-36°40'E). One of its headwater tributaries flows out of the mountains parallel with the Ewaso Narok, a few kilometres to the east, and spreads over Pesi Swamp (0°05'-0°10'N/36°36'E) on reaching the plateau. Some 40 km farther north this tributary joins the Ewaso Narok in the Narok Swamp. This latter swamp is 55 km long and 12 km wide. From here the river flows to its confluence with the Ewaso Ngiro North, after which the combined stream flows north and then east to Barasalinga (0°47'N/37°06'E), and then southeast and east to Archer's Post (0°38'N/37°40'E) where its mean flow is 740 million m^3/yr or 23.5 m^3/sec. Below Archer's Post the river crosses an undulating plateau eastwards, descends Chanler's Falls (0°46'N/38°04'E) and then flows ENE, spreading its waters near Sericho (1°08'N/39°06'E) into a vast swamp/floodplain. The upper swamp is generally called Lorian Swamp, but this narrows and continues southeast and east into Somalia. Here the river used to be known as the Lak or Lagh Dera, a variant of which name is still used in Somalia.

The swampy zone (0°11'-1°15'N/38°47'- 40°21'E) is 196 km long and 25 km wide at maximum, with a total area of 231 000 ha. A floodplain begins at longitude 40°21'E and continues, 2-5 km wide, as far as the Somalian border (41°00'E), becoming permanently swampy again at the border. The flow of the Ewaso Ngiro does not pass Lorian Swamp in dry cycles, but in addition to water arriving via the Ewaso Ngiro, the swamp is also fed by 15 wadis from the SW and 16 from the NE, and in wet years local precipitation makes a major contribution to the hydrological regime. Although mean annual rainfall over the swamp and local catchments is only 180-250 mm, annual totals are very variable; falls can be much greater than this in wet years and vice versa. The area inundated is thus subject to considerable expansion and contraction.

Flora & Fauna: Riverine forest accompanies the upper course of the river, containing *Acacia elatior* and *Hyphaene coriacea*, while saline grasslands adjacent to the upper river are dominated by *Sporobolus spicatus* with *Salvadora persica* bushes. Other briefly flooded areas support *Cynodon dactylon*, *Echinochloa* and *Setaria* spp. occur on floodplains, while the swamps are freshwater riverine grass/sedge swamps. They are infested with malarial mosquitoes and species of *Biomphalaria* and *Bulinus* which are vectors of the causative organisms of bilharzia. *Crocodylus niloticus* is present all along the river, and *Cercopithecus aethiops* lives in the riverine woodland. Many of the large savanna mammals visit the floodplains, including *Loxodonta africana* and *Syncerus caffer*.

Human Impact & Utilisation: At present these swamps are little utilised.

Conservation Status: A 22 km section of the right (south) bank of the river is protected in the Buffalo Springs National Reserve 85 km north of Mt. Kenya (0°31'-0°39'N/37°31'-37°41'E), while a 32 km section of the left (north) bank forms the southern boundary of the Samburu National Reserve. 9 km farther downstream another 34 km of the south bank is protected in the Shaba National Reserve, situated some 70 km NNE of Mt. Kenya, and this reserve includes a large swamp. All these reserves are situated on the undulating plateau below the foothills of Mt. Kenya. Otherwise unprotected.

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(D) THE EWASO NGIRO SOUTH

General: The Ewaso Ngiro rises as the Guaso Ngiro just south of Shabaltarngwa village (0°33'S/35°48'E), about 2550 m asl. It then flows southwards down the densely forested dip slopes of the Mau Escarpment in parallel with 21 affluents to the SW. These anastomose to form 3 major streams, the Ewaso Ngiro, Engare Narok and the Engare Siapei. The latter pair join the Ewaso Ngiro sequentially as that river descends a trough oriented NNW-SSE into the Rift Valley. It then flows southwards along the western side of the valley, under the Nkuruman Escarpment, passing 12 km west of Lake Magadi, to enter Lake Natron (610 m asl) in Tanzania through the Ngare Ngiro Swamp (2°01'-2°11'S/35°59'-36°09'E). The wetland comprises a permanent herb swamp of some 4000 ha upstream, and a seasonal floodplain of about 8000 ha, which extends down to the lake and along the eastern lakeshore. Lacustrine sediments above the level of the present Lake Natron suggest that it was at one time continuous with Lake Magadi, 21 km north.

Flora & fauna: The lake is endorheic and highly saline and has no macrophyte flora, but the herb swamp in Kenya is a fresh water system with a typical spectrum of sedges and grasses. Stands of *Hyphaene coriacea* and *Raphia farinifera* have been reported here. There is a rich vertebrate fauna with an abundance of birds.

Human Impact & Utilisation: The swamp is virtually un-utilised.

Conservation Status: Unprotected.

(E) SOUTHWESTERN RIVERS

General: These rivers rise in the highlands and flow into Lake Victoria, contributing a mean total volume of 7.29 billion m^3 water/yr. The most important ones are, from north to south, the Sio, which forms the border with Uganda, and the Nzoia, Yala, Nyando, Sondu and Gucha/Migori Rivers. Between them are many minor streams. The Sio rises on the southern slopes of Mt. Elgon, while the Nzoia, a much larger river, rises high in the Cherangany Hills, but receives 4 major affluents from Mt. Elgon and another from the highlands along the central western part of the Rift Valley. Of the tributaries from Mt. Elgon, the Sosio rises over 3500 m asl, and the Ewaso Rongai, Koitobos and Kuywa Rivers have sources near the 3000 m contour. The Yala drains the central highlands west of the Rift Valley, as does the Nyando, which has sources near Mt. Tinderet (0°06'S/35°21'E), 2640 m asl. The Sondu rises on the dip (western) slopes of the Mau Escarpment, while the Gucha and Migori Rivers drain Mts. Kijaur (0°45'S/34°58'E), 2166 m asl, and Moita (1°05'S/34°44'E), 2037 m asl.

All these rivers tend to flood in concert, having catchments in high rainfall zones with a prolonged summer wet season from April to October. Since in places, the lacustrine plains are very flat, several of these rivers form extensive swamps on the lakeshore. The Yala Swamps (0°07'N-0°01'S/33°58'-34°15'E) encompass the Nzoia Delta and all the lakeshore south to Ugowe Bay, and all the land east to Lake Kanyaboli. They also extend back up the Yala river in the south. In total they comprise 30 000 ha of wetland, including Lake Kanyaboli (1500 ha), and stretch 25 km from W-E and 15 km from N-S at the lakeshore. They also include several minor lakes. Another swamp (0°11'-0°19'S/34°47'-34°57'E) is situated at the mouth of the Nyando River at Nyakach Bay, extending back onto the Kano Plains, while another (0°18'-0°21'S/34°45'-34°48'E) occurs at the

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mouth of the Sondu River. The Nyando Swamp measures 15 km from W-E and some 6 km from N-S. Together the swamps on the Kano Plains occupy about 10 000 ha. To the south the Gucha Delta (0°54'-0°58'S/34°08'-34°11'E) is also swampy, while small swamps occur immediately south of the town of Kisumu and at the mouth of the Mogusi River (0°28'S/34°31'E) on Homa Bay.

Other small wetlands, including seasonally flooded areas and permanent swamps, occur on the upper courses of these rivers and their tributaries. The most important of these are found at the foot of the dip slopes on the west side of the Rift Valley, from the Cherangany Hills south to the equator. One such wetland, which includes both floodplain and permanent swamp, occurs on the Nzoia River (1°00'-1°09'N/34°57'-35°05'E) immediately north and east of Kitale. This wetland is 20 km long from NW-SE and 1-5 km wide and used to extend to about 6000 ha. A small permanent swamp, c. 1000 ha is situated (0°52'N/35°13'E) north of the Little Nzoia River. A seasonal floodplain occurs on the Kimandi River, a tributary of the Yala River (0°12'-0°16'N/35°10'-35°16'E). This measures 12x6 km and covers 4800 ha.

Flora & Fauna: These are mixed grass and papyrus swamps, with scattered stands of arborescent swamp forest, as described in the regional introduction.

Human Impact & Utilisation: Both the Yala Swamp, and the Nyando and Sondu Swamps on the Kano Plains are being drained for agriculture. It is estimated that at least 14 000 ha of the Yala Swamp can be made productive, and by 1980, 380 ha had been converted for rice production. On the Kano Plains, 900 ha had been converted for rice and sugar cane.

Conservation Status: Unprotected.

4. Natural Lakes

(A) LAKE VICTORIA

Location: 0°30'N-3°12'S/31°37'-34°53'E
Area: 6 889 000 ha (c. 413 340 ha in Kenya)
Altitude: 1134 m asl
Nearest Towns: Kisumu (on lake); Nairobi (610 km E)

General: In terms of surface area, Lake Victoria is the 3rd largest lake in the world. It has a maximum recorded depth of 85 m and a mean depth of 40 m. It stretches 412 km from north to south between latitudes 0°30'N and 3°12'S, and 355 km from west to east between longitudes 31°37' and 34°53'E. It contains numerous islands and has a highly indented shoreline which Welcomme (1972) estimates as 3460 km long. However, published shoreline measurements are notoriously variable, since they depend absolutely upon the scale of map used for their determination and how far each indentation is measured. Welcomme's estimate appears conservative, especially if island shores are included.

The hydrology, water chemistry and biology of the lake are dealt with in some detail in section 2.9 Tanzania, but a brief account of the lake is given here, as it relates to Kenya. The lake level rose by more than 2 m between 1961 and 1964 after a very long period of stability. Just 6% of the lake surface is Kenyan territory, but along the 550 km of

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Kenyan lakeshore, 6 major rivers discharge a mean average of 7.29 billion m^3 water each year, while the contribution from the minor streams has not been properly assessed. However, a survey in 1969-70 indicated that the 10 small rivers entering Winam Gulf, the Kisyan, Muguruk, Luanda, Awach Seme, Nyandina, Obera, Awach Kibos, Awach Kaboun, Awach Tende and Olando, have an estimated mean average combined discharge of 473 million m^3 of water each year, assuming run-off to be 18% of rainfall over the catchments. The principal swamps on the lakeshore have been mentioned in section 2.5.3e.

Over Winam Gulf the climate is similar to that cited in the introduction for Kisumu, with mean monthly air temperatures ranging from 21.9-24.3°C. February and March are the warmest months, while December and January are the coolest ones. Winam Gulf is comparatively shallow, having a maximum depth of 35 m and a mean depth of 6 m. Water temperatures range from 23.5-29.0°C, the absolute maximum reading having been made in June 1984. Secchi depths range from 35-155 cm. Generally the gulf is more turbid than the main body of the lake and its waters less productive. Water chemistry is not significantly different from that cited for the whole lake in section 2.5. It is normally well oxygenated throughout the water column, with concentrations ranging from 4.6-9.4 mg O/l.

Flora & Fauna: The phytoplankton is dominated by cyanophytes. Islands of *Cyperus papyrus*, with its typical associates, detach from the fringing swamps. The lake itself contains submerged species such as *Ceratophyllum demersum* and *Potamogeton* spp. around the margins, while waterlilies and *Pistia stratiotes* are found floating in quiet spots. Copepods and rotifers are abundant in the zooplankton. The fish fauna is essentially nilotic, but there are many endemics. According to Greenwood (1965a) the lake contains 177 species of fish, of which 127 are cichlids. *Lates albertianus, Oreochromis leucostictus, O. niloticus* and *Tilapia zillii* had been introduced into the lake before 1962 and are now widely distributed. They certainly occur in all Kenyan waters. Certain species which are common in the lake are comparatively scarce in Winam Gulf, e.g. *Barbus altianalis, Labeo victorianus, Mormyrus kannume, Oreochromis esculentus* and *Schilbe mystus*. Many of the Equatorial East African animals cited in the regional introduction occur in, or on the shores, of the Kenyan part of Lake Victoria, including water turtles, aquatic snakes, monitor lizards, crocodiles, a wealth of birds, rodents, otters and *Hippopotamus amphibius*.

Human Impact & Utilisation: Apart from the swamp areas the Kenyan shores of the lake are fairly densely populated. The lake is fished commercially by trawling, and by artisans using seines and lines from beaches and canoes. There is some evidence to suggest that Winam Gulf is currently being overfished. The total annual catch recorded from Kenyan waters has risen steadily from 14 918 tonnes in 1971 to 60 958 tonnes in 1982, but with a sharp drop to about 30 000 tonnes in 1979-80. *Lates niloticus* comprised 54% of the catch by weight in 1982, most of which came from Winam Gulf. In decreasing order of importance *Lates* was followed by species of *Engraulicypris* 17%, *Bagrus* 4%, *Haplochromis* 4%, *Mormyrus* 4% and *Oreochromis* 4%. Kisumu is one of the largest towns in Kenya, it is an important terminal for shipping services on the lake, and an industrial centre.

Conservation Status: Unprotected.

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(B) LAKE AMBOSELI

Location: 2°33'-2°44'S/37°01'-37°15'E
Area: c. 10 000 ha
Altitude: 1189 m asl (lake bed)
Nearest Towns: Nairobi (140 km NNW); Voi (175 km SE)

General: Lake Amboseli is a temporary lake, dry for long periods, situated on the floor of a flat basin 20 km northwest of the massif of Mt. Kilimanjaro. The area subject to flooding is 30 km long, and 10 km wide at maximum, and aligned NE-SW. It extends 5 km into Tanzania at the southwestern end, where it is fed by two seasonal rivers, the Maiteri and Namanga, while the Ngatataik enters it in the northwest, in Kenya. Direct precipitation over the 'lake' averages 305 mm/yr. Several watercourses descend the flanks of Mt. Kilimanjaro toward the lake, but disappear underground before reaching the Amboseli Basin. However, their waters feed extensive, but discontinuous, swamps, between longitudes 37°17' and 37°33'E. A swampy belt therefore extends north of Mt. Kilimanjaro, between Lake Amboseli and the sources of the Kikarankot River (a tributary of the Tsavo). These swamps, of which the Longinye and Namalog Swamps are most important, are the only sources of permanent water in the district and are important watering points for animals.

Flora & Fauna: The basin is set in deciduous *Acacia-Commiphora* bushland, but moist drainage lines support *Acacia tortilis* and *A. xanthophloea*. Most of the floor is flat and alkaline, and supports *Salvadora persica* and *Suaeda monoica* bushes. The swamps contain *Cyperus papyrus* and several other sedges, together with some grasses, including *Aristida* sp., *Cynodon dactylon*, *Digitaria* sp., *Phragmites mauritianus* and *Sporobolus* spp. Over 420 species of birds have been recorded in the area, very many utilising the swamps or the temporary lake. Large mammals regularly present in the swamps include *Hippopotamus amphibius*, *Loxodonta africana*, *Panthera pardus*, *Papio cynocephalus* and *Syncerus caffer*.

Human Impact & Utilisation: Traditionally the wetlands have been of importance to pastoralists and the needs of these people were acknowledged, both when the area was first protected as part of a larger game reserve, and again when it became a National Reserve in 1948. However, the pastoralists agreed to leave when the National Park was created in 1977, in return for various concessions outside the park.

Conservation Status: Swamps and 'lake' protected in Amboseli National Park.

(C) LAKE MAGADI

Location: 1°44'-2°00'S/36°12'-36°18'E
Area: 10 500 ha total wetland (9 700 ha 'lake' surface)
Altitude: 580 m asl
Nearest Towns: Magadi (on lake); Nairobi (85 km NE)

General: Lake Magadi is oriented almost due N-S, and the main basin is 29 km long and 4.5 km wide, with a NW arm, 12 km long and 2.5 km wide. It is situated on the floor of the Rift Valley and contains water only after heavy rain over local catchments when run-off reaches the northern end of the lake by three wadis. The 'lake' bed is a vast expanse of solid sodium carbonate (trona) and allied salts. However, shallow lagoons at

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both northern and southern extremities of the basin are perennial and are fed by very hot springs. Water temperatures in the lagoons are just above 40°C, salinities reach 40‰, and pH values in the region of 10.5 are regularly obtained. Sodium, bicarbonate and carbonate are the principal ions.

Flora & Fauna: The lagoons support carpets of cyanophytes and swarms of a cichlid fish, *Oreochromis alcalicus*. The subspecies present, *Oreochromis alcalicus grahami*, is endemic, but the species also occurs in Lakes Natron and Manyara farther south in Tanzania. These fish grow to 10 cm and are the only species present. Flamingoes visit the lake to feed after rains, but their numbers fluctuate greatly.

Human Impact & Utilisation: The sodium carbonate deposits of the lake bed are exploited commercially. Apart from this, the lake is virtually unutilised.

Conservation Status: Unprotected.

(D) LAKE NAIVASHA

Location: 0°42'-0°50'S/36°16'-36°26'E
Area: 15 600 ha (including islands)
Altitude: 1884 m asl
Nearest Towns: Naivasha (2 km E); Nairobi (65 km SE)

General: Lake Naivasha is situated on the floor of the Rift Valley. It is roughly circular, measuring 14 km from north to south and 17 km from east to west. Crescent Island, actually joined to the eastern shore, is the rim of an old volcanic crater, and Lake Oloidien at the southwestern extremity becomes a discrete, but contiguous, basin at low water. Some 6000-13 000 years ago the lake was part of a much larger lake that encompassed the present lakes Elmenteita and Nakuru, and discharged down the Rift Valley southwards. This lake contracted rapidly after 6000 BP and reached present levels approximately 4200 BP, roughly coincident with the great contraction of the Saharan waterbodies.

Hydrology & Water Quality: Lake Naivasha is remarkable in that, although it is endorheic, it is a fresh water lake with a catchment of 2378 km^2. Wadis from Mt. Longonot, a volcano 2776 m asl, just 13 km south of the lake, do not reach the lake, but no doubt feed it beneath the surface. Other temporary watercourses descend the forested slopes of the (Ol Doinyo Opuru) ridge, which extends eastwards from the Mau Escarpment, across the valley north of the lake. These approach to within 5 km of the shore, but again do not reach the lake on the surface. The principal water supply derives from the Aberdare mountains and an area of high plateau farther north along the eastern rim of the Rift Valley. Two rivers drain these areas and enter Lake Naivasha in parallel on the north shore. The easternmost stream, the Malewa, drains the western slopes of the nearby Aberdare Mountains by 9 major affluents, but rises close to the source of the western river, the Gilgil, on the plateau some 55 km north of the lake. A third and shorter river, the Karati, enters the swamp from the Aberdare Range at the northeastern extremity. The Malewa has a catchment of 1730 km^2 and provides 90% of the inflow. The Gilgil, with a catchment of only 420 km^2, may dissipate its waters before they reach the lake, while the Karati flows to the lake only in the December-February period. Groundwater seepage, particularly along the N and NE shores is reputedly responsible

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for up to 16% of the total influx. There is probably a subterranean drainage system, but this has not yet been verified.

Water depth shows seasonal fluctuations of about 50 cm, but long term fluctuations are much greater and the surface has varied by 8 m over the past 50 years. Maximum depth was 7.3 m in 1973, and mean depth 4.6 m, but by 1979, these figures had increased to 10.0 m and 6.5 m respectively. Oxygen concentrations are of the order 6-9 mg/l, pH in the main lake is 8.5-9.0, but may reach 9.2 in the Oloidien basin. Secchi depths are 1-1.5 m in the main lake, but may be as high as 5.7 m in the basin secluded by Crescent Island and as low as 50 cm in the Oloidien basin. Total dissolved solids ranged from 230-750 mg/l over the period 1919-1974. Concentrations of the principal ions have been known to vary considerably over a five year interval, e.g. from 24-40 mg/l for sodium; 12-20 mg/l for potassium; 16-21 mg/l for calcium; 24-34 mg/l for silicate; 7-14 mg/l for chloride. Bicarbonate is the principal anion however, with concentrations exceeding 190 mg/l. The lake usually stratifies in the mornings, but this persists only for a few hours. Normally the lake is well mixed, even in the Crescent Island Crater basin.

Flora & Fauna: The lake is fringed by *Cyperus papyrus* and *Typha domingensis* along its eastern and northwestern shores, but there is a large floating papyrus swamp along the northern lakeshore, encompassing the mouths of the three affluent rivers. Narrow arms of this extend, more or less continuously around the eastern lakeshore, inside the rooted fringing swamp. These narrow strip swamps have been called papyrus 'reefs'. There is an abundant submerged macroflora in the main lake, including many typical species, e.g. *Ceratophyllum demersum*, *Najas pectinata* and *Potamogeton* spp. Water-lilies are locally abundant. However, the Oloidien basin is less well vegetated, and may support little more than a narrow strip of *Najas pectinata*. The phytoplankton is dominated by cyanophytes, but there are numerous diatoms and chlorophytes.

The density of the zooplankton shows bi-modal peaks, corresponding with the two rainy seasons. The American freshwater crayfish *Procambarus clarkii* was introduced and now forms the basis of a commercial enterprise, but at some cost to the traditional fishery. The only indigenous fish is *Aplocheilichthys antinorii*, but this may recently have become extinct in the lake. *Oreochromis leucostictus* was introduced accidently and now provides the bulk of the commercial catch. *Oreochromis nigra*, which was deliberately introduced, seems to have died out. *Micropterus salmoides* and *Tilapia zillii* have both survived since their introduction, the former being popular with sport fishermen. Since the introduction of fish, the avifauna has diversified and now includes a number of piscivorous species. *Crocodylus niloticus* survives here, as does *Hippopotamus amphibius* (about a dozen individuals).

Gaudet (1976, 1977a,b) has written about the origin of the swamps and ecology of the lake.

Human Impact & Utilisation: The total annual fish catch on the lake is small, approximately 400 tonnes. The adjacent lands are irrigated from the lake, producing vegetables and flowers. The lake is a popular tourist resort, being just 2 km from the town of Naivasha. Crayfish is exported to Europe.

Conservation Status: Unprotected.

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(E) LAKE ELMENTEITA

Location: 0°27'S/36°15'E
Area: 1800 ha
Altitude: 1776 m asl
Nearest Towns: Nakuru (15 km NW); Nairobi (100 km SSE)

General: This is a shallow saline lake with a maximum depth of 1.9 m. It is situated close to the eastern side of the Rift Valley and is oriented N-S. Its southern end is set at the foot of a lava field which rises to 2128 m asl, while land at the northern end rises to 1950 m asl. It is fed by a small stream from the eastern plateau, which enters at the north end of the lake and there is no outlet. The water is highly saline (c. 40‰ with a mean pH of 9.4 and conductivities which range from 12 000–40 000 µSiemens/cm. Secchi depths vary between 10 and 20 cm. The concentrations of the principal ions vary depending upon the season and the amount of fresh water which has recently entered. However, typical concentrations are sodium 3700 mg/l; potassium 275 mg/l; chloride 1982 mg/l; silicate 200 mg/l; sulphate 140 mg/l; and phosphate 3 mg/l. Little is known of the biology of the lake, but cyanophytes are present, and some copepods have been detected but so far not identified. Large numbers of flamingoes are sometimes present. The lake is little used and unprotected.

(F) LAKE NAKURU

Location: 0°19'-0°24'S/36°04'-36°07'E
Area: c. 4900 ha
Altitude: 1758 m asl
Nearest Towns: Nakuru (2 km N); Nairobi (120 km SSE)

General: The lake is 9 km long and 5.5 km wide at maximum. It is a soda lake with a mean salinity of 45‰. It is bordered by a scarp of the Rift Valley on the west and a salt-dome hill in the east. The blue-green colour of the water is due to high densities of the cyanophyte *Spirulina platensis*. There are swamps around the lake and alkaline mudflats are exposed around the shores at low water. The open surface normally varies between 3500–4900 ha, depending upon water level fluctuations over cycles of a few years, but the lake has been known to dry completely. It was once, 6000-13 000 years BP, part of a larger lake which discharged southwards and encompassed lakes Elmenteita and Naivasha. The climate is bi-modal, with two wet and two dry seasons. The mean annual rainfall over the lake is 876 mm, but with substantial annual variations. The lake is set on the floor of the Rift Valley, surrounded by *Acacia* woodland or grasslands with occasional *Acacia* trees, but hills come close to the lake in the east and southwest. Vareschi (1978) gives an account of the ecology of the lake.

Hydrology & Water Quality: The lake is shallow with a maximum depth of 4.5 m and a mean depth of 3.5 m at high water. There are two perennial affluents, the Nderit and Njoro Rivers and three intermittent affluents, but no effluent. Most of the run-off comes from the western side of the Rift Valley, as all but one affluent originates on the Mau Escarpment, but there are alkaline springs along the north, northeastern and eastern shores. It is believed that evaporation roughly balances inflow. The surface water temperature varies between 25-30°C, but readings of 38°C have been obtained. The pH is 10.5 with little variation, but by contrast conductivity is extremely variable, and

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readings of 9500 - 165 000 µSiemens/cm have been made. Changes in conductivity do not reflect changes in chemical composition which is homogeneous and stable. Oxygen concentrations approach 1 mg/l at the bottom of the lake, and the lake is generally well mixed. Stratification seldom persists for more than 4 hours/day, if it occurs.

Flora & Fauna: Cyanophytes dominate the phytoplankton, but diatoms and chlorophytes also occur here. There are no macrophytes in the lake. *Cyperus laevigatus* occurs around the margins, at the fringes of the mudflats, with *Sporobolus spicatus* swards behind this. *Typha domingensis* is found at the mouths of the affluent streams. The zooplankton is dominated by a single species of copepod, *Paradiaptomus africana*, but rotifers are present, notably *Brachionus* spp. Chironomid larvae occur in the benthos. There are no indigenous fish, but *Oreochromis alcalicus grahami* has been introduced from Lake Magadi on several occasions for mosquito control. The last introductions were made in 1962, when the lake had recovered from having dried completely. *Oreochromis alcalicus* is herbivorous and has flourished, attracting large numbers of piscivorous birds to the lake. The lake is famous for the great concentrations of *Phoenicopterus ruber* and *Phoeniconaias minor* which gather to feed there, the latter sometimes numbering 1.5 million birds. In addition, a further 117 species are closely associated with the lake, the most numerous of these being *Pelecanus onocrotalus roseus* and *Phalacrocorax carbo*. Others are *Anas capensis*, *Nycticorax nycticorax* and *Platalea alba*. *Hippopotamus amphibius* still survives on the lake in small numbers, while *Aonyx capensis*, *Kobus ellipsiprymnus*, *Redunca arundinum* and *Syncerus caffer* frequent the affluent watercourses and their galleries, together with frogs, crocodiles, monitors, snakes, rodents, otters and monkeys.

Human Impact & Utilisation: The lake is a popular tourist attraction, with over 72 000 visitors in 1979. The manufacturing town of Nakuru (pop. 60 000) is just 2 km distant and sewage is processed on the north shore of the lake and on one of the effluent streams. A substantial proportion, perhaps 45%, of the land in the catchment is cultivated or grazed.

Conservation Status: The entire lake and its immediate surrounds have been protected in the Nakuru National Park since 1964, and the area of the park was increased to 16 000 ha in 1973.

(G) LAKE BOGORIA

Location: 0°11'-0°20'N/36°07'E
Area: 4250 ha (high water)
Altitude: 963 m asl (mean)
Nearest Towns: Nakuru (50 km SSW); Nairobi (175 km SSE)

General: This lake was formerly known as Lake Hannington. It lies on the floor of the Rift Valley and is 17 km long and has a maximum width of 4.5 km at high water, but both its depth and area vary considerably from year to year. It has a mean lake surface of about 3000 ha. It is an endorheic alkaline soda lake, with hot springs, geysers and fumaroles along its shore. It is fed by these, and by the Waseges River which enters at the northern end. This stream rises south of the lake on the Rift Valley slopes of the Nyandarua Plateau at the foot of the Aberdare Mountains. It flows north, passing the lake to the east, but then turns through 180° to enter the north end of the lake through a

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swamp. The maximum recorded depth is 8.5 m. Salinity is generally about 35‰, the water temperature is about 24°C, Secchi depths vary from 28-43 cm, conductivities are 10 000-70 000 µSiemens/cm, and the pH range is 9.8-10.3. The lake is often the feeding ground for large numbers of flamingoes, and as many as 2 million have been determined. The phytoplankton is dominated by cyanophytes, often by *Spirulina platensis*, yet on occasions this species has been almost absent. There are no macrophytes in the lake, but the lakeshore grassland is dominated by *Sporobolus spicatus*, and the galleries on the affluent stream by *Acacia tortilis*. The zooplankton is relatively abundant and the benthos mainly comprises chironomid larvae. The lake is not utilised and is protected in the Lake Bogoria National Reserve.

(H) LAKE BARINGO

Location: 0°32'-0°44'N/36°02'-36°08'E
Area: 13 000 ha
Altitude: 975 m asl
Nearest Towns: Nakuru (88 km S); Nairobi (202 km SSE)

General: The lake is set amongst dry *Acacia* scrub on the floor of the Rift Valley north of Lake Bogoria. It is 22 km long, up to 10 km wide, and reaches a maximum depth of about 8 m. There are several small islands in the lake, and the large volcanic Ol Kokwa Island in the centre, on which there are hot springs which discharge into the lake. Mt. Karosi (1448 m asl) is situated at the end of a trough delimited by steep scarps 5 km apart which runs NNE from the head of the lake, while a low watershed in the south separates the Baringo basin from that of Lake Bogoria.

Hydrology & Water Quality: The lake is fed by 6 rivers. The Ndau and an un-named stream drain the nearby Amasya and Thugen Hills and enter the lake in the southwest. The largest affluent, the Molo, has many tributaries with which it drains the northern end of the Mau Escarpment and Mts. Lodiani (0°07'S/35°42'E), 3009 m asl, and Gea (0°03'N/35°26'E), 2772 m asl. It enters the lake through an extensive swamp belt in the south. The Ngusero/Ol Arabel system drains the northern extremity of the Aberdare Range and enters the lake in the southeast, while the Tangulbei and another un-named stream rise on the Laikipia Plateau east of the Rift Valley and also enter the lake in the southeast. The lake is fresh despite the fact that the springs which discharge into it are highly saline, and there is no surface outflow. However, Gregory, who discovered it in 1893, reported that its waters escaped freely under the lava at the northern end, and it cannot be seriously doubted that there is a subterranean effluent.

The lake is well oxygenated, but turbid, with Secchi depths as low as 10 cm having been recorded. The pH range is 8-9, and conductivity is low, c. 420 µSiemens/cm.

Flora & Fauna: The Molo Swamps at the southern end of the lake are dominated by *Cyperus papyrus*. *Pistia stratiotes* and *Nymphaea caerulea* float on the surfaces of small bays and along the lakeward faces of the papyrus. There are beds of submerged aquatics, and the phytoplankton is dominated by cyanophytes, notably *Anabaena circinalis* and *Microcystis aeruginosa*. Rotifers are plentiful in the zooplankton, especially *Branchionus calyciflorus* and *Keratella tropica*, together with cladocerans and copepods. *Barbus gregori, Clarias mossambicus, Labeo cylindricus* and *Oreochromis niloticus* are common fishes. Some 300 species of birds have been identified at the lake, with many

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piscivores, including *Anhinga rufa, Ardea goliath, Haliaeetus vocifer* and *Nycticorax nycticorax*. There is an abundant small mammal fauna.

Human Impact & Utilisation: There are no towns in the area, but about 10% of the catchment is cultivated. However, increased erosion in recent years has led to increased siltation and turbidity in the lake. The waters are as yet unpolluted by pesticides and insecticides. There is a fishery with an estimated maximum sustainable yield of 1500 tonnes/yr. Yields in the 1960s were of the order of 600 tonnes/yr, but had declined to less than 450 tonnes/yr by the early 1980s. Tourism is increasing. There are hotels on the western shore and on the large island.

Conservation Status: Unprotected.

(i) LAKE TURKANA

Location: 2°23'-4°35'N/35°50'-36°42'E
Area: 756 000 ha
Altitude: 375 m asl
Nearest Towns: Nairobi (405 km S); Eldoret (252 km SW)

General: This lake was formerly known as Lake Rudolph. It is set in hot barren desert country, much of which receives less than 200 mm rain/yr, in the extreme northwest of Kenya. Mean maximum air temperatures range from 31-33°C, and the climate is remarkably constant. Such rain as does fall may fall at any time of the year. The lake extends 249 km from north to south (265 km along its axis) and has a maximum width of 48 km. There are three islands, North, Central and South Islands, of which the latter is the largest, measuring some 11x4.5 km. The delta of the Omo River at the north is situated in Ethiopia. The lake is famous for the colour of its water which is largely due to the presence of blue-green algae in the phytoplankton. The maximum depth, 114 m, occurs in a depression of the lake bed close to the southern end, otherwise the deepest part is along the axis, reaching 84 m off Alia Bay on the eastern shore. There are extensive seasonal floodplains in the Omo Delta and in places around the lakeshore. The lake has been in existence since at least early Miocene times, but has varied greatly in size. It was greatly expanded between 9000 and 7500 BP, when it covered the Lotikipi Plains to the west and discharged from them to the Nile. It was this temporary connection that permitted the ingress of a nilotic fauna. The lake level was then 80 m above the present level, and at this time it also received overspill from Lake Ch'ew Bahir, in Ethiopia. The level is still very variable, having been 15 m higher than the current level in 1895 and 5 metres lower in the 1950s. The Omo Delta has been forested in the past, and the remains of a forest, destroyed by recent high water levels, are evident. The floodplains of the delta and the western shore are littered with the remains of contemporary fishes and molluscs. Hopson (1978) provides a comprehensive survey of the lake.

Hydrology & Water Quality: The lake is fed by 12 principal rivers, while a thirteenth, the Suguta, peters out 36 km south of the lake. The largest affluent is the Omo River which flows south down the Rift Valley from Ethiopia to enter the northern extremity of the lake through a large and swampy delta. The Omo contributes some 18.6 billion m^3 of water each year, which is more than 98% of the total riverine inflow (Beadle, 1981), although its catchment represents only 38% of the total lake catchment. This inflow represents a mean discharge rate of 591.4 m^3/sec. Thus it is clear that it is rainfall over

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SW Ethiopia which determines the seasonal, annual, and long term fluctuations of the lake level. The Omo Delta is also joined on its eastern side by the small Macho Alas River and an un-named stream, both of which drain the Hummer Range (2049 m asl) in southern Ethiopia. The only affluents on the eastern shore are two un-named temporary watercourses which reach the lake in dry wadis. They may not flow in some years, and in general never discharge water into the lake for more than a few hours in any one year. The western shore affluents are, from north to south, the Loburin, Katabai, Kanukurdio, Kalakol, Turkwell, Lokichar and Kerio Rivers. Of these, only the Turkwell and Kerio are important, between them contributing about 98% of the riverine inflow.

The Kerio drains the Amasya Hills west of Lake Bogoria, the Elgeyo Escarpment along the western side of the Rift Valley and the eastern slopes of the Cherangany Hills. It flows northwards, often deeply entrenched, and in places occupying the floor of a canyon, to enter the lake through a delta. Immediately north, and almost contiguous is another delta formed by the Turkwell and Lokichar Rivers. The Turkwell has sources in the Cherangany Hills which unite on the Suk Plains in the Rift Valley. This river then flows north across the Lebatin Plains to Lodwar, where it swings through 90° to flow east to the lake. Neither the Kerio nor Turkwell Rivers are perennial in their lower courses, but both usually discharge to the lake for a few months each year.

Seasonal water level fluctuations are of the order of 50–100 cm, but annual variations may be larger. The salinity of the lake has varied between 1.7 and 2.7‰ in recent years. The northern end tends to be less saline and more productive than the southern end. The lake is well oxygenated and well mixed, due to strong, often violent, winds which blow over the lake every morning. However, regional differences in water chemistry do occur, and shallow bays and sheltered inlets may be atypical.

Flora & Fauna: The phytoplankton is dominated by cyanophytes, chiefly *Microcystis aeruginosa*, but with many other species. *Anabaena circinalis* and *Botyococcus braunii* are most important in Ferguson's Gulf on the middle western shore which is very shallow, c. 1.7 m. Papyrus is apparently absent from the lake, as it is from the lower Omo River and Lakes Abaya and Cha'amo. Thus, the salinity in the lake cannot be accepted as the reason for its absence. The principal emergent macrophytes are the grasses *Paspalidium geminatum* and *Sporobolus spicatus* which cover the seasonally exposed shallows, and provide important nurseries for fish. There are extensive *Potamogeton* beds in the shallow bays. *Salvadora persica* forms a bushland on Central and South Islands. Galleries of forest occur along the affluent watercourses, being characterised by *Acacia elatior, Balanites aegyptiaca* and *Hyphaene coriacea*.

The zooplankton is dominated by protozoans in terms of numbers, but by crustaceans in terms of biomass. There are 5 gastropod molluscs, *Bellamya unicolor, Ceratophallus natalensis, Cleopatra pirothi, Gabbiella rosea* and *Melanoides tuberculata*, and two shrimps, *Caradina nilotica* and *Macrobrachium nilaticum*. Some 48 species of fish have been identified in the lake, of which 30 are widespread Soudanian types, 8 have restricted distributions and 10 are endemic. Common species include *Alestes baremose, A. dentex, Bagrus bayad, Borbus bynni, Citharinus citharus, Clarias lazera, Haplochromis rudolfianus, Hydrocynus forskalii, Lates longispinis* (endemic), *L. nilaticus, Oreochromis galilaeus, O. niloticus, Synodontis schall* and *Tilapia zillii*. Less common species are *Gymnarchus niloticus* which is confined to the Omo Delta, and *Hyperopisus bebe* and

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Mormyrus kannume which live in affluent streams and venture short distances into the lake when their home streams are in flood. *Malapterus electricus* has been found in the lake but is rare. Several species occur in the crater lake on Central Island which has been isolated from the main lake for about 75 years, and which is three times more saline than Lake Turkana. *Crocodylus niloticus* and *Varanus niloticus* are common, and over 350 birds have been recorded from the lake and its environs. Among them *Alopochen aegyptiacus, Calidris minuta, Himantopus himantopus, Mycteria ibis, Plegadis falcinellus, Pterocles exustus, P. lichtensteinii* and *Threskiornis aethiopicus*. Several large mammals visit the lakeshores including *Acinonyx jubatus, Alcelaphus buselaphus, Damaliscus lunatus* and *Panthera leo*.

Human Impact & Utilisation: There are fisheries on the lake, despite its isolation, and there have been attempts to develop them in recent years as the commercial potential seems great. Hopson (1978) gives a comprehensive survey of the fisheries. There are three hotels on the lakeshore and there is now some tourism.

Conservation Status: Mostly unprotected but an area of the eastern lakeshore and Central Island with its crater lake are protected in the Sibiloi National Park, established in 1972 as a wilderness reserve. There is a crocodile colony with some 12 000 individuals on the Central Island. Early hominid remains, c. 2 million years old, have been found at Koobi Fora, north of Alia Bay, together with evidence of a lush forest climate. Itinerant fishermen call at Central Island and have cut a lot of the *Salvadora persica* bush for firewood, despite efforts to maintain the island as a sanctuary. The southeastern section of the lake is also protected in the Mount Kulal Biosphere Reserve, approved in 1978. This includes the South Island National Park of 3880 ha. Part of the gorge section of the Turkwell River is protected in the Nasolot National Reserve, and a 25 km section of the left bank of the Kerio River is situated in the South Turkana National Reserve, 100 km north of Kitale.

5. Isolated Swamps & Pans

General: A large area subject to shallow seasonal inundation occurs between the Kokani and Galana/Sabaki Rivers in a low rainfall zone of the coastal lowlands (2°19'-2°39'S/ 39°27'-39°38'E). This measures 32 km from N-S and 21 km from E-W at maximum. It has an area of 34 000 ha and lies inland, 90 km due west of Formosa Bay. It is fed by direct precipitation, peripheral run-off, and several ephemeral streams from the west. Another similar area, containing several separate pans with a total area approaching 16 000 ha, is situated farther north between the Kokani and Galole Rivers (1°40'-1°52'S/ 39°16'-39°32'E). Direct precipitation over these pans is 300-500 mm/yr.

Temporary wetlands occur in the Boni National Reserve just inland from the sea, west of the Mundane Hills, on the Kenya/Somalia border. The Dodori River traverses this area and a number of wadis lead down westwards from the hills towards it. On the very flat plain at the bottom of the hills, depressions in two large pans (ziwas) may be flooded to a depth of 2 m. Patches of groundwater forest occur on the plain, sustaining *Chlorophora excelsa, Memecylon* sp. and *Sterculia africana* among other species.

In northeastern Kenya, south of the village of Wajir (1°45'N/40°03'E), and west of the Somali border, a great many wadis, descending gentle slopes from the north, west and

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southwest, reach a flat area where they terminate in pans and swamps. This area is traversed from west to east by the Ewaso Ngiro/Lagh Dera system, which usually dissipates its waters here, in the Lorian Swamp, described in section 2.5.3c. Most wadis do not carry water this far and thus a collection of pans and swamps occurs north and south of the river bed. They are all isolated from the river for years on end, but dry watercourses below some indicate an overflow, to, or towards the Ewaso Ngiro in wet cycles. Direct precipitation over this region is approximately 200-250 mm/yr.

The largest of these isolated wetlands is the swampy Boji Plain, an oval area 62 km long and 19 km wide, about 160 m asl. This is oriented NW-SE and lies immediately north of Lagh Bogal (1°07'-1°31'N/39°41'-40°07'E). It contains 61 000 ha of hydromorphic soil, and is at least partially waterlogged for long periods. In wet cycles it is flooded. Fifty-five kilometres southeast of this, south of the Bogal, at the upper end of the Bun Plains, about 130 m asl, there is another endorheic wetland (0°40'-0°59'N/40°28'-40°37'E), comprising a permanent swamp and a floodplain fed by a dozen temporary streams from the NE. This measures 28 km from SW-NE and is 7 km wide in the swamps at its southwestern end, while the northeastern end comprises a floodplain which drains to the swamps. Closer to the Ewaso Ngiro is the Maiti Swamp, 43 km long and 5 km wide, about 115 m asl, and also oriented NW-SE (0°31'-0°51'N/39°53'-40°05'E). Immediately south of this, south of the Ewaso Ngiro, is an oval swamp (0°07'N-0°07'S/39°53'-40°01'E), measuring 30x15 km, which receives drainage from the SW. This also is flooded in wet cycles, and is semi-permanently waterlogged.

West and northwest of Lorian Swamp there are lava fields, but another semi-permanent swamp (0°45'-1°01'N/38°30'-38°49'E) is situated 367 m asl, at the foot of a lava massif 40 km west of Lorian Swamp. This covers 24 000 ha and may discharge northwestwards by a series of minor wadis to the Ewaso Ngiro in wet years. The most northerly of these isolated swamps is situated another 100 km north. This is a seasonally inundated wetland and covers 26 000 ha (1°54'-2°11'N/38°21'-38°37'E), 1050 m asl. It is set against the southern flank of a large lava field, and is fed by run-off from the NE, some of which emanates from the Marsabit Range about 40 km away. In wet years this swampy pan drains by a wadi from the southwestern tip towards the Ewaso Ngiro which is 85 km distant.

Another large pan occurs on the Milgis River which has sources in the Karisia Hills on the eastern rim of the Rift Valley. These hills rise to 2531 m asl (1°15'N/36°40'E) near Maralal. The Milgis River flows northeast from its sources and cuts through the Ol Doinyo Lengeyo Hills, thereafter descending to the semi-desert zone where it terminates in a swampy pan 45 km long and 15 km wide (1°34'-1°50'N/38°06'-38°24'E) at an altitude of about 400 m. In wet years some 40 000 ha may be inundated.

Other permanent swamps and seasonally inundated pans occur on the floor of the Rift Valley. Large seasonal wetlands are situated about the base of Mt. Susua (2357 m asl), in a comparatively high rainfall zone. Numerous watercourses drain the mountain in radial fashion, and discharge into pans to the north and south. The southern system (1°14'-1°21'S/36°15'-36°25'E) is not continuous, but comprises three separate areas, while the northern wetland (0°58'-1°05'S/36°15'-36°23'E) is an integral, although much branched, pan. This is situated between Mt. Susua and Mt. Longonot (2776 m asl), from the southern slopes of which it also receives run-off. To the south, west of Lake Magadi,

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is the En Doinyo Ngiro system, a small seasonally inundated plain with areas of permanent swamp (1°45'S/36°11'E). This is fed by temporary watercourses rising on Mt. Kisamis (990 m asl) 10 km to the north.

Flora & Fauna: *Phragmites, Typha* and papyrus are present in the wettest sites, and there are numerous halophytic species including *Cyperus laevigatus, Salvadora persica, Scirpus littoralis, Sporobolus spicatus* and *Suaeda monoica* on the fringes of the most saline, and *Hyphaene coriacea* and stunted figs grow along some watercourses. *Echinochloa* and *Setaria* spp. are common floodplain grasses. Many animals visit these wetlands for water. Species of *Chlorophora, Memecylon* and *Sterculia* occur in groundwater forests around some coastal pans. *Crocodylus niloticus* survives in Lorian Swamp, and amphibians, snakes and *Varanus niloticus* are widespread. The avifauna is often prolific and includes flamingoes, herons, weavers and warblers.

Human Impact & Utilisation: All these wetlands are situated in very sparsely populated areas and none is intensively utilised.

Conservation Status: Unprotected.

6. Minor Lakes

General: There are a large number of glacial tarns (small lakes) in the high mountains, for example on Mts. Kenya and Elgon, and in the Aberdare Range and the Cherangany Hills. A number of these are protected in the Mt. Kenya National Park, at altitudes of 3950-4800 m.

Some small isolated lakes occur in the Rift Valley. In the far north, Lake Logipi (2°13'N/36°24'E) is situated 15 km south of Lake Turkana in the Suguta Valley. In the far south, Lakes Kwenia (1°47'S/36°30'E) and Kabongo (2°05'S/36°24'E) are situated east and southeast of Lake Magadi respectively. Lake Kwenia is 4 km long and 2 km wide, with a 6 km floodplain at its northern end, in total providing a maximum of 1600 ha of wetland. Lake Kabongo appears to be fed by underground water. In the central part of the Rift Valley, Lake Elpolosat (0°10'S/36°26'E) is situated on the Nyandarua Plateau at the foot of the Aberdare Mountains. It is about 5 km long and a few hundred metres wide, with an extensive permanent swamp 10 km long on its eastern side, joined by a tract of seasonally inundated land in the south to the Wanjohi River, a tributary of the Malewa River which feeds Lake Naivasha.

Along the southern border with Tanzania there are two more small lakes, Lake Chala (3°19'S/37°42'E) and Lake Jipe (3°31'-3°40'S/37°45'E). The national boundary passes through both lakes, which are approximately half in Kenya and half in Tanzania. Lake Chala occupies about 600 ha and is 20 km east of the Kilimanjaro Massif. Lake Jipe is farther east and receives drainage from Mt. Kilimanjaro and the North Pare Mountains in Tanzania. It has a swampy littoral, and a belt of permanent swampland extends along the border for 30 km west of the lake, occupying some 7500 ha. Another, smaller swamp extends southeastwards from the other end of the lake.

At the coast Lake Mukunguya (2°25'S/40°41'E) is set in an extensive but broken zone of swamps which extends alongshore between Formosa Bay and Lamu Bay. Farther inland, but in the same district, there are a number of temporary lakes or ziwas. The largest of these

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are Ziwa Roka (2°05'S/40°44'E), Ziwa Shalu (2°08'S/40°27'E), Ziwa Oambi (2°11'S/40°27'E), Ziwa Kiboko (2°15'S/40°24'E) and Ziwa Kambe (2°17'S/40°34'E).

7. Artificial Impoundments

General: The only major impoundments are those constructed or proposed on the Tana River and dealt with in section 2.5.3a.

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Map of Rwanda

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2.6 RWANDA

Introduction

Rwanda has an area of 26 330 km^2, a population of 5 580 000 ((1983), and the highest mean population density of any African state, 212 persons/km^2. It is a mountainous country situated on the eastern margin of the Western Rift Valley and bounded by Uganda in the north, Tanzania in the east, Burundi in the south, and by Zaire in the west. It stretches 185 km from north to south between latitudes 1°04' and 2°51'S, and 225 km from west to east between longitudes 28°51' and 30°54'E.

The western third of the country is dominated by the N-S chain of mountains along the rim of the Rift Valley. In the northwest these rise to 4507 m asl at Mt. Karisimbi (1°30'S/29°27'E) and to 4127 m at Mt. Muhavura (1°24'S/29°40'E) on the Zaire border. West of the mountains the land slopes steeply down to the surface of Lake Kivu (1460 m asl) on the floor of the Rift Valley, while to the east it slopes more gently to the dissected eastern plateaux. However, the eastern slopes in the middle of the mountain chain do fall steeply, to the deeply cleft valley of the Nyawarungu (Nyabarongo) River, the floor of which is oriented N-S at about the same altitude as Lake Kivu. The middle third of the country is a high plateau, 1500-1750 m asl, while the eastern third is another plateau, set at 1200-1400 m asl, but with many hill ridges rising above it to heights of 1600-1800 m.

The western slopes of the mountains drain by torrential streams, full of waterfalls and cataracts, either to Lake Kivu, or to the Ruzizi River, by which Lake Kivu drains southwards to Lake Tanganyika. Both the eastern slopes of the mountains and most of the high central plateau drain to the Nyawarungu River, which after receiving the Akanyaru as a tributary, flows along the Rwanda/Burundi border to join the Kagera River at the southeastern extremity of the country. From here the Kagera delimits the Rwanda/Tanzania border all the way north to Uganda, after which it swings east to enter Lake Victoria. Thus, run-off from Rwanda finds its way, either to the Atlantic Ocean via Lake Tanganyika and the Zaire River, or to the Mediterranean Sea via Lake Victoria and the Nile.

Climate

Despite the proximity of Rwanda to the equator, the climate is mild, being moderated by altitude. The high peaks experience almost permanently inclement weather, cool or cold and very rainy. The high plateau is temperate, but still comparatively wet, while the eastern third of the country has a tropical rather than an equatorial climate. Mean annual rainfall may reach 2800 mm on the western faces of the highest peaks, but is probably no more that 2400 mm/yr over most of the western dorsale. It averages 1200 mm/yr in central districts but declines eastwards with loss of altitude to as little as 650 mm/yr in stations on the Tanzanian border. Over most of the country there are 4 seasons, two warm and wet, and two warm and dry. The short rainy season lasts from October to December, the short dry season from January to February, the long rains from March to May, and the long dry season from June to September. The eastern half of the country experiences 2200-2400 hours of sunshine each year, with a maximum in July and a minimum in

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January. During the long dry season relative humidity may fall to 20%. Wind speeds are usually light, 3-6 km/hr during the wet season, but higher during the dry. The SW monsoon brings thunderstorms, and most of the rain.

Mean annual rainfall is 1001 mm at Kigali (1°57'S/30°04'E), 1552 m asl, and 1116 mm at Rubona (2°29'S/29°46'E), 1650 m asl. April is the wettest month at both stations (137 and 161 m respectively) and July the driest month (6 and 8 mm respectively). The mean annual temperature at Rubona is 19.5°C, with mean annual maxima and minima of 25.7 and 13.3°C. Absolute maxima at this centre are close to 32°C each year while absolute minima are close to 6°C. Frosts occur in the high mountains during the dry seasons.

Vegetation

The eastern half of Rwanda supports evergreen Afro-montane vegetation and the western half a mosaic of evergreen bushland and secondary grasslands with *Acacia* spp. Within these broad vegetational zones most valley floors and parts of the western dorsale carry edaphically determined vegetation.

Wetlands

There are two great swamps in Rwanda. These are the Mugesera-Rugwero Swamps in the south and the Kagera Swamps along the Tanzanian border in the east. There are other minor swampy areas in flat places in the high valleys, and many very extensive bogs on the mountainous dorsale and on the high central plateau. There are several natural lakes of very different characters.

List of Wetlands Described

1. The Nyawarungu/Akanyaru River System
2. Lake Kivu
3. The Mushaka Swamp
4. The Kamiranzovu Swamp
5. Crater Lakes & Swamps of the Virunga Volcanoes
6. The Rugezi Swamp
7. Lakes Bulera & Luhondo
8. The Tshohoha Lakes
9. Lake Mohasi
10. The Mugesera/Rugwero Lake/Swamp Complex
11. The Kagera Swamps & Lakes
12. The Northeastern Rivers

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1. The Nyawarungu/Akanyaru River System

General: The Nyawarungu has several sources in southern Rwanda in forested country at 2600-2750 m asl, chief among which are the Birurume and Lukarara/Mwogo Rivers. Below the confluence of these major headwater tributaries the Nyawarungu flows east, through much boggy highland country, before descending to 1500 m and entering a deep and narrow valley oriented N-S. It continues in this valley for 80 km before swinging SE at Muramba (1°43'S/29°36'E). From here it meanders over its narrow valley floor, receiving first the overspill from Lake Mohasi via the Nyabugogo River on the left bank, and then, some 35 km farther on, the Akanyaru River on the right bank.

The Akanyaru is the most important tributary of the Nyawarungu. It has sources at 2°45'S/29°26'E and 2°46'S/29°26'E, close to 2300 m asl in the south of the country, but the Mugere, an important headwater tributary, rises in Burundi at 2450 m asl. In its lower course the river flows sluggishly through a broad belt of permanent swamps, up to 7 km wide and 82 km long immediately above its confluence with the Nyawarungu. The swamps cover some 25 000 ha, of which the lower 7000 ha are in Rwanda. The Akanyaru descends from 1465 m asl at the head of the swamps in Burundi (2°47'S/29°50'E), to 1400 m asl at the confluence with the Nyawarungu (2°05'S/3°01'E) where the swamps end. Above this, in the swamp belt in Rwanda, it receives overspill from the two Tshohoha Lakes on the right bank. The boundary between Rwanda and Burundi runs through Lake Tshohoha South for 22 km, and about 25% of the lake surface is in Rwanda. The lake is described in section 2.1.2. Below this the river receives the seasonal overspill from Lake Tshohoha North, described in section 2.6.8. Many of the higher tributary valleys are choked by papyrus, with seasonal swamp forest behind. This latter is dominated by *Syzygium guineense*, but with *S. owariense* in the wettest sites, and often with *Ficus verruculosa* and *Myrica kandtiana* as associates. Seasonally inundated savannas, with *Acacia polyacantha* var. *campylacantha*, *A. sieberana* and *Bridelia micrantha* occur on the margins of Lake Tshohoha and around the permanent swamps.

Below the Akanyaru/Nyawarungu confluence the swollen river flows due east in a broad valley which soon becomes swampy again. At first it carries galleries of forest flooded only seasonally, but *Ficus verruculosa*, *Myrica kandtiana*, *Phoenix reclinata* and *Cyperus papyrus* become progressively more common at the riverside in passing downstream. Then, after turning SE again, the river traverses the Mugesera/Rugwero Swamp, dominated by floating islands of *Cyperus papyrus*, with great beds of *Miscanthidium violaceum* rooted on the margins. This swamp is described in section 2.6.10. After leaving the swamps the river flows 35 km eastwards to a confluence with the Ruvuvu River, forming the Kagera River, which is the principal affluent of Lake Victoria.

The Nyawarungu/Kagera River system descends with a mean gradient of 1:2326 in traversing Rwanda between the head of the high valley at 1500 m and the Tanzanian border. The floor of the high valley of the Nyawarungu is inundated in the wet seasons but is intensively cultivated in the long dry season. There are mine workings along it at several points. Swamps in some tributary valleys along its upper course have been drained, more or less completely, with attendant problems of increased erosion, and decreased soil fertility because silt is no longer deposited. Along the swampy middle course, some areas are being used for rice cultivation, and many drier sites have been converted for the cultivation of sugar cane.

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There is a rich avifauna in undisturbed parts of the river system, especially in the Mugesera/Rugwero Swamps, while in developed areas some water birds still survive, including *Balearica pavonina*. Very many of the animals listed for Eastern Equatorial Africa in the regional introduction are present in undisturbed areas, but only the smaller species survive in densely populated areas. No part of the valley is protected.

2. Lake Kivu

Location: 1°35'-2°31'S/28°49'-29°20'E
Area: c. 260 000 ha (excluding islands; c. 165 000 ha in Zaire)
Altitude: 1460 m asl
Nearest Towns: Kibuye (on central lakeshore); Gisenye (at N end)

General: Lake Kivu lies in the Western Rift Valley, enclosed on three sides by land which rises steeply from the lake to altitudes of over 2000 m, and to 4507 m just to the north. The lake is 100 km long, and has a maximum width of 50 km almost exactly along the parallel 2°S. There are 68 islands in the lake, most small, and most in Rwanda, but Idjwi Island, 40 km long and with an area of 69 000 ha is in Zaire.

Hydrology & Water Quality: The lake receives run-off from the surrounding mountains, with no less than 30 rivers entering it along the highly indented Rwandan shore. In addition it is believed that warm water is injected into the lake from submerged hot springs, and that the effluents from the small group of Mokoto Lakes (in Zaire) reach Lake Kivu underground. Rainfall in the catchments exceeds 2400 mm and is not markedly seasonal. The lake is deep, c. 480 m, meromictic, and the most firmly stratified lake in Africa. Water density increases towards the bottom, but not as a steady gradient; there is a series of discrete layers. The surface water has a salinity of 1‰, and the top 70 metres are mixed, but it seems that below this the hypolimnion is completely stagnant, highly saline, and very rich in nitrogen and phosphorus. The pH of the surface waters is about 9.1. It appears that natural phenomena, other than earth movements and the pouring of hot lava into the lake, do not cause upwellings of the bottom water, which is highly nutritive but contains much dissolved sulphide and methane. The temperature at the surface is close to 25°C, decreasing with depth to about 22°C at 70 m, but then increasing again to 25°C at 375 m depth. The 70 m contour is very close to the shore, and since only the upper 70 m of the water column is oxygenated, it has been estimated that only 12% of the lake floor receives any oxygen. This is the most saline lake in the Western Rift Valley.

Flora & Fauna: There is little information regarding the phytoplankton, but it is neither diverse nor abundant. The macrophyte flora, which extends down to a depth of 8 m is extremely poor, and there is only a narrow fringe of lake bottom above this depth. The deep lake floor is covered by an organic ooze, although towards the shores the bottom is quite sandy, but encrusted with calcareous scale. Here *Cladophora* sp. is the dominant plant. Higher up there are beds of *Ceratophyllum demersum*, *Najas marina* and *Potamogeton pectinatus*, the latter species being most abundant. Around the shallowest margins there are beds of *Phragmites mauritianus* and species of *Cyperus* and *Scirpus*. The fish fauna is poor, comprising just 16 species. Of these, 3 also occur in Lake Tanganyika, namely *Barbus serrifer*, *Barilius moori* and *Clarias mossambicus*. The first

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and last have wide distributions and were possibly introduced, but *Barilius moori* is found only in these two lakes. There are 6 species of *Haplochromis*, all endemic, and a distinct subspecies of *Oreochromis niloticus* ssp. *regani*, which suggests that speciation has occurred in the lake over the last 20 000 years. There is no large predatory species in the lake. Birds and otters are the principal piscivores, and the lake supports many birds of passage.

Human Impact & Utilisation: *Limnothrissa miodon* was introduced some years ago, and a small sardine fishery has developed, but prior to this there was no commercial fishery of significance.

Conservation Status: Unprotected. However, the high mountain catchments to the north are protected in the Virunga National Park.

3. The Mushaka Swamp

Location: 2°38'S/28°55'E
Area: c. 1250 ha
Altitude: 1580 - 1620 m asl
Nearest Towns: Cyangugu (17 km NW); Kigali (145 km NE)

General: This small swamp is situated south of the village of Mushaka on a west-facing plateau above the Ruzizi River. It is fed by two streams from the highlands above, and is drained by a single stream to the Ruzizi River. We have no specific information regarding its flora and fauna. It is not protected.

4. The Kamiranzovu Swamp

Location: approximately. 2°29'S/29°15'E
Area: 1300 ha
Altitude: 2300 m asl
Nearest Towns: Cyangugu (40 km W); Butare (55 km ESE)

General: This swamp is situated in an area receiving some 2200 mm rain/yr in the Afro-montane vegetational zone on the high dorsale of southern Rwanda. The centre of the swamp is dominated by clumps of *Cyperus* and *Lobelia* spp. The margins are fringed by a swamp forest dominated by *Anthocleista grandifolia*, *Podocarpus latifolius* and *Syzygium guineense*. Animals present include *Aonyx capensis*, *Cephalophus niger*, *Tragelaphus scriptus* and some snakes, birds and rodents. The swamp is an important natural reservoir near the source of the Lukarara River, a headwater tributary of the Nyawarungu River. It is protected in the Nyungwe Forest Reserve.

5. Crater Lakes & Swamps of the Virunga Volcanoes

General: There are two lakes. One is in the crater of Mt. Bisole (1°27'S/29°29'E), 3711 m asl, and the other is in the crater of Mt. Muhavura (1°24'S/29°40'E), 4127 m asl. There is a *Sphagnum* bog in the crater of Mt. Gahinga (1°23'S/29°39'E), 3474 m asl, and a swamp on the southeastern shoulder of Mt. Karisimbi, at an altitude of 3800 m

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(1°31'S/29°28'E). The swamp covers 400 ha. All are situated in the Volcanoes National Park, which has been a protected area since 1929 when it was part of the Albert National Park. This was subdivided upon the independence of Zaire in 1960. It was accepted as a Biosphere Reserve in 1983.

6. The Rugezi Swamp

Location: 1°22'-1°36'S/29°50'-29°59'E
Area: 12 000 ha
Altitude: c. 1950-2150 m
Nearest Towns: Biumba (9 km E); Ruhengeri (25 km W)

General: This high altitude swamp is situated immediately east of Lakes Bulera and Luhondo below the high peaks of the Virunga volcanoes. It is 30 km long, oriented NW-SE in the valley of the Hondo River, and reaches a maximum width of 6 km at the southeastern end. It drains via the Hondo River, from its northwestern end, over two waterfalls, into Lake Bulera. It contains *Cyperus papyrus*, *Miscanthidium violaceum*, and several lesser species of *Cyperus* and *Scirpus*. Part of it has been drained and cultivated in recent years, and it is not protected. The fauna includes an abundance of amphibians, a variety of water birds including herons, egrets, ducks, warblers and weavers, and *Aonyx capensis*, *Lutra maculicollis* and some rodents among the mammals. It is an important reservoir, buffering inflows to lake Bulera to which it drains.

7. Lakes Bulera & Luhondo

General: These lakes are situated on the southern slopes of Mt. Muhavura in NW Rwanda. Lake Bulera (1°23'-1°30'S/29°45'-29°49'E), 1862 m asl, is 12 km long and reaches 8 km in width. It contains two small islands and is fed by 6 streams. The largest affluents are the Kabga and Kageri Rivers, and the Hondo River which drains the Rugezi Swamp. The lake has a maximum depth of 173 m and an open water surface of approximately 3500 ha. It drains from its southwestern extremity to Lake Luhondo (1°28'-1°33'S/29°42'-29°46'E), 1764 m asl. This latter lake is shaped like an inverted 'V'. Its eastern arm is 9 km long and reaches 3 km in width, and the lake has an area of 2800 ha. In addition to the overflow from Lake Bulera, it receives water from 4 other streams, of which the Gasura is the most important. There is a 500 ha swamp at the northern end of the lake, i.e. at the apex of the 'V'. It drains to the southwest via the Mukungwa River, a tributary of the Nyawarungu, and a hydroelectric power station has been constructed where the Mukungwa leaves the lake. Both lakes are very young, a fact reflected by their poor floras and faunas. They both contain *Clarias* sp., while tilapias have been introduced and now constitute the basis of a local fishery.

8. The Tshohoha Lakes

General: The Rwanda/Burundi border runs through Lake Tshohoha South (2°20'-2°32'S/29°59'-30°10'E) which covers some 7000 ha at high water, and of this about 2000 ha is situated in Rwanda. The lake is 30 km long, about 1.3 km wide, oriented SE-NW, and

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has a highly indented perimeter with several long narrow arms. It is situated on the floor of a forested basin at about 1460 m asl, between two low hill ridges rising in parallel to 1531 m on the southwestern side and to 1510 m on the northeastern side. It is fringed by papyrus and *Miscanthidium* swamps, with scattered patches of swamp forest. It is fed at the southeastern end (in Burundi) by the Muburiba River, and drains to the Akanyaru River some 3.5 km distant from the northwestern end in Rwanda. The lake is fished but is not protected.

Lake Tshoboha North is situated entirely in Rwanda (2°14'-2°19'S/30°05'-30°09'E). The lake is fed at its southern end by a river from Burundi, and drains from its northeastern end through 10 km of permanent swamps to the Akanyaru River. The lake occupies the floor of a triangular basin about 1450 m asl, situated between two low undulating ridges oriented SW-NE and NW-SE. Its effluent river passes between these hills at the narrow western end of the basin. The shallow lake is 12 km long and about 1 km wide, with an open water surface of 1200 ha at high water. It is fringed at the waterside by papyrus, and peripheral vegetation similar to that described in section 2.6.10. Agriculture is locally intensive on the floodplains of the affluent and effluent rivers, and in places around the lake margin where it has been possible to drain the swamps. The system is not protected.

9. Lake Mohasi

Location: 1°49'-1°54'S/30°11'-30°30'E
Area: 3450 ha
Altitude: 1480 m asl
Nearest Towns: Kigali (22 km ENE); Kibungu (31 km SSE)

General: This lake is 40 km long and has a mean width close to 1 km, with a maximum width of 2 km. It occupies the floor of a system of valleys, tributary to a main valley aligned E-W, and extends into the tributary valleys as a series of 13 narrow arms. Much of the lake shore is swampy and there are swamps at the heads of all 13 arms. The lake is fed by the Mohagumbo River at the eastern end, and by 13 other small streams, and drains from the western end via the Nyabugogo River to the Nyawarungu River.

10. The Mugesera/Rugwero Lake/Swamp Complex

Location: 2°04'-2°28'S/30°12'-30°27'E
Area: 55 500 ha (including open water)
Altitude: c. 1300 m asl
Nearest Towns: Kigali (33 km NW); Kibungu (18 km W)

General: The system occupies the lowest part of a very flat valley, 35 km wide, aligned NNW-SSE. The Nyawarungu River meanders through this, overtopping its banks, filling depressions which contain lakes, and inundating a zone of permanent swamps and a peripheral floodplain. The permanent swamps occupy a central zone up to 14 km wide, but are best developed on the right (west) bank of the river. There are 4 lakes on the left (east) bank. From north to south these are Lake Mugesera, an un-named lake, and Lakes Birira and Sake. The left bank lakes are, also from north to south, Lakes Gashaga,

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Murago, Rumira, Milay, Kilimbi, Gaharwa, Rugwero and Kazigiri. The last is situated entirely within Burundi, while Lake Rugwero is mostly in Burundi.

The largest lakes are Mugesera (2°04'-2°13'S/30°18'-30°27'E) and Rugwero (2°21'-2°28'S/30°16'-30°23'E). Lake Mugesera (4000 ha) at the upper (northeastern) end of the system is fed by the Bubindi, Gitinga, Mwambu, Nyaruvoma and Rwazurasu Rivers and ten other minor streams, which are all in spate twice a year. These rivers originate on hilly ridges to the north, east and south of the lake, north of Kibungu, while the southern swamps near Lake Rugwero receive several similar streams from hills in the east, south of Kibungu. Lake Mugesera comprises a main basin oriented NNE-SSW, with 4 arms running roughly eastwards separated by ridges of low hills. Lake Rugwero (10 000 ha) is fed by streams from the central plateau of Burundi, and by overspill from Lake Kanzigiri which finds its way northwards through the swamps, either to Lake Rugwero or directly to the Nyawarungu River. The other lakes, none of which is known to exceed 5 metres in depth, are much smaller, each a few hundred hectares in extent in the dry seasons. Flood waters which are not dissipated in the main swamp basin collect back into the Nyawarungu which leaves the southeastern end of the basin and flows through a narrow swamp belt to a confluence with the Ruvuvu River immediately above the Rusumu Falls (2°23'S/30°47'E).

Hydrology & Water Quality: Water levels rise 1-2 m twice a year, corresponding with the rains. Mean water temperatures in the lakes are 24-26°C and the level of oxygen is generally high, but the bottoms may become anoxic during the long dry season. The mean pH of Lake Gaharwa is 10.0, that of Lake Rugwero is 7.5, and that of Lake Gashanga is 7.0, while the others have a range of 7.7-8.2. Transparencies vary between 30-90 cm, depending upon the season, with the lowest figures during the long rains.

Flora & Fauna: The central swamp is essentially a papyrus swamp with many islands of floating vegetation, and these are especially well developed on Lake Rugwero. The papyrus grows 4-5 m tall, with an understorey of *Dryopteris gongylodes* up to 1.5 m, and *Ipomoea fragrans* climbing to 4 m. *Polygonum* spp. are also common associates, while *Echinochloa crus-pavonis*, *Hydrocotyle ranunculoides*, *Leersia hexandra*, *Utricularia inflexa* and *Vossia cuspidata* occur in the water along the outer margins of the papyrus. Islands of papyrus occur in the lakes, and are especially abundant in Lake Rugwero. Extensive stands of *Miscanthidium violaceum* are rooted in the shallower parts of the swamp. There are also groves of *Phoenix reclinata* and thickets of *Aeschynomene elaphroxylon*, *Dissotis incana*, *Ficus verruculosa* and *Myrica kandtiana* on the margins, on levées, and on island shores. Permanent deep water is covered by carpets of floating-leaved or free floating plants, principally *Lemna paucicostata*, *Ludwigia stolonifera*, *Nymphaea caerulea*, *N. nouchalii*, *Pistia stratiotes* and *Trapa natans*, and it supports dense beds of submerged aquatics, including *Ceratophyllum demersum*, *Myriophyllum spicatum*, *Potamogeton pectinatus*, *Utricularia* spp., and *Vallisneria spiralis*.

Savannas surrounding the lakes, subject to seasonal inundation, are dominated by *Acacia campylacantha* and *A. sieberana*, with *Boerhaavia plumbaginea*, *Bridelia micrantha*, *Cordia abyssinica*, *Crassocephalum bojeri*, *Panicum deustum*, *Securinega virosa*, *Setaria kagerensis* and *Sorghum verticilliflorum*. Peripheral floodplain supports the grasses *Hyparrhenia filipendula* and *H. rufa*, or *Bothriochloa insculpta* and *Themeda triandra*.

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The phytoplankton and zooplankton are abundant, if not very diverse, and there is a high mollusc biomass. Some 30 species of fish have been identified belonging to 9 families, and of these, 22 are also found in Lake Victoria. *Alestes*, *Clarias* and *Oreochromis* are well represented, and some cichlids have been introduced, reputedly *Oreochromis esculentus* and *O. macrochir*. No less than 173 birds have been identified, of which 30 are piscivorous and 50 feed on insects and molluscs. There are a number of European migrants, e.g. *Hippolais icterina*, *Hirundo rustica*, *Motacilla flava*, *Phyllascopus trochilus*, *Riparia riparia* and *Sylvia borin*. Other species of interest include *Anhinga rufa*, *Ardea goliath*, *Ardeola ralloides*, *Balearica regularum*, *Ceryle rudis*, *Haliaeetus vocifer*, *Pandion haliaetus*, *Phalacrocorax africanus*, *P. carbo*, *Plectropterus gambensis* and *Quelea erythrops*. There are water turtles (*Pelusios*), crocodiles, monitors, snakes, otters and rodents. *Hippopotamus amphibius* is now scarce.

Human Impact & Utilisation: The lakes and swamps are fished, mainly from canoes, with yields of up to 125 kg/ha/yr, comprising some 60% cichlids and 20% clariids. Population density of the swamp margins is locally very high.

Conservation Status: Unprotected.

11. The Kagera Swamps & Lakes

Location: 1°19'-2°11'S/30°33'-31°01'E
Area: 144 400 ha (50 000 ha lake surfaces)
Altitude: 1270-1300 m asl
Nearest Towns: Kigali (69 km W); Kibungu (20 km W)

General: The wetland lies in a N-S anticline on the Rwanda/Tanzania border between two ridges of low hills, below Rusumu Falls. The Kagera River, which delimits the Rwanda/Tanzania border, meanders along the centre of the the flat bottomed valley for about 110 km, spilling over to inundate a swamp belt 2-18 km wide. This is lined on each margin by a series of substantial lakes, 20 on the right bank being situated in Tanzania. These are, from north to south, Lakes Gwelu, Nyakatsle, Nyaruwale, three un-named, Lubuga, lahaka, Duko, Kashani, Twamwala, Mujunju, un-named, Kashanga, Weru Kwa Kalambi, three un-named, Katabi-Kazinga and Bisongo. The swamp belt is more extensively developed on the left bank, in Rwanda, where there are 21 lakes, and from north to south these are Lakes Ferongo, Rwanye-Kizinga, Mihindi, un-named, Kishandju, two un-named, Muhari, Hago, Nkelenhe, Kivumba, Sekama, five un-named, Ihema, Rwakibale, Nasho, Rwehikama and Rwampanga. The lakes lie partly in and partly out of the permanent swamp belt. Outside the permanent swamps some are fringed by seasonally inundated savannas. The river descends about 40 m from the foot of the Rusumu Falls to an altitude of 1270 m asl at the northern end of the swamp complex.

The largest lakes are Ihema (9100 ha), which measures 20 km in length and is 7 km wide in places, Mujunju (2250 ha), which is 11 km long and up to 3 km wide, and Bisongo (c. 2000 ha). Lake Mujunju is the deepest, with a maximum depth of 11 m and a mean depth of 5.9 m; the others have maximum depths between 7.8 and 4.3 m and mean depths between 5.2 and 2.6 m (Rwanye-Kizinga). Very few of the lakes have permanent connections with the Kagera River, and in the past 30 years, the river has changed course and lost connection with lakes with which it formerly had continuity.

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Hydrology & Water Quality: Many small seasonal streams feed the lakes or swamps directly and flow twice a year, but the bulk of the riverine inflow is provided by the Kagera River, which also rises in response to seasonal rains. Direct precipitation contributes some 650-900 mm/rain/yr, and the water level in the system has an annual amplitude of 1-1.5 m. During the dry season several of the lakes are isolated from the river. The water of the lakes tends to become stratified during the dry season when temperature differences as great as 4°C have been observed between the top and bottom waters of an individual lake. Mean pH values are 6-7.5 at the lake bottoms, and 7-9 at the surfaces.

Flora & Fauna: The flora and fauna is very similar to that described in the previous section for the Mugesera/Rugwero Swamps, but with the difference that a variety of large mammals survive in the Kagera National Park covering the northern half of the swamp complex. These include *Hippopotamus amphibius*, *Hippotragus equinus*, *Kobus ellipsiprymnus*, *Loxodonta africana*, *Panthera pardus*, *Phacochoerus aethiopicus*, *Redunca arundinum*, *Sylvicapra grimmia*, *Syncerus caffer* and *Tragelaphus spekei*. Amphibians, crocodiles and water turtles are abundant.

Human Impact & Utilisation: A controlled fishery operates on Lake Ihema, but otherwise, outside the National Park, fishing is uncontrolled, and overfishing occurs locally. Fishing in the Kagera National Park is illegal but this fact does not prevent it from occurring. Many channels through the vegetation, connecting the lakes with the river, are kept open by local fishermen.

Conservation Status: Some 60 000 ha of swampland is protected in the Kagera National Park, but the remainder is unprotected and subject to intense hunting and fishing pressures.

12. The Northeastern Rivers

General: Long strips of permanent swampland occur along the three major rivers which flow across the northeastern extremity of the country to join the Kagera River north of its Lake/Swamp Complex. Swamps occur on the Kamababa River above its confluence with the Kagera, and also on its headwater tributaries in patches up to 10 km long and 1.5 km wide. North of this, swamps extend for over 40 km up the Kalangaza River, beginning about 18 km above its confluence with the Kagera. In the far NE, other swamps occur on the Kakitumba River, and on its two affluents, the Muvumba and Kalungeri Rivers. In total there are close to 19 000 ha of permanent swamp on these rivers, together with narrow peripheral floodplains. The flora and fauna of these rivers is similar to that along the Akanyaru/Nyawarungu/Kagera system.

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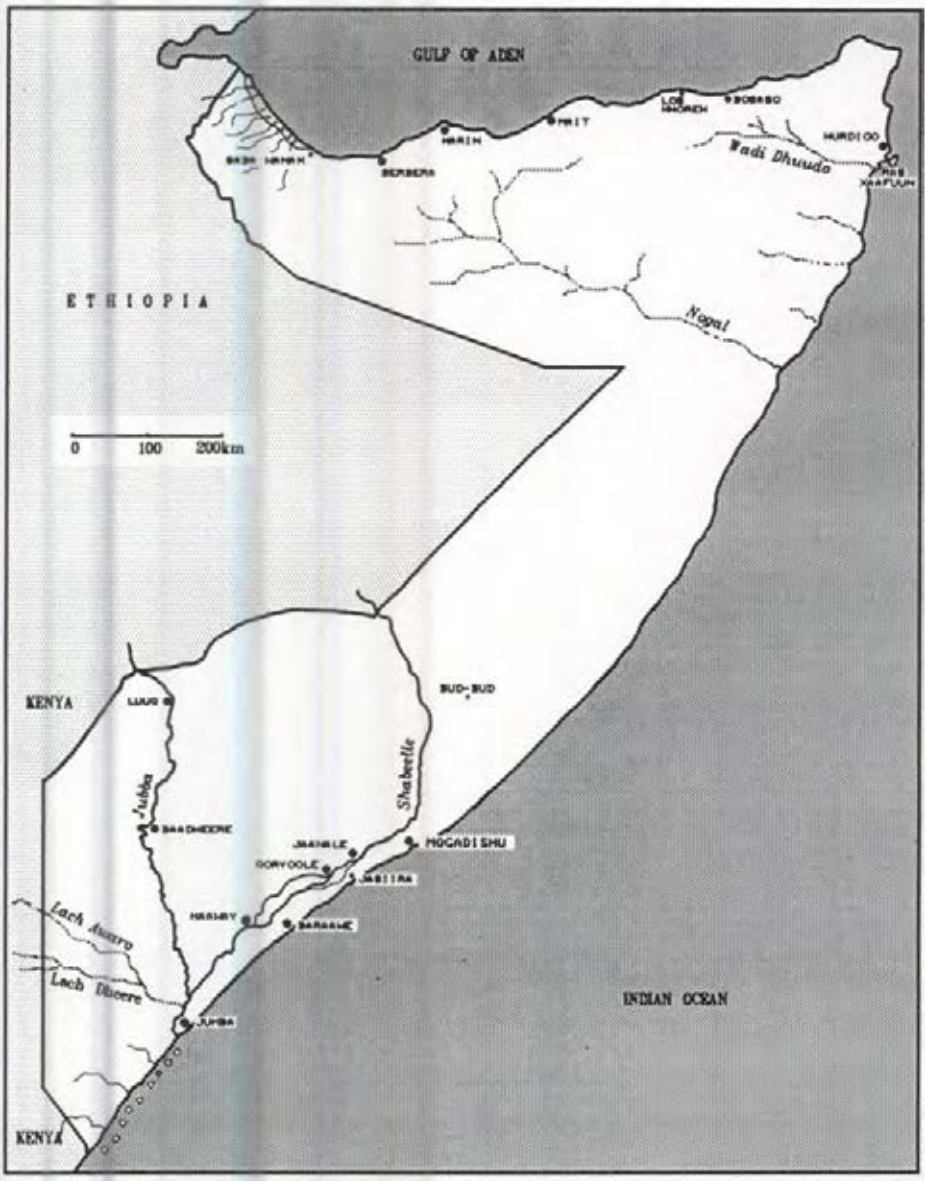

Map of Somalia

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2.7 SOMALIA

Introduction

Somalia has an area of 630 000 km^2, a population of 3 862 000 (1982) and thus a mean population density of 6.1 persons/km^2. It is bounded by Kenya, Ethiopia and Djibouti in the west, by the Gulf of Aden in the north, and by the Indian Ocean in the south and east. It stretches approximately 1550 km from north to south between latitudes 12°00'N and 1°37'S, 1095 km from west to east between longitudes 41°00' and 51°21'E, and has a coastline of 3160 km.

The coastal plain along the Gulf of Aden is narrow, mostly 5-10 km wide, but with a maximum width of 35 km near Djibouti, and non-existent in other places, e.g. between Bacaad (11°20'N/49°25'E) and Xabo (11°50'N/50°34'E) where cliffs reach 200-400 m. Along the Indian Ocean it is narrow in the north, but widens to 125 km in the south, and to 200 km in the valley of the Jubba River. Between latitudes 4 and 8°N the coastal plain is 5-10 km wide and is backed by a very steep escarpment, which rises abruptly to a plateau just over 200 m in height, and farther inland to 500 m asl. In southern Somalia there is an escarpment some 135 km inland, which rises sharply to a plateau at 550 m asl, and on this, in Bakool Province, another escarpment completely encircles a higher plateau (200x100 km) at 1100 m. However, the highest land is in the north, parallel with the Gulf of Aden, where a mountain chain is an extension of the southern margin of the Ethiopian Rift Valley, and marks the south side of the ancient rift that is now the Gulf of Aden. Here Shimbiris Mountain (10°40'N/47°11'E) rises to 2416 m, the highest point in Somalia. Inland of this the land slopes to the southeast, to the lower plateau along the Indian Ocean.

Drainage from the northern mountains is either northwards, by a series of wadis leading to the Gulf of Aden, or southeastwards into the desert lands where a few wadis reach the Indian Ocean. Along the central Indian Ocean coast there are no watercourses and the coast is smooth and sandy, exposed to strong wave action, but in the south, the Shabeelle (Shabele) and Jubba (Genale) Rivers enter the country from Ethiopia, and have cut deep and dramatic gorges into the plateau through which they flow to the coastal plain. Here the Shabeelle turns SW and flows parallel to the coast to a confluence with the Jubba below Kamsuuma (0°08'N/42°46'E), the combined streams continuing parallel with the coast to a confluence with the Lach Dera (0°01'S/42°37'E), before reaching the sea at Jumbo (0°14'S/42°37'E). Apart from this river, no major watercourses reach the sea on the Somalian coast between the equator and 7°58'N, where the first of the northern watercourses, the Nogal, has a mouth. South of Jumbo however, three short seasonal streams reach the sea.

Climate

Somalia is hot and humid at the coast, and hot and dry in the interior. Mean annual rainfall is higher in the south (300-500 mm) than the north, but also reaches 500 mm locally in the western Ogo Highlands. In the south, temperatures tend to be rather uniform throughout the year, but with a greater diurnal range inland, and a sea breeze often moderates the temperature at the coast. In the north, temperature regimes are more

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extreme, this being due to increasing altitude and latitude. Temperatures regularly reach 42°C on the gulf coast in summer and fall to 0°C in the Ogo Highlands. There are two rainy seasons. The first is from March to June and the second from September to December, but either or both seasons may be shorter than this. The rains are unreliable and droughts are commonplace.

Mean annual rainfall at Berbera (10°25'N/45°02'E) on the Gulf of Aden is 59 mm and April is the wettest month with an average receipt of 10 mm. Corresponding figures for stations in the Ogo Mountains are Hargeysa (9°30'N/44°03'E) 389 mm (August-90 mm), and Erigavo (10°37'N/47°24'E) 436 mm (September-100 mm), while south of the mountains, Burao (9°30'N/45°30'E) has a mean annual receipt of 200 mm (May-60 mm) and Gardo (9°30'N/49°03'E) 96 mm (May-30 mm). Rainfall increases southwards, down the Indian Ocean coast, from a mean annual figure of 148 mm at Iddan (6°03'N/49°01'E) to 203 mm at Obbia (5°20'N/48°38'E), 401 mm at Mogadiscio (2°01'N/45°20'E) and 384 mm at Brava (1°05'N/44°02'E). In the central and southern interior, Oddur (4°10'N/43°53'E) receives 362 mm, Baidoa (3°04'N/43°48'E) receives 589 mm, Bulo Berti (3°52'N/45°40'E) on the Shebeelle River receives 329 mm, Bardera (2°21'N/42°20'E) on the Jubba River receives 375 mm, and Afmadu (0°32'N/42°10'E) on the Lach River receives 549 mm/yr.

Vegetation

The interior is largely covered by deciduous bushland dominated by species of *Acacia* and *Commiphora*, while the coastal regions are grassy scrublands. The mountains support evergreen bushland at higher levels with Afro-montane vegetation about the peaks. Much of the northeastern extremity, the Horn of Africa, is devoid of trees. In general, vegetation becomes more dense towards the south.

Wetlands

There are some tidal wetlands along the Gulf of Aden, a few lagoons on the east coast, and some deep mangrove lined inlets in the south. There are extensive permanent swamps and floodplains on the Shebeelle River and some swamps on the Jubba, the two large perennial rivers which cross the country from Ethiopia. Some fossil courses (desheks) of the Jubba exist south of Bardera which are inundated seasonally or semi-permanently during wet cycles. In addition, there is permanent water at sites in the Nogal Valley, tugs and bullehs, and there are pans, springs and pools in most of the small northern wadis discharging to the Gulf of Aden and the Indian Ocean along the Horn of Africa. Much of the interior is overlain with limestone in which there are numerous sink holes, and a small lake at Bud Bud (4°15'N/46°30'E). However, the central section of the country, between latitudes 3 and 8°N, is devoid of sizeable wetland. Many Somalian wetlands are officially protected, but in practice this implies little more than preventing the poaching of elephants and rhinoceroses. Habitat protection and conservation are neither understood nor implemented. It appears that no stand of trees that can be cut for firewood or building, is genuinely safe.

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List of Wetlands Described

1. Tidal Wetlands
2. Wetlands of the Shabeelle-Jubba Rivers
3. Wetlands of the Lachs District
4. Bullehs, Tugs & Dholos
5. The Central Districts
6. Artificial Impoundments

1. Tidal Wetlands

General: A number of tidal wetlands, marshes and swamps, occur along the coast of the Gulf of Aden. These are best developed in the west between Saada Din Island (11°26'N/43°27'E) and Saba Wanak (10°33'N/44°07'E). Along this 44 km stretch of coast, no less than 27 watercourses approach the sea. A salt-marsh/swamp is more or less continuous in this sector, locally extending up to 3 km inland. Many watercourses peter out at the back of it. The wetland has developed on the alluvium brought down from the Ogo Mountains by these temporary streams. Farther eastwards, tidal wetlands occur in the bays west of Berbera (10°25'N/45°02'E) and east of Karin (10°54'N/45°52'E), and from Mait (11°00'N/47°07'E) to Ras Kalwein (11°07'N/47°55'E), and from Los Khoreh (11°10'N/48°13'E) to Bosaso (11°07'N/49°11'E).

On the Indian Ocean coast the principal northern sites are in the two bays on either side of Ras Xaafuun. The northern one is just south of Hurdigo (10°35'N/51°06'E), extending into the great bay of Hurdigo, and this supports a large breeding population of flamingoes. The southern one is at Ashira (10°21'N/50°57'E), at the mouth of the Wadi Dhuudo. In passing southwards down the coast, other tidal swamps occur in a small bay where three little wadis reach the sea (9°48'N/50°51'E); in the small lagoon at Jasiira (1°57'N/45°15'E); and on the coast north of Baraawe, between latitudes 1°11' and 1°24'N. In the far south, near the Kenyan border, they occur on the coast, around the chain of 12 offshore islands, and in three estuaries (0°51'S/42°06'E; 1°04'S/41°57'E; and 1°13'S/42°06'E).

Some of these wetlands support mangroves, the best stands being in the sector between Saada Din Island and Saba Wanak, in the estuaries of three watercourses which reach the sea west of Bosaso (Bender Cassim), and in the three estuaries just north of the Kenyan border. These latter are tidal for long distances inland, the Caanoole Estuary probably for 40 km, and the Bushbush Estuary for 30 km. On the northern coasts *Avicennia marina* is the dominant species, but *Bruguiera gymnorrhiza*, *Ceriops tagal*, *Lumnitzera racemosa* and *Rhizophora mucronata* all occur on the Indian Ocean coast, and *Sonneratia alba* is reputed to occur in the southern estuaries. In addition to these species, *Phoenix reclinata* is common in tidal swamps on both coasts, but on the Gulf of Aden it occurs in association with *Tamarix nilotica* at the mouths of tugs along the Gulf of Aden, both in sites where *Avicennia* is present and in others where it is not. Often there is a seaward sward of *Suaeda fruticosa* in front of the *Phoenix* and *Tamarix* stands, and in adjacent wet dune swales on this coast, the small procumbent palm, *Hyphaene reptans*, is found. Salt-marsh vegetation in the north is similar to that described in the

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regional introduction for Red Sea coasts, and in the south corresponds to that described for Equatorial East Africa.

Mangroves stands are constantly ravaged for firewood and construction timber, and since this has been the practice from time immemorial, many stands have been obliterated. They have been completely cut out so that no arborescent vegetation remains, and now only salt-marshes have replaced the mangroves.

2. Wetlands of the Shabeelle-Jubba Rivers

General: These rivers each have several sources at altitudes of close to 3000 m asl in the SE Highlands of Ethiopia. They flow roughly in parallel southeastwards across that country and enter Somalia. Here they both descend below the 500 m contour into deep, dramatic, scarp-sided trenches, in which they continue to flow southeastwards to the coastal plain. The northernmost stream, the Shebeelle, soon meets a crescent shaped line of dunes, 350 km long, which deflects its flow, first southwards and then southwestwards. Thereafter it flows parallel with the coast for 450 km to a confluence with the Jubba. The entire sub-coastal valley of the Shebeelle is beset with swamps around which there are peripheral floodplains. The greatest development of this wetland begins (1°52'N/44°47'E) below Jannaale where the river divides into two channels. Then at Qoryoole (1°45'N/44°35'E) it divides again, so that three channels traverse a swamp belt 25 km broad and 150 km long, to a point (1°09'N/43°45'E) near Haaway where the three channels reunite. In this main swamp belt there are some 300 000 ha of permanent swampland.

Permanent swamps and floodplains develop on the Jubba River almost immediately after it enters Somalia, on the floor of its deeply entrenched valley near Luuq (3°47'N/42°36'E). Permanent swamps are not well developed below this place, although there is a floodplain, but just south of Baardheere (2°17'N/42°18'E) there is a series of fossil river courses which are seasonally or semi-permanently flooded. These are known locally as desheks, and they occupy 6000 ha, or perhaps more. The river then flows to its confluence with the Shebeelle, above which both streams develop a common floodplain, and below which they traverse marshy land to a mangrove clad estuary at Jumba (0°17'S/42°35'E).

The wetlands on both of these rivers are extremely important to wildlife, especially that on the lower Shebeelle, and a wide spectrum of the flora cited in the regional introduction, for swamps and gallery forests of Equatorial East Africa, is present here. *Crocodylus niloticus* is still common locally and *Pelusios sinuatus* occurs in lakes and permanent pools throughout the country. Several snakes are present, the avifauna is large, and most of the small mammals cited are present. However, the two systems are under enormous pressure. This is partly because refugees from successive famines in Ethiopia have been settled in camps along the upper rivers, and partly because numerous ill-planned schemes have been proposed for the conversion of the lower wetlands. The refugees make demands upon the water resources, and on the adjacent land for cultivation (which is often abandoned after a few years), and the ill-planned schemes seem likely to go ahead if financial backers can be produced. Co-ordinated policies for management of these areas are not even devised, let alone implemented. A threat to riverine woodlands and

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its wildlife throughout southern Somalia comes from tsetse fly eradication campaigns involving spraying, and from other spraying campaigns to eradicate or control *Quelea*. There are also plans for the construction of reservoirs which might destroy the wetlands and their wildlife at a single stroke. None of these wetlands is effectively protected.

Soma 40 km above the estuary the Jubba receives the waters of the seasonal Lach Dheere River, which with its affluents has drained the NE Kenya Plateau.

3. Wetlands of the Lachs District

General: A number of large temporary watercourses known as lachs or laks drain the SE sloping plateau of NE Kenya into southern Somalia. The principal streams are, from north to south, the Lach Awaro (Bor), Lach Bogal and Lach Dheere (Dera). Lach Bogal peters out in swamps in Kenya before reaching Somalia but the others, having drained extensive swamps in Kenya, cross the border into Somalia where, when in spate, they spread their waters over broad floodplains. Some of the channels of the Lach Awaro system produce an E-W floodplain, some 80 m asl, 55 km long and 10 km wide, with a minimum area of 33 000 ha in Somalia (0°57'-1°09'N/41°00'-41°31'E). This is effectively a terminal, endorheic floodplain or pan, but most of the water from the Lach Awaro passes this floodplain to the SE to enter a much larger pan created by the Lach Dheere in Somalia. This latter stream is flanked by permanent swamps where it enters Somalia at an altitude of 70 m, and on passing east this widens to a floodplain over 40 km across with an area of 228 000 ha. This includes some 6000 ha of permanent swamp at its narrow, upper, western end, and a further 5000 ha along its mid-northern margin. The pan is located south of the Awaro Pan (0°08'-0°53'N/41°00'-41°58'E) and is not always a single integral pan, since in drier years there may be a series of fragmented pans within this area. However, the flood waters pass through the pan and again inundate a broad area, about 50x50 km (250 000 ha) almost immediately north (1°02'-1°31'N/41°45'-42°20'E). From here the waters make their way through a series of channels with floodplains and swamps to a confluence with the Jubba (0°05'S/42°38'E) near Yoontoy, only about 40 km from the estuary.

About 120 km due north of these wetlands there is another large pan, 63 km in length with a maximum width of 9 km. It covers 33 000 ha (2°31'-2°52'N/41°21'-41°52'E) and is situated on the plateau at an elevation of 290 m among hills which rise to 345 m close by. It is fed by more than 20 small watercourses which drain the surrounding hills, and it is usually flooded for a short period every year. Direct precipitation over this pan is about 420 mm/yr.

None of these wetlands is effectively protected. Hunting pressure is extreme, and trees are cut down in large numbers. The mangroves at the mouth of the system have been decimated over the past 25 years.

4. Bulleha, Tugs & Dhoks

General: A bulleh is a small endorheic depression, which holds water after rains. It may be filled by peripheral sheet run-off, but more usually by a temporary watercourse. Bullehs tend to retain soil moisture for much longer than the surrounding land and carry

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a characteristic vegetation, significantly richer than that of their environs. The beds of small temporary watercourses of low gradient tend to be flat, so that their waters spread widely over broad deposits of alluvium at times of flood. These watercourses are known as tugs. Often a tug ends in a flat inland delta, known as a dholo, set in the valley of a larger watercourse, or such a delta may spread over raised coral reefs along the coast. Tugs and their dholos are periodically flooded and tend to retain moisture longer than the surrounding land, and thus have floras and faunas similar to those of bullehs.

Acacia tortilis is virtually ubiquitous in tugs, dholos and bullehs, usually growing with a flat-topped habit, 6-8 m high, but occasionally reaching 20 m. It appears indifferent to the nature of the local parent rock. In gypsum areas, on inland deltas, this tree is often accompanied by *Acacia stuhlmannii* and the grass *Paspalidium desertorum* or a species of *Panicum* (*turgidum*?). In the Nogal Valley, where water 50-100 cm sometimes stands in bullehs for considerable periods, it grows on the fringes with *Ziziphus mauritianus* bushes scattered over the more deeply inundated areas. This latter species will tolerate quite deep inundation for several weeks, or even months. *Euphorbia robecchii* is an associate of *Acacia tortilis* on some small tugs, and on larger tug floors it may grow with bushes of *Cadaba heterotricha*, *Commiphora cerasiformis*, *C. coriacea*, *C. crenulata*, *Coleus ignarius*, *Salvadora persica*, *Senra incana* and *Zygophyllum hildebrandtii* and the grasses *Sporobolus longebrachiatus*, *S. ruspolianus*, *S. somalensis* and *Tripogon subtilissimum*. On tug banks *Cadaba glandulosa*, *C. heterotricha*, *C. mirabilis*, *Ficus sycomorus*, *Maerua crassifolia* and *Salvadora persica* are common associates of *Acacia tortilis*.

In some of the large interior valleys, and on the coastal plains, tugs have been filled by alluvium and wind blown materials so that they are semi-fossil water courses. Nevertheless, they still carry the primary drainage of the area after rain, and consequently retain water for a lot longer than their surroundings, even if they do not flow at the surface. In these places *Acacia tortilis* may grow with *A. mellifera* and the grasses *Andropogon kelleri*, *Bothriochloa radicans*, *Cenchrus ciliaris*, *Chloris myriostachya*, *Chrysopogon aucheri*, *Cymbopogon divaricatus*, *Digitaria rivae*, *Enteropogon somalensis*, *Latipes senegalensis*, *Sporobolus helvolus* and *S. ruspolianus*. These watercourses, although filled in, are conspicuous by virtue of the density and diversity of their vegetation, by contrast with that of the surrounding country.

On the coastal plains along the Gulf of Aden the tugs often flow for short periods twice a year, and there are one or two semi-perennial stretches in the larger tugs where fresh water fish occur. *Conocarpus lancifolius* often reaches 10-20 m in height, with a trunk 60-100 cm in diameter, on sandy tug beds beneath which there is always water. However, this tree is much sought after and its timber is exported to Arabia for dhow building. It also grows on large deltas over the coral shelves, where water drainage to the sea is impeded by dunes and water is retained. If tugs traverse gypsum country their water is saline, and then *Phoenix reclinata* and *Tamarix nilotica* are dominant on their banks, but *Acacia tortilis* is usually also present. Around wells, pools and springs in the coastal strip, *Hyphaene carinensis* is dominant, usually with an outer fringe of *Phoenix reclinata* and *Tamarix nilatica*, and sometimes also with *Cadaba tangifolia*.

Specific sites are too numerous to list, but there are many bullehs and tugs with pools of semi-permanent water in the Nogal Valley. This temporary river has sources in the Ogo

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Mountains and drains ESE across southern Migiurtinia Province to reach the Indian Ocean in Negro Bay (8°00'N/50°00'E). Other tugs and bullehs are present in the Dudo and Lhut Valleys to the north, which also reach the Indian Ocean, but on the Horn of Africa. The fauna of some semi-permanent pools includes *Lutra maculicollis* and *Pelusios sinuatus*, as well as snakes and a variey of birds.

5. The Central Districts

General: A karst region covers much of the central part of the country in which no major wetlands exist, but there are numerous sink holes of various sizes and depths, and a small lake at Bud Bud (4°15'N/46°30'E), which is of some special interest because caves off it contain the endemic blind fish *Phreatichthys andruzzii*. The lake shelters *Alopochen aegyptiacus* and various other waterfowl. In this interior limestone country, shallow sink holes are fringed by *Acacia tortilis* in association with *Euphorbia robecchii* and *Commiphora* spp., but around deep sinkholes *Celtis kraussiana* and *Ficus salicifolia* are the most important associates, or in other sites, *Acacia tortilis* grows with *Ficus glumosa*, *F. vasta* and occasionally *Capparis galeata*. In some saline dune swales along the coast *Acacia tortilis* grows with *Phoenix reclinata*, *Tamarix nilotica* and *Urochondra setulosa*. The environment of this region is not presently endangered, nor is it protected.

Towards the coast there are several large and virtually unexplored pans. These hold surface water only very occasionally, and then only for short periods.

6. Artificial Impoundments

General: There are some 240 small reservoirs constructed for watering livestock.

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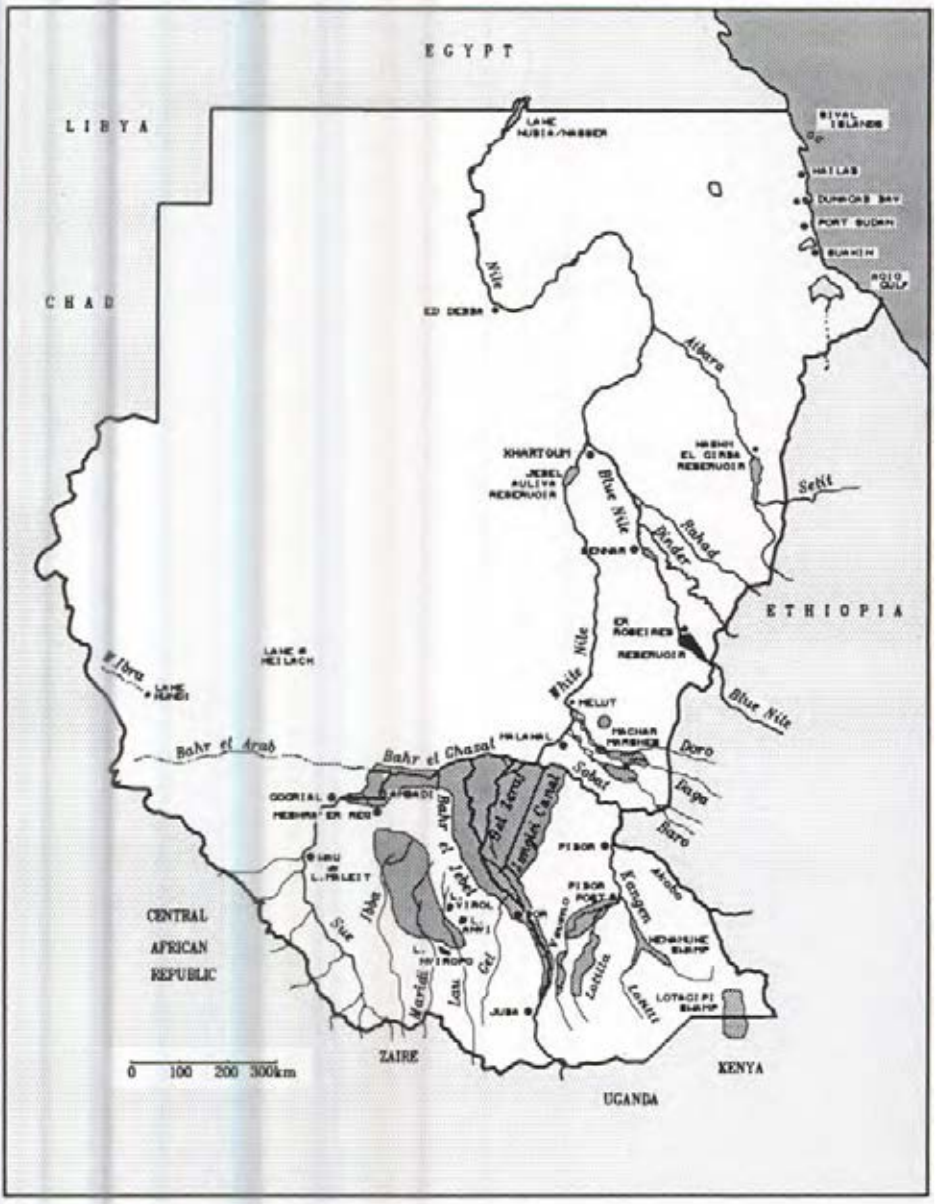

Map of Sudan

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2.8 SUDAN

Introduction

Sudan is the largest country in Africa with an area of 2 505 815 km^2. It had a population of 20 564 364 in 1983, as determined by a census, and thus at that time had a mean population density of 8.2 persons/km^2. It is bounded by Libya and Egypt in the north, by the Red Sea and Ethiopia in the east, by Kenya, Uganda and Zaire in the south, and by the Central African Republic and Chad in the west. It extends approximately 2075 km from south to north between latitudes 3°31' and 22°00'N, and 1810 km from west to east between longitudes 21°50' and 38°34'E.

The highlands of Sudan are all peripheral. Vast flat interior plains, 500-1000 m asl fall towards the Nile Valley which runs N-S through the country. In the east, mountains run parallel to the Red Sea, some 50 km inland, rising to peaks of 2217 m asl at Jebel Asoteriba (21°51'N/36°28'E), 2218 m asl at Jebel Erba (20°46'N/36°46'E), 2260 m asl at Jebel Oda (20°20'N/36°39'E) and to over 2000 m at Jebel Hamoyet (17°36'N/38°01'E) on the Ethiopian border. In the far south, close to the Ugandan border, Mt. Kinyeti (3°56'N/32°53'E), the highest point in Sudan, rises to 3187 m asl, while in the far west, Jebel Gimbala (12°58'N/24°21'E), frequently cited as the highest point, rises to 3071 m asl in the Jebel Marra. This latter range is the largest highland massif in Sudan with more than 8500 km^2 of land surface rising above the 1500 m contour and more than 1500 km^2 over the 2000 m contour.

The Red Sea coastal plain is 10-30 km wide and approximately 1000 km long. The coast is fringed by coral reefs, the inner ones raised, and is highly indented in the central section where wadis from the highest mountains of the coastal range reach the sea.

Almost the whole of Sudan drains to the Nile, except for the area east of the watershed along the coast mountains, and that part west of the Jebel Marra in Darfur, which drains to Lake Chad. The Nile Valley is broad, over 300 km at its narrowest point between the Ethiopian Highlands in the east and the high plateau of Kordofan in the west. The bed of the White Nile (Bahr el Jebel) descends below the 500 m contour about 125 km after crossing into Sudan from Uganda, at a latitude close to 4°20'N. It then flows northwards through the Sudd and the Sudanese savannas and desert, to descend below the 200 m contour, over 16° of latitude farther north. Thereafter it swells into Lake Nubia before crossing the Egyptian border at 22°N, a river distance of more than 3000 km. Drainage from the southwestern corner collects into the Bahr el Ghazal, and that from the southeastern corner into the Sobat River. Both these streams enter the Nile at the northern end of the Sudd. Drainage from the mid-west reaches the Nile via the Wadi el Malik which enters the Nile at Ed Debba (18°01'N/30°54'E). Drainage from eastern Sudan collects into the Blue Nile and Atbara Rivers which enter the Nile at Khartoum (15°33'N/32°32'E) and Atbara (17°42'N/34°00'E) respectively, and into the Wadi Amûr which reaches the Nile 240 km downstream of Atbara, and the Wadi Jabjabah which enters Lake Nasser in Egypt.

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Climate

Northern Sudan is a desert with negligible rainfall and high mean daily temperatures, c. 35°C in summer and 20°C in winter. South of latitude 10°N thunder showers may fall between March and November, with the most widespread rain in mid-summer. The Red Sea coastal plain and the eastern slopes of the coast mountains have a different regime, with most rain falling in winter. Rainfall is convectional in origin and increases steadily to the south of Khartoum, amounting to 1000-1200 mm near the southern border. Potential evaporation reaches and often exceeds 3000 mm/yr in the north, and is always over 1400 mm, even in the humid south.

Vegetation

Sahelian grassland and then scrub form a belt south of the desert, situated roughly between latitudes 16° and 13°30'N, but deflected to higher latitudes in the east along the flanks of the Ethiopian Highlands. South of this, in southwestern districts, a Soudanian savanna, rich in *Isoberlinia* spp., extends to approximately 5°N. This gives way in the central south to edaphic grasslands in the Nile Basin, and these in the southeast to Ethiopian savannas around the flanks of the Ethiopian Massif. Along the borders with Zaire there is a mosaic of rain forest and secondary grassland, while towards the Kenyan border the savanna grades into a zone of bushland dominated by species of *Acacia* and *Commiphora*.

Wetlands

Vast swamps, known as the Sudd, occur along the Bahr el Jebel and its tributaries in upper Sudan, and these enclose several substantial lakes e.g. Lake Ambadi (8°43'N/29°21'E) on the Bahr el Ghazal, Lakes Nuong (7°23'N/30°32'E) and Fajarial (6°17'N/31°28'E) on the Bahr el Jebel, and Lake Nyubor (6°52'N/30°18'E) on the River Lau. To the north and east of the Sudd (north of the Sobat River) lie the Machar Marshes, fed by the Dagar River (Dakar Wenz) and drained by the Adar River to the right bank of the White Nile at a point (10°20'N/32°16'E) just below Melyut. Immediately south of Khartoum, a large area of land between the Blue and White Nile Rivers, above their confluence, was in the past subject to inundation when the flood on the Blue Nile caused the waters of the White Nile to back up. This area, El Geizira, is now irrigated and cultivated whenever conditions are suitable. Three different types of swamps are recognised along the Nile; (a) permanent swamps fringing rivers, lakes, lagoons, channels and subsidiary streams; (b) the most deeply flooded landward fringes of the permanent swamps, which nevertheless experience great seasonal variations in water level and may dry completely in the dry season; and (c) extensive peripheral floodplains around the swamp margins which are flooded shallowly for a few months each year. The latter two categories are often both referred to as toiches and are heavily exploited by people and wildlife during the dry seasons.

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The Jonglei Canal Project provides for a canal 360 km long, bypassing the Sudd between Bor (6°16'N/31°33'E) and the point where the Sobat River enters the White Nile. Excavation began in 1978, but was halted in 1984, for technical, financial and political reasons. However, with the completion of the canal, evaporation in the Sudd will be reduced and far less White Nile water will be lost to Egypt and Sudan. Completion of the canal will significantly alter the ecology of Jonglei Province.

There are a number of impoundments, the largest being the lake on the Nile behind the Aswan High Dam in Egypt which produces Lake Nasser, stretching back into Sudan where it is known as Lake Nubia. The Atbara was impounded (14°53'N/35°55'E) near Khasm el Girba in 1972, and the Blue Nile is dammed at El Roseires (11°49'N/34°20'E) and Sennar (13°33'N/33°37'E).

Surface water is scarce in the north, except in a few guellas in canyons in rocky hills. Some of the larger wadis, e.g. Wadis Malik, Abu Habl and Azum flow for several days in the July-September period, after which pools may persist at the surface for some time. Some pools are persistent, and those on the Wadis Umm Badr, Abu Zabad and Er Rahad may last until the following rainy season. Some pans may hold water until January or February, and brick-making activities in the vicinities of En Nahud (12°43'N/28°26'E), El Obeid (13°10'N/30°12'E) and Umm Ruaba (12°51'N/31°19'E) have created semi-permanent reservoirs or fulas.

South of the parallel 12°N there are a number of perennial lakes such as Lake Keilak (10°48'N/29°19'E) in Kordofan and Lake Kundi (10°30'N/25°15'E) in Darfur, as well as many other rain fed pools and small artificial reservoirs. Small rivers at these latitudes may hold water for parts of the year. Mangrove swamps, salt-marshes and coastal reed swamps are found along the 1000 km Red Sea Coast, reed swamps being best developed in deltas at the mouths of large wadis, e.g. Wadis Oko and Ibib.

List of Wetlands Described

1. Coastal Wetlands
2. Permanent Swamps & Seasonal Floodplains
   - (a) Lotagipi Swamp
   - (b) Kenamuke/Kobowen Swamp
   - (c) The Lotilla Swamps
   - (d) Badigeru Swamp
   - (e) The Veveno/Adiet/Lilebook Swamps
   - (f) The Sudd
   - (g) The Machar Marshes
   - (h) The Dinder/Rahad Floodplain
   - (i) Minor Wetlands
   - (j) The Nile Valley below Malakal
   - (k) The Bahr el Ghazal
   - (l) Floodplains of the southern rivers

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3. Natural Lakes
   (a) Lake Keilack
   (b) Lake Kundi
   (c) Lake Ambadi
   (d) Lake Malcit
   (e) Lake Yirol
   (f) Lake Anyi
   (g) Lake Nyiropo
4. Artificial Impoundments
   (a) Lake Nubia/Nasser
   (b) El Roseires
   (c) Sennar
   (d) Kashm el Girba
   (e) Gebel Auliya

1. Coastal Wetlands

General: Mangrove vegetation occurs sporadically along the entire Sudanese coast, which is in many places fringed by raised Pleistocene coral reefs. Where wadis discharge, waters have cut through the raised reefs, and bays in the reefs provide sheltered habitats for mangroves. Reefs are well developed inshore of the Siyal Islands along a stretch of coast (22°38'-22°44'N/35°53'-36°16'E), and again at Halaib between 22°10' and 22°14'N and 36°40' and 36°46'E. However, the largest and most complex development is in Dungunab Bay (21°00'-21°13'N/37°06'-37°17'E) and between the mouth of the bay and Mukawar Island (20°49'N/37°16'E). Here there are several lines of raised reefs with contemporary reefs to seaward of them. From this place, reefs are apparent almost continuously south to Port Sudan (19°37'N/37°13'E) and they are 1 km wide at Suakin (19°07'N/37°22'E). South of this, reefs extend up to 16 km offshore in an area (18°43'-18°52'N/37°27'-37°41'E) where the coast runs E-W for a distance. Close to the Ethiopian border, the Gulf of Aqiq and its associated lagoons also support mangrove stands (8°00'-8°25'N/38°05'-38°35'E). *Avicennia marina* is the dominant mangrove species, but *Rhizophora mucronata* also occurs here, and *Bruguiera gymnorrhiza* has been reported. Salt marshes are widespread, with floras as described in the regional introduction.

2. Permanent Swamps & Seasonal Floodplains

(A) LOTAGIPI SWAMP

Location: 3°52'-5°04'N/34°18'-35°27'E
Area: c. 720 000 ha total floodplain (c. 215 000 ha in Sudan)
Altitude: 490-500 m asl
Nearest Towns: Nimule (325 km WSW); Juba (350 km W)

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General: The Lotagipi Swamp, 90 km west of Lake Turkana, occupies the lowest part of an endorheic basin straddling the Kenya/Sudan border in the *Acacia-Commiphora* zone. It is a seasonal floodplain, 120 km long, oriented N-S, with a maximum E-W width of 125 km at the northern end, and a mean width of about 60 km, where it extends 85 km into Kenya. There is a large permanent swamp zone along the lowest part of the plain, traversed, from north to south, by the Tarach and Narengor Rivers. The plain is fed by drainage from the Didinga Hills in the west, the Murua Ngithigerr and Mersuk Hills in the south, the Murua Lokwana (Lokuwanamoru) Range to the east and the Ethiopian Highlands in the north. The surrounding land slopes down to the swamp fairly gently on all sides except the north. Here the swamp boundary, close to the 500 m contour, rises quite steeply over a distance of 10 km to the Moru Agippi Plateau at an altitude of 1000 m.

Hydrology & Water Quality: The swamp is flooded during the rains to depths in excess of 1 m. The 9 rivers feeding it are seasonal, but some retain pools of water in their beds during the dry season. A small lake forms in the swamp after the rains at a point 4°59'N/34°41'E in Sudan, but disappears during the dry season. Precipitation over the swamps is 250-500 mm/yr, but reaches 650 mm in the Ugandan catchments and 800 mm in those of Ethiopia.

Flora & Fauna: Essentially it is a grassy floodplain but with reeds and papyrus in the wettest sites, and scattered *Acacia* trees. See regional introduction.

Human Impact & Utilisation: Apparently little utilised. Some hunting occurs here.

Conservation Status: Unprotected.

(B) KENAMUKE/KOBOWEN SWAMP

Location: 5°17'-6°27'N/33°37'-34°06'E
Area: c. 172 000 ha
Altitude: 600-700 m asl
Nearest Towns: Juba (260 km WSW); Malakal (450 km NW)

General: The Kenamuke/Kobowen Swamp is approximately 130 km long and varies in width from 5-30 km. It is oriented N-S and is supplied by a number of rivers, the most important ones rising either in the Didinga Hills to the south or the Ethiopian Highlands to the east. The long narrow swamp occupies the floor of a valley system and drains from the northernmost end by the Kangen River to the Sobat River, and thence to the White Nile. A southeastern outlier at the head of the system is a SE-NW oriented depression, lying immediately below the western side of the Moru Agippi Plateau at an altitude close to 700 m asl. Occasionally, after heavy rains, this latter area floods, and in 1940 for example, it contained a boomerang-shaped lake 25 km long and 12 km wide (5°07'-5°16'N/34°16'-34°28'E). Chief among the tributary streams are the Gerra, Lomen, Chilmun, Chalbono and Nakua Rivers. Rainfall over the system is 800 - 1100 mm/yr.

Flora & Fauna: A broad floodplain grassland swamp containing black cotton soils in the Soudanian savanna zone, with typical floodplain grasses as described in the regional introduction and *Cyperus papyrus*, *Miscanthidium violaceum*, *Phragmites mauritianus* and *Typha domingensis* in the wettest sites. A rich mammal flora is present including

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Hippotragus equinus, *Kobus kob leucotis*, *Loxodonta africana*, *Panthera pardus*, *Redunca arundinum* and *Syncerus caffer*. See regional introduction.

Human Impact & Utilisation: The floodplain is impassable during the wet season, but there is some fishing, and the swamp area is relatively undisturbed, although traditional hunting occurs in the surrounding *Acacia* woodlands.

Conservation Status: Largely contained within the Boma National Park.

(C) THE LOTILLA SWAMPS

Location: 5°02'-6°43'N/32°34'-33°15'E
Area: 219 000 ha
Altitude: 415-620 m asl
Nearest Towns: Pibor (at N end); Juba (170 km W of S end)

General: The swamps are situated in the valley of the Lotilla River which has its headwaters in the Didinga Hills and flows north to join the Kangen River at Pibor Post (6°49'N/33°08'E). The swamps comprise two major blocks, a southern block 140 km long and up to 27 km wide, which contains patches of swamp forest on the plateau at about 600 m asl, and a smaller northern block, c. 95x7 km which ends some 30 km above Pibor. The course of the river is not always clear in the upper swamp, but it is well defined where it meanders through the lower northern swamp.

Flora & Fauna: This is a typical floodplain system dominated by grasses, as described in the regional introduction, with areas of permanent swamp dominated by *Cyperus papyrus*, *Phragmites mauritianus* (or *P. karka*?) and *Typha domingensis* along the river.

Human Impact & Utilisation: This swamp is very sparsely inhabited and comparatively undisturbed. Some fishing occurs on the floodplain and in the rivers, and there is some hunting.

Conservation Status: Unprotected.

(D) BADIGERU SWAMP

Location: 4°41'-5°31'N/31°57'-32°31'E
Area: 550 000 ha
Altitude: c. 480-700 m asl
Nearest Towns: Juba (75 km SW); Bor (90 km NW)

General: Badigeru Swamp is supplied by the Kinyeti River and other streams which drain the northern slopes of the Kinyeti Massif (3187 m) on the Sudan/Uganda border. The swamps are discontinuous and are oriented SSW-NNE. They are 110 km long and up to 25 km wide at high water, but have a mean width of just 5 km. Water from the northern end of Badigeru Swamp may filter east to the Veveno River basin and thence eventually to the Sobat and White Nile, or west to the Bahr el Jebel above Mongalla (5°12'N/31°46'E). Rainfall over the swamps varies from 800-900 mm/yr but is over 2000 mm/yr in the upper catchments.

Flora & Fauna: A valley swamp with papyrus along the river and typical grasses on the floodplain. See regional introduction.

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Human Impact & Utilisation: Little disturbed and little utilised except for hunting and fishing on the floodplain.

Conservation Status: Unprotected.

(E) THE VEVENO/ADIET/LILEBOOK SWAMPS

Location: 5°27'-7°04'N/32°00'-33°03'E
Area: 645 000 ha
Altitude: 400-500 m asl
Nearest Towns: Bor (47 km W); Pibor Post (at NE end)

General: This vast area of seasonal swampland lies to the east of the Sudd and is oriented SW-NE. It is 215 km long and up to 60 km wide. Run-off, from the highlands to the south and southeast, flows northwestwards until it meets the Veveno River which crosses its path from SW to NE. The Veveno leaves the swamp at the northeastern end, to join the Lotilla River, and thereafter the combined stream joins the Pibor River. North of the Veveno, water drains north or northwestwards until it collects into tributaries of the Adiet (Manaam) River, which flows outside the swamp, on the northern side, parallel with the Veveno. The Lilebook River drains the far northeastern end of the swamp, flowing northeastwards between, and in parallel with, the Adiet and Veveno Rivers. Like them, it enters the Pibor River *en route* to the Sobat and the White Nile. Broad belts of permanent swampland occur along all these rivers.

Flora & Fauna: See regional introduction. A seasonal river valley/floodplain swamp system with large areas of permanent swampland. Papyrus, *Phragmites*, *Miscanthidium* and *Typha* dominate the permanent swamps, and floodplain grasses the seasonal swamps.

Human Impact & Utilisation: The southwestern and central parts of the system are very sparsely inhabited, but there are numerous villages along the Kangen/Pibor River at the northeastern end of the swamp. The floodplains are fished and the area is subject to hunting.

Conservation Status: Unprotected.

(F) THE SUDD

Location: 4°55'-9°37'N/29°59'-31°57'E
Area: c. 1 650 000 ha (permanently inundated in 1980)
Altitude: 380-450 m asl
Nearest Towns: Mongalla (at S end); Malakal (at N end)

General: Permanent swamps begin on the west bank of the Bahr el Jebel 10 km below Juba, at a point (4°55'N/31°38'E) near Gondokoro Village, and on the east bank (5°00'N/31°41'E) near the village of Tibari, some 20 km below Juba. Below Mongalla (5°12'N/31°46'E) the river channel widens in places to more than 2 km, bifurcates at a latitude of 5°30'N, and flows in three or more channels for some distance below Buka (5°47'N). The banks, which are generally clearly defined in the upper reaches of the Sudd, become lower and finally disappear below Bor (6°14'N/31°34'E). Then the swamp widens, with numerous lakes and parallel streams, all beset with islands of floating papyrus. Between Mongalla and Bor the swamps are 10-13 km wide over a straight line

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distance of 115 km, but below Bor they widen to 25 km and with the peripheral floodplains are wider still. Major channels occur to the east, and there are several large lakes enclosed by permanent swamps on both banks, e.g. Lakes Fajarial (6°22'N/31°26'E) and Nuong (7°26'N/30°34'E) on the west bank. Both have open water areas close to 2500 ha, and there are at least 40 other lakes between Bor and Zeraf Cuts (7°46'N/30°32'E) on this stretch of the river. At Zeraf Cuts two canals on the east bank join the main channel of the Bahr el Jebel with the Bahr el Zeraf, but only the southern canal is kept open. Here, water flows from the Bahr el Jebel to the Bahr el Zeraf, which re-enters the Bahr el Jebel near Tonga (9°22'N/31°06'E) and thus isolates Zeraf Island between the two rivers. This island, east of the Bahr el Jebel, 180 km long and up to 65 km wide, was once mostly dry land, but following the rise in water levels which has been sustained since the 1963-64 floods, it has become a seasonal floodplain. Meanwhile the seasonal floodplain on the west bank of the Bahr el Jebel is 25 km wide in places and at Lake No (9°31'N/30°27'E), 190 km due north of Zeraf Cuts, the Bahr el Jebel receives the Bahr el Ghazal. This river flows NE for 200 km through a broad swampy tract to reach Lake No, a shallow lake of some 2000 ha. From Lake No, the river, now often known as the White Nile, swings abruptly eastwards for 115 km to a confluence with the Sobat River (9°22'N/31°33'E). It then flows northeastwards, past Malakal, having left the Sudd above the Sobat. The riverine distance through the Sudd, between Gondokoro and the Sobat confluence exceeds 680 km, and the total area of permanent wetland, including lakes and open river surface, is in the region of 1 650 000 ha (Mefit-Babtie, 1983), to which can be added at least a further 1 500 000 ha of seasonally inundated floodplain.

Hydrology & Water Quality: Long term variations in the amount of water discharged from the East African lakes are well documented. Prior to 1960 the mean annual inflow to the Sudd at Mongalla was 26 831 billion m^3, but between 1961-1980 it was 50 324 billion m^3, while the respective mean annual outflows at Malakal were 14 158 and 21 387 billion m^3. The high water levels after 1961 led not only to a great increase in total wetland area, but also to a corresponding increase in loss by evaporation. While current outflow is 58% of inflow, the apparent reduction of 42% does not take account of the input by direct precipitation. This ranges from 780-910 mm/yr over the swamps, and thus amounts to between 23.4 and 27.3 billion m^3/yr assuming a swamp area of 3 million ha. The total loss by evaporation and seepage can thus amount to as much as 56 237 billion m^3/yr, considerably more than the riverine inflow at Mongalla, and the total input from all sources can exceed 77 624 billion m^3/yr. The extent of the permanent swamp reflects annual riverine inflow closely, since this has proved more variable than direct precipitation over the past 82 years. During the low water phase of 1950-52, the area of permanent swamp was reduced to about 300 000 ha, while by 1980 it had increased to 1 650 000 ha. During these 30 years, riverine inflow increased by some 24 000 billion m^3, but outflow only by about 7250 billion m^3, i.e. approximately 66% of the additional riverine inflow was lost in the swamps.

The annual input from the Bahr el Ghazal is of the order of 925 million m^3, with normal peak flow rates of 46 m^3/sec, although rates of 92 m^3/sec occur in exceptional years. This is only a fraction of the volume carried by the Bahr el Jebel at Lake No, but the waters of the White Nile back up to Lake No, and even above it, when the Sobat River is in flood.

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The seasonal floodplain area is greater in the east than the west. Often direct precipitation seals the black cracking clays of the floodplains before the riverine flood. Often the flood first begins to rise as a consequence of surface run-off from local rain which moves on a front in a northwesterly direction down very shallow gradients. It is the seasonal floodplains which account for the great evaporative losses from the system, since comparatively little water returns from the floodplains to the river as the flood subsides, and the eastern areas at least, dry very quickly. Nevertheless, there are many isolated pools on the floodplain which persist well into the dry season.

Water quality varies seasonally and spatially. In the main channels water temperatures vary between 22 and 30°C, but higher temperatures are recorded on the floodplain as the water is receding. Transparency is greatest during the dry season, and over the year Secchi depths in the channels range from 17-150 cm, while conductivity ranges from 150-370 µSiemens/cm at 20°C. The waters are generally well oxygenated in the channels, but decomposition in the swamps invariably leads to low oxygen concentrations. River water has been found to have lowered oxygen concentrations during the flood, possibly because organic materials are flushed out of the swamp at this time. The river water and swamps become more alkaline in the dry season over a pH range of 6.7-8.4. The principal cation concentrations are calcium 4-9 mg/l; magnesium 3-10 mg/l; silicon 1-14 mg/l and iron 0.05-1.3 mg/l, while the principal anion concentrations are chloride 4-12 mg/l; sulphate 0.5-10 mg/l; phosphate 0.005-0.14 mg/l; nitrate 0.006-0.06 mg/l and ammonium 0.006-0.11 mg/l. The concentrations of silicon, iron and ammonium increase northwards, i.e. downstream, whereas those of nitrate, phosphate and sulphate decrease.

In the Sudd, every gradation from riverine to lacustrine conditions may be found. There are widenings of river channels, through which flow rate is reduced, extensive basins with tenuous river connections with long retention times, and apparently isolated shallow water bodies. Few of these 'lakes' have depths greater than 3 m at high water. Lakes enclosed by papyrus tend to have clear water throughout the year. Shallow lakes, with much submerged vegetation, become saturated with oxygen, but the interstitial waters of the swamps are strongly reducing.

Flora & Fauna: *Cyperus papyrus* is dominant at riversides, forming a riparian belt which extends right through the swamps. *Phragmites karka* and *Vossia cuspidata* are associated with the papyrus and, in places, *Phragmites* dominates swamps behind the papyrus. Elsewhere, *Typha domingensis* forms enormous pure stands behind the papyrus, and this species has probably shown the greatest increase since the water level rise of 1961-62. *Eichhornia crassipes*, which was first recorded on the Nile in 1950, occupies the niche formerly held by *Pistia stratiotes*. However, this latter species is still present in the Sudd although diminished in importance. Other common macrophytes are *Ceratophyllum demersum*, *Najas pectinata*, *Nymphaea lotus*, *Ottelia* spp., *Potamogeton* spp., *Trapa natans* and *Vallisneria spiralis*. *Oryza longistaminata* is the predominant floodplain grass, with *Echinochloa pyramidalis* and *Vossia cuspidata* its most widespread associates.

The invertebrate zooplankton is abundant and rich in terms of species, but the zoobenthos is impoverished and comprises mainly oligochaetes, but molluscs are important in the lakes.

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Just under 100 species of fish have been recorded from the Sudd including 31 siluroids, 16 characoids, 14 cyprinids, 11 mormyrids, 8 cichlids and 7 cyprinodonts. Many species leave the rivers and move onto the floodplains to spawn as the flood rises, returning to the permanent watercourses when it recedes. The most numerous species are *Alestes dentex*, *Auchenoglanis biscutatus*, *Chelaethiops bibie*, *Citharinus citharus*, *Distichodus rostratus*, *Eutropius niloticus*, *Heterotis niloticus*, *Hydrocynus forskalii*, *Labeo niloticus*, *Lates niloticus*, *Micralestes acutidens*, *Mormyrus cashive*, *Oreochromis niloticus* and *Synodontis frontosus*. *Aplocheilichthys* spp., *Clarias* spp., *Epiplatys* spp., *Gymnarchus niloticus*, *Heterotis niloticus* and *Polypterus bichir* are associated with the papyrus and *Typha* swamps.

Frogs are abundant. There are several species of snakes in the swamps, and *Crocodylus niloticus* is still widespread. The Sudd is important to migratory birds, and has a rich avifauna, including numerous water birds and species associated with reeds as listed in the regional introduction. Numerous weavers, warblers, flycatchers (including *Alseonax aquatica*), kingfishers, ducks, herons, ibises, egrets, storks (including *Balaeniceps rex*), kites, crows and vultures (*Necrosyrtes monachus*) are found here. Large mammals found in the wetland system include *Alcelaphus buselaphus*, *Damaliscus korrigum*, *D. lunatus*, *Hippopotamus amphibius*, *Hippotragus equinus*, *Kobus ellipsiprymnus*, *K. megaceros*, *Loxodonta africana*, *Panthera pardus*, *Redunca redunca* and *Syncerus caffer*.

Human Impact & Utilisation: Traditionally cattle are driven onto the floodplains for grazing as the floods recede. The cattle and their herders follow established routes and set up cattle camps along the way, from which they hunt and fish in the swamps. Fishing is mostly spear fishing, and *Clarias*, *Gymnarchus*, *Heterotis*, *Polypterus* and *Protopterus* are prominent in the catches. It is estimated that some 400 000 people live in the Sudd area. There are few villages and communications are seriously disrupted during the flood season, and, since the 1960-61 water level rise, the area available for seasonal grazing has decreased while that available for permanent fishing has increased. Hence, in recent years, the number of permanent fishing camps in the Sudd has increased greatly. Here fishing is chiefly by staked gill nets, but cast nets, seines and drift nets are also used. Fish to be sent to market are mostly sun-dried, but a salt-fish industry, operated by Arab merchants and the Government Fisheries Department has recently been established. The catches comprise, in decreasing order of importance, species of *Distichodus*, *Citharinus*, *Heterotis*, *Oreochromis*, *Lates*, *Gymnarchus*, *Mormyrus*, *Clarias* and *Labeo*. Nomadic fishermen also visit the swamps. Coming from the western provinces they set up temporary camps on the west bank, often on lakes shores such as those of Lake No. An FAO/UNDP Sudd Fisheries Development Programme has been established with a base at Bor, but at present, reliable predictions as to the maximum sustained yield from the Sudd are unavailable. Certainly the Sudd is presently underfished, and equally certainly some past estimates of MSY (e.g. 200 000 tonnes) are too high.

Hunting has always been an important activity on the floodplains, being concentrated around the villages, with *Alcelaphus buselaphus*, *Damaliscus lunatus* and *Gazella dama* the principal species taken.

It is intended to reduce water loss from the Sudd by channelling water around the swamps through the Jonglei Canal, which will run from a point below Bor, near Jonglei Village, to a point on the Sobat River, just above its confluence with the White Nile. The canal

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will be 360 km long, 50 m wide and 4 m deep and will divert some 20 million m^3 of water per day, or 7.3 billion m^3/yr, around the swamps. The canal will be navigable and will be constructed beside an allweather road, both of which will improve communications in the area. However, it is clear that the canal will bring about a diminution of the Sudd and a change in the distribution of wetlands in the area. Predictions are that the permanent swamps will shrink by 21-25% and the floodplains by 15-17%, provided that the flow of the Nile does not fall from its present high levels. Should it decline to its 1950-52 level however, an operational Jonglei Canal would bring about a drastic reduction in the size of the Sudd. Drijver & Marchand (1985) analyse the present and future consequences of the construction of the Jonglei Canal.

The Nile is of great importance for navigation and the main waterways are kept clear of sudds by cutting or by the use of explosives. *Eichhornia crassipes* obstructs minor waterways and passages have to be cleared by local fishermen, but in addition weevils, *Neochetina* spp., have been introduced as a biological control. Harvesting and utilisation of *Eichhornia* has also been suggested.

Conservation Status: The Sudd is one of the most important wetlands in Africa and three areas have been designated as game reserves. These are Zeraf Island (675 000 ha), Shambe (100 000 ha) on the west bank and Mongalla (7500 ha) on the east bank.

(G) THE MACHAR MARSHES

Location: 8°27'-9°58'N/32°11'-34°09'E
Area: c. 900 000 ha (500 000 in Sudan)
Altitude: 290-600 m asl
Nearest Town: Malakal (60 km W)

General: The Machar Marshes are not well mapped. They comprise a vast area of swamps and seasonal floodplains interlaced by an intricate reticulate system of watercourses and numerous lakes. Run-off from direct precipitation, and drainage from the Ethiopian Highlands, tends to move across the 'marshes' to, or towards, the White Nile below Malakal. The wetland system extends at least 200 km from north to south and 180 km from east to west and is situated north of the Sobat River. Streams from the Ethiopian Highlands descend quite abruptly to a very flat area around 300 m asl, and on this plain the rivers break up into the complex of minor watercourses mentioned above, often losing their integrity in the swamps. The wetland system extends over the border into Ethiopia in the SE, where there is at least 400 000 ha of wetland, much in the valley of the Gambela River. The major river in Sudan is the Daga, which becomes the Khor Daga and then the Khor Adar.

Flora & Fauna: There are extensive grassy floodplains and permanent herb swamps dominated either by papyrus along the innumerable watercourses, or by *Phragmites* and *Typha* away from them. See regional introduction for details of species found in the area.

Human Impact & Utilisation: Little utilised. The area is sparsely populated. Cattle are grazed on the floodplain areas during the dry season, and hunting and fishing occur in the wetland system.

Conservation Status: Unprotected.

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(H) THE DINDER/RAHAD FLOODPLAIN

Location: 11°45'-12°47'N/34°46'-35°49'E
Area: c. 500 000 ha
Altitude: 700-800 m asl
Nearest Towns: Sennar (130 km NW); Khartoum (360 km NW)

General: The floodplain occupies the land between the Dinder and Rahad Rivers which flow down from the Ethiopian Highlands to a flat plain, sloping gently northwestwards towards the Blue Nile. A number of tributary rivers, e.g. the Galegu, with numerous ox-bow lakes, lie between the two major rivers, and much of the intervening land may be flooded during the rainy season in the mountains. Direct precipitation over the floodplain amounts to 800 mm/yr in the south and 600 mm/yr in the north, and is received between June and October. Daily maximum temperatures range from 20°C in January to 44°C in May.

Flora & Fauna: Gallery forests subject to inundation, occur along the watercourses and contain *Acacia sieberana*, *Ficus* spp., *Mimosa pigra*, *Tamarindus indica* and *Ziziphus abyssinica*, or in places stands of *Hyphaene thebaica*. Areas of thornbush savanna are also subject to inundation and are covered by *Acacia seyal* and *Balanites aegyptiaca*, with *Sorghum* and *Brachiaria* spp. the dominant grasses. In swampy lakes *Echinochloa* spp., *Ipomoea aquatica*, *Leersia hexandra* and *Nymphaea* spp. are dominant. *Oryza longistaminata* and *Echinochloa pyramidalis* occur on the most deeply flooded parts of the plain, but with *Cynodon dactylon*, *Hyparrhenia* spp., *Panicum* spp., and *Themeda triandra* covering those parts of the floodplain which are less deeply inundated. The swampy areas around lakes, lagoons, pans, pools and depressions are very important grazing sites for wildlife during the dry season. Large mammals present include *Damaliscus lunatus*, *Hippotragus equinus*, *Kobus ellipsiprymnus*, *Redunca redunca*, *Syncerus caffer*, *Tragelaphus scriptus* and *T. strepticeros*. *Panthera pardus* is the chief predator. *Acinonyx jubatus*, *Crocuta crocuta*, *Giraffa camelopardalis*, *Ourebia ourebi*, *Hyaena hyaena* and *Panthera leo* are present in the dry season, as is *Struthio camelus*.

Human Impact & Utilisation: While the area is fully protected, poaching and illegal herding are threats to both the vegetation and wildlife.

Conservation Status: The entire wetland system is protected in the Dinder National Park, which has also been designated a Biosphere Reserve. There is an extensive (270 000 ha) buffer zone immediately to the west, but illegal farming has penetrated this latter zone, and up to 60% of the park is burnt each year, either by park rangers or nomadic herdsman. The combination of burning and grazing by cattle has altered the flora significantly in recent years. The dry season is very harsh and the wildlife in the park (wetland) has always depended upon adjacent grazing areas, which the buffer zone helps to protect. Thus the additional pressure created by the presence of herds of cattle is very detrimental, in addition to which it is believed that serious outbreaks of disease among the wildlife have been introduced by cattle driven onto the floodplain in the dry season.

(I) MINOR WETLANDS

General: Seasonally flooded areas with some permanent swampland occur at innumerable sites on the plains on either side of the White Nile below Malakal. The principal

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wetlands known on the eastern side occupy 50 000 ha (10°30'-10°46'N/32°45'-33°00'E); 15 000 ha (10°32'-10°37'N/33°16'-33°29'E); 5250 ha (10°57'-11°00'N/33°00'-33°08'E); 9750 ha (11°49'-11°55'N/33°01'-33°10'E) and 5000 ha (11°50'-11°58'N/32°51'-32°55'E). On the western side they occur at 10°08'-10°18'N/31°48'-31°57'E (9000 ha); 10°09'-10°19'N/31°35'-31°49'E (18 000 ha); 10°31'-10°37'N/31°52'-32°00'E (6600 ha) and 11°02'-11°05'N/31°39'-31°46'E (7500 ha). Some of these wetlands contain permanent or semi-permanent lakes. They are little utilised and most occur in very sparsley populated areas. None is protected.

South of Malakal there are numerous swamps on the plateau to the west of the Nile Valley, i.e. west of the Sudd at altitudes between 400-600 m asl. Wetlands, most incorporating areas of permanent swamp have been mapped around the centres 5°05'N/31°18'E (5000 ha); 5°10'N/31°06'E (1200 ha); 5°11'N/29°13'E (3000 ha-720 m asl); 5°19'N/31°25'E (4500 ha); 5°25'N/31°33'E (2000 ha); 5°25'N/31°24'E (5200 ha); 5°27'N/31°29'E (4000 ha); 5°34'N/30°07'E (3000 ha); 5°36'N/31°13'E (1500 ha); 5°48'N/30°03'E (5500 ha); 6°05'N/29°52'E (6800 ha); 6°14'N/29°46'E (3500 ha); 6°36'N/29°41'E (3200 ha); 6°41'N/29°55'E (5600 ha); 6°48'N/28°45'E (2500 ha); 6°51'N/29°46'E (16 000 ha); 6°52'N/29°35'E (2000 ha); 6°52'N/29°59'E (9000 ha); 6°54'N/29°11'E (4000 ha); 6°55'N/29°56'E (4000 ha); 7°02'N/29°13'E (3000 ha); 7°05'N/29°04'E (4000 ha); 7°12'N/30°11'E (31 500 ha); 7°29'N/29°37'E (8400 ha); 7°45'N/29°43'E (5000 ha); 7°46'N/29°35'E (6000 ha); 7°52'N/29°51'E (6000 ha); 7°53'N/29°57'E (4000 ha) and 8°00'N/29°38'E (9600 ha).

(J) THE NILE VALLEY BELOW MALAKAL

General: The Nile flows in a broad sandy trough below Malakal, descending northwards at a mean gradient of 1:19 000. Within the trough, which may be 6 km wide in places, the river channel is accompanied by old abandoned channels on both banks. During the flood the entire trough is inundated, but in dry season the river is confined to its incised channel. Swamps, 200-300 m wide, line the riverside, but in places these may expand, and between 11°03' and 11°52'N for example, the swamp belt reaches 20 km in width locally. The channel is island-studded between latitudes 12°30' and 15°00'N, but then bifurcates and even trifurcates. The incised sandy trough flattens and the river develops a floodplain at latitude 13°30'N which persists, 3-10 km wide, to latitude 15°00'N, after which the river broadens into the lake behind the Jebel Auliya Dam (15°15'N). In total the floodplain covers 113 000 ha. Below the dam there is another floodplain which leads into Khartoum and the confluence with the Blue Nile. When the latter stream is in flood, water in the White Nile backs up; hence the floodplain above Khartoum. The Jebel Auliya Reservoir contains and regulates the flow of the White Nile when the Blue Nile is in spate. Below Khartoum the Nile receives the Atbara River on the right bank, its final major tributary, and follows a course locally and narrowly fringed with swamps through the desert until it enters Lake Nubia at Ambikol (21°24'N/30°54'E), just above the Egyptian border.

(K) THE BAHR EL GHAZAL

General: Swamps and floodplain accompany the Bahr el Ghazal from Meshra' er Req (8°26'N/29°16'E) through Lake Ambadi virtually continuously to Lake No and the

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confluence with the Bahr el Jebel. The perennial swamp belt is 10 km wide from Meshra' er Req downstream for 70 km, but it then tapers over the succeeding 60 km, while a floodplain behind the swamps widens and eventually, to the south of Lake No, merges with the floodplain of the Bahr el Jebel. There are some 90 000 ha of perennial swamps on the river, the flora and fauna of which are similar to that of the Sudd. No part of the Bahr el Ghazal is protected. Artisanal fisheries occur on the river.

(L) FLOODPLAINS OF THE SOUTHERN RIVERS

General: Mean annual rainfall over the provinces of Western Equatoria and El Buheyrat in southern Sudan ranges from 800-1400 mm and, because most of this is received over a period of just a few months, the intensity of precipitation is high and the rivers rise rapidly and overtop their banks. Thus there are floodplains on the Pongo, Busseri, Wau, Numatinna, Yabu, Mbangu, Biki, Sue, Lesi, Ibba, Maridi, Era, Lau and Gel Rivers. These rivers all flow through the Soudanian Savanna zone down to the Nile Valley and the Sudd, their waters reaching the Nile on the west bank, largely by diffuse drainage through the swamps. Rainfall decreases to the west in these provinces and the western rivers are not perennial, while those of the east are. *Andropogon gayanus* and *Setaria sphacelata* are important grasses in the headwater floodplains, where *Mitragyna inermis* and *Terminalia macroptera* are scattered trees. The latter may however, fill depressions, and is then usually accompanied by *Brachiaria jubata* as the dominant grass. Long stretches of these rivers are fringed by gallery forest, subject to seasonal inundation, carrying trees such as *Acacia sieberana*, *Diospyros mespiliformis*, *Khaya senegalensis*, *Ficus sycomorus*, *Tamarindus indica* and *Syzygium cordatum*, behind which there are areas of floodplain which carry savanna vegetation where *Hyparrhenia cyanescens*, *Pennisetum polystachion* and *P. unisetum* are the dominant grasses and *Borassus aethiopum*, *Mitragyna inermis* and *Terminalia macroptera* are common but scattered trees. The floodplains in these provinces have not been mapped comprehensively, but there are more than 4250 km of major river channels, and from the few areas indicated as subject to inundation on available maps an estimate of 500 000 ha of floodplain appears conservative.

3. Natural Lakes

(A) LAKE KEILACK

Location: 10°49'N/29°19'E
Area: 3000 ha (at high water)
Altitude: c. 450 m asl
Nearest Towns: El Obeid (277 km NNE); Malakal (300 km ESE)

General: This endorheic lake is situated on the plateau of Kordofan. It is perennial but shrinks to about 500 ha in the dry season and expands to over 3000 ha in the wet season. Maximum depth is about 4 m at high water and 2 m at low water. The lake is often turbid with Secchi depths averaging 50 cm. It is generally well oxygenated, but little is known of its water chemistry. The floor of the perennial lake is covered by beds of *Ceratophyllum demersum* and *Najas pectinata*, with carpets of waterlilies, both *Nymphaea caerulea* and *N. lotus*, and with *Aeschynomene elaphroxylon* and an emergent species

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of *Polygonum* around the margins, together with reeds and sedges. 94 invertebrate species have been recorded, together with a number of fish, including *Clarias lazera*, *Schilbe mystus* and *Tilapia zillii*. Frogs, toads and snakes are also present and a number of birds have been recorded, the latter including 6 herons and *Haliaeetus vocifer*. There is an artisanal fishery and the lake is an important watering site for nomadic cattle herders, reputedly from as far away as Nigeria, as well as for large mammals of the Soudanian savannas. The lake is unprotected.

(B) LAKE KUNDI

Location: 10°30'N/25°16'E
Area: c. 1200 ha (at high water)
Altitude: c. 460 m asl
Nearest Towns: El Fasher (350 km N); Khartoum (1225 km NE)

General: This endorheic lake is situated in Southern Darfur below the mouth of the Wadi Ibra, the headwater tributaries of which drain the southern slopes of the Jebel Marra. The lake is perennial, but contracts to a very small size, c. 100-200 ha in the dry season. Details of its hydrology are not known. It probably has a maximum depth of about 3 m in the wet season and 2 m in the dry. The waters give an almost neutral reaction, but details of the water chemistry are not known. The perennial lake flora is covered by beds of *Ceratophyllum demersum*, *Najas pectinata* and other submerged aquatics, and there are waterlilies at the surface. Among the fishes, *Clarias lazera* and *Tilapia zillii* have been recorded and some 30 birds, including several anatids (*Nettapus auritus*, *Plectropterus gambensis*, *Sarkidiornis melanotos*), *Haliaeetus vocifer*, *Mycteria ibis*, and herons, egrets and sandpipers. There is an artisanal fishery, birds are hunted by local villagers, and the lake is a watering point for wildlife and for the cattle of nomadic herders. The lake is unprotected.

(C) LAKE AMBADI

Location: 8°38'-8°43'N/29°17'E
Area: c. 1000 ha
Altitude: 388 m
Nearest Towns: Malakal (280 km ENE); Juba (500 km SE)

General: The lake is formed by a widening of the channel of the Bahr el Ghazal. It is 10 km long, 1-3 km wide, and has a maximum depth of 3 m. It is set in perennial herb swamps on an otherwise featureless plain. The Bahr el Ghazal flows in at the south and out at the north, while the River Jur flows in on the western side. The principal input is from the Jur, a seasonal stream, the flow rate of which may reach 35 million m^3/day in September. The water of the lake is generally clear with Secchi depths exceeding 2 m. It is acidic, with a pH range of 6.4-6.8, and moderately well oxygenated. The floor is covered by a mat of vegetation dominated by *Ceratophyllum demersum*, *Myriophyllum spicatum*, *Najas pectinata* and *Potamogeton pectinatus*. The peripheral vegetation is dominated by *Vossia cuspidata*, with some *Echinochloa*, and floating carpets of *Eichhornia crassipes*. It has a distinctive fish fauna, supports an artisanal fishery, and is unprotected.

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(D) LAKE MALEIT

Location: 7°52'-8°03'N/28°33'-28°40'E
Area: 25 000 ha (5000 ha maximum open water)
Altitude: c. 400 m asl
Nearest Towns: Wau (65 km WSW); Bor (380 km SE)

General: This lake occupies the floor of a small endorheic basin. At high water in a wet season it may exceed 25 km in length and 4 km in width, developing an open water surface in excess of 5000 ha. The lake is surrounded by a perennial swamp and a broad floodplain, the entire wetland having an area of approximately 25 000 ha, with a maximum width of 12 km in the south. The lake is oriented SW-NE and is shallow, with maximum high water depths in the vicinity of 4 m. Details of its water chemistry are not known. The bed of the perennial lake is densely vegetated, and the surrounding swamp contains *Aeschynomene elaphroxylon*, *Cyperus papyrus*, *Phragmites karka*, *Typha domingensis* and several minor sedges. It contains several species of fish, including *Clarias lazera*, *Gymnarchus niloticus*, *Polypterus bichir* and *Protopterus aethiopicus*, and has a rich amphibian fauna. It is visited by typical reptiles and the avifauna includes ducks, geese, herons, egrets, weavers, warblers, kingfishers and *Haliaeetus vocifer*. The mammals are similar to those found in the Sudd swamps (see regional introduction) and there is an artisanal fishery. The lake is not protected.

(E) LAKE YIROL

Location: 6°33'-6°37'N/30°27'-30°31'E
Area: 1600 ha
Altitude: c. 440 m asl
Nearest Towns: Shambe (65 km NE); Juba (230 km SE)

General: Lake Yirol is 9 km long, 2.5 km wide at maximum, and is fed by a local stream. It is shallow, swamp-fringed, has a peripheral floodplain and drains from its southern end to the Lau or Yei River, which eventually peters out in the Sudd. The lake supports a small artisanal fishery, is an important watering point for wildlife and is unprotected.

(F) LAKE ANYI

Location: 6°25'-6°28'N/30°34'-30°38'E
Area: 1400 ha
Altitude: c. 450 m asl
Nearest Towns: Shambe (75 km NE); Juba (210 km SE)

General: This lake is shaped like an inverted L, with each arm 6.5 km long and 1-2 km wide. It is shallow, swamp-fringed, and has a peripheral foodplain. It has a rich avifauna and supports a small artisanal fishery. It is fed by two streams at the southern and, the largest of which, the Rara River, is 40 km long and rises only a few metres higher than the lake. It appears to drain to the Lau or Yei River from the northwestern end. It is unprotected.

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(G) LAKE NYIROPO

Location: 6°08'N/30°11'E
Area: c. 700 ha
Altitude: 500 m asl
Nearest Towns: Bor (150 km W); Juba (210 km SE)

General: This small lake is 5 km long and 1.5 km wide at high water, and is oriented SW-NE at an altitude of 500 m. It is a shallow lake, probably not exceeding 3 m in depth, and drains to the Lau River, 2 km distant from its northern end. It is situated 150 km west of the Bahr el Jebel as it flows past Bor. It is a permanent lake, with dense beds of aquatic vegetation and fringing swamps. It has a narrow peripheral floodplain and is unprotected.

4. Artificial Impoundments

(A) LAKE NUBIA/NASSER

Location: 20°27'-23°58'N/30°07'-33°15'E
Area: 685 000 ha (104 000 in Sudan)
Altitude: 183 m asl (at capacity)
Nearest Towns: Dongola (260 km S); Khartoum (632 km SSW)

General: This is the southern (Sudanese) sector of the Lake created by the construction of the Aswan High Dam, full details of which are given in section 2.3 Egypt. The lake is set in the desert and the surrounding country is virtually unvegetated. It can be divided into three sectors. The northern sector (in Egypt) is fully lacustrine and extends south from the dam to Tushka. The middle sector, which extends from Egypt into northern Sudan, is lacustrine in character for most of the year, but exhibits riverine features during the flood. The southern sector, which is entirely within Sudan, is essentially riverine. The fish fauna of the lake changes progressively in moving north, because of the changing character of the lake, and hence although the commercial fishery in Sudan produces a similar spectrum of species to that in Egypt, the proportions of each species in the catch tends to be different. As in Egypt, the relative importance of different species in the catch has changed from what it was immediately after impoundment, because the fish fauna of the lake has now stabilised and the number of species regularly recorded in the Sudanese part of the lake has decreased, from 40 in 1967 to 20 in 1979.

Flora & Fauna: The fishes now common in the lake are *Alestes baemose*, *A. dentex*, *A. nurse*, *Bagrus bayad*, *B. docmac*, *Barbus bynni*, *Distichodus niloticus*, *Eutropius niloticus*, *Hydrocynus forskalii*, *Hyperopisus bebe*, *Labeo coubie*, *L. horie*, *L. niloticus*, *Lates niloticus*, *Oreochromis galilaeus*, *O. niloticus*, *Schilbe uranoscopus*, *Synodontis batensoda*, *S. schall* and *S. serrata*. Species which have become scarce are the swamp/marsh and shallow water species, including *Auchenoglanis* spp., *Clarias* spp., *Gymnarchus niloticus*, *Heterotis niloticus*, *Malapterus electricus*, *Marcusenius* spp., *Polypterus* spp. and *Protopterus aethiopicus*.

Human Impact & Utilisation: Construction of the dam necessitated the resettling of people but led to the establishment of a more productive fishery. Today cichlids (*Oreochromis* spp.) comprise 64% of the annual catch by weight. Thereafter *Lates*

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comprises 14%, *Labeo* 11%, *Barbus* 7%, *Synodontis* 2% and *Bagrus* 2%. An account of the fishery, containing many references, is given by Ali (1984).

Conservation Status: Unprotected.

(B) EL ROSEIRES

Location: 11°47'N/34°23'E
Area: 29 000 ha
Altitude: 480 m asl (at capacity)
Nearest Towns: El Roseires (10 km N); Khartoum (475 km NW)

General: The dam across the Blue Nile just above El Roseires was closed in 1966 to produce the 17th largest artificial lake in Africa, having a volume of 3 billion m^3 at capacity. When full, the reservoir has a maximum depth of 67.7 m and a mean depth of 10 m. Lacustrine conditions pertain for 120 km upstream of the dam, and the lake has a maximum width of 26.5 km at the northern end. There is a commercial fishery on the lake.

(C) SENNAR

Location: 13°36'N/33°37'E
Area: 16 000 ha
Altitude: 422 m (at capacity)
Nearest Towns: Sennar (on lake); Khartoum (260 km NW)

General: The Sennar Dam on the Blue Nile was closed in 1925 and subtends an artificial lake of 16 000 ha, the 25th largest impoundment in Africa. It has a maximum depth of 26 m at capacity, with an annual fluctuation of surface level of up to 17 m.

(D) KASHM EL GIRBA

Location: 14°55'N/35°55'E
Area: 12 500 ha
Altitude: c. 420 m asl
Nearest Towns: Kassala (75 km NE); Khartoum (380 km ENE)

General: The Kashm el Girba Dam on the Atbara River was closed in 1964, producing a long (55 km), narrow (4 km) lake oriented N-S.

(E) GEBEL AULIYA

Location: 15°15'N/32°28'E
Area: 150 000 ha
Altitude: 377 m asl (at capacity)
Nearest Town: Khartoum (25 km N)

General: This barrage across the White Nile above Khartoum was constructed in 1937 to hold back the flow of the White Nile during the period when the Blue Nile is in spate. Lacustrine conditions extend a very long way back up the valley of the White Nile, so that its lake is deemed to cover 150 000 ha and to form the 7th largest artificial impoundment in Africa. Water is used for irrigation and a commercial fishery operates on the lake.

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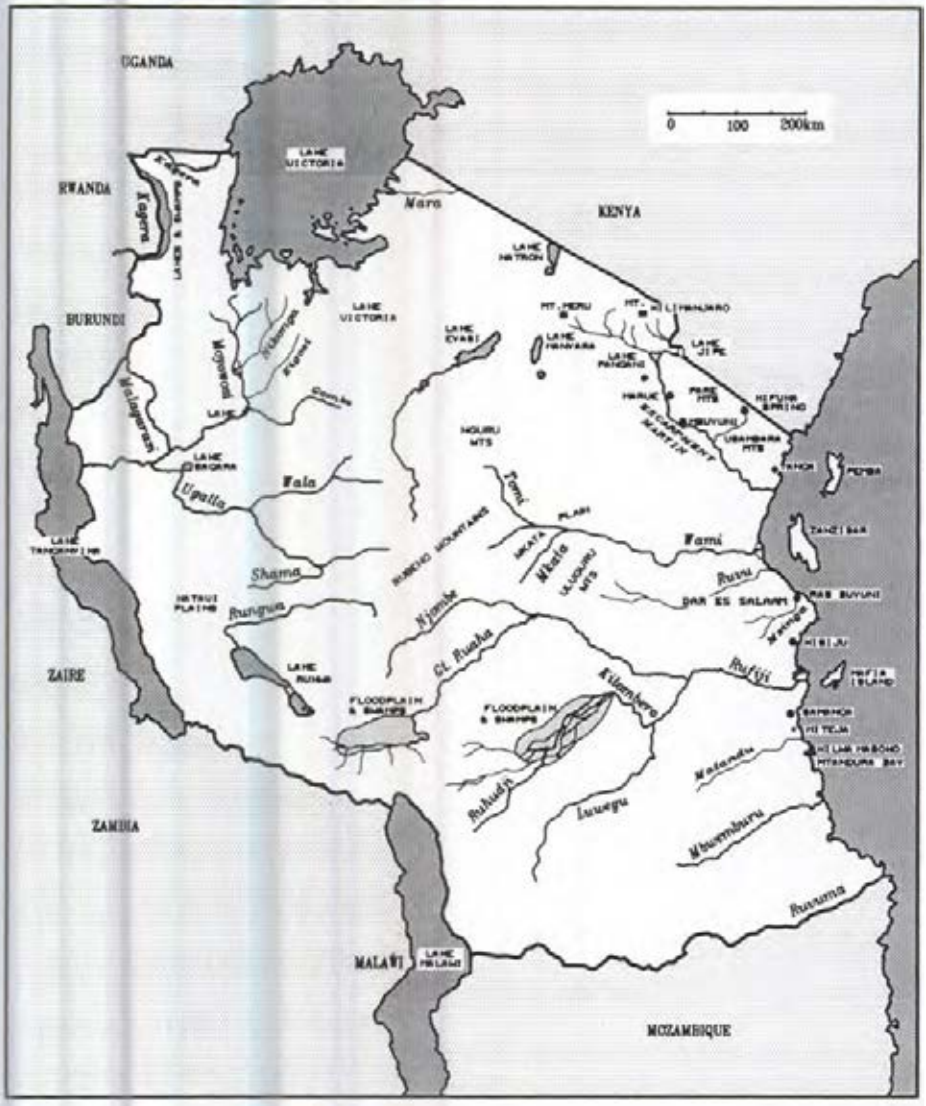

Map of Tanzania

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2.9 TANZANIA

Introduction

Tanzania has an area of 939 760 km^2, a population of 19 730 000 (1983), and thus a mean population density of 20.9 persons/km^2. It stretches approximately 1200 km from north to south between latitudes 1°00' and 11°36'S, and 1230 km from west to east between longitudes 29°21' and 40°29'E. It is bounded by Mozambique in the south, by Malawi, Zambia, Zaire, Burundi and Rwanda in the west, by Uganda and Kenya in the north, and by the Indian Ocean in the east. The Indian Ocean coast is highly indented and some 1300 km long, excluding offshore islands, while in the southwest there is a frontage of 305 km to Lake Malawi and another of 650 km to Lake Tanganyika in the central west. In the northwest there is a frontage of 1420 km on to Lake Victoria.

The coastal plain is only 15-30 km wide, and rises by slopes and scarps to an interior plateau 1000-1500 m asl north of the Rufiji River. This plateau is fringed by mountains except along the shore of Lake Victoria. In the northwest a highland range lies parallel with the Rwanda border, while in the west other mountain ranges occur along the shores of Lake Tanganyika. In the southwest the border with Zambia is mountainous, and around the head of Lake Malawi the Kipengere Range rises to 2595 m asl at Mt. Rungwe (9°08'S/33°41'E). Highland ranges also extend along the northwestern side of the Rufiji Valley, and then northwards parallel with the coast to culminate in the Usambara Mountains, close to the Kenyan border. The Eastern or Gregory Rift bisects this interior plateau, crossing the border into Kenya. Mountains also line both margins of this valley, the highest point here being Mt. Loolmalasin (3°02'S/35°48'E), 3648 m asl, on the eastern side. The isolated volcanic massifs of Mt. Meru (3°15'S/36°44'E) and Mt. Kilimanjaro (3°04'S/37°04'E) are situated on the plateau 100 and 150 km east of this rift respectively. The summit of Mt. Meru reaches 4565 m asl, while that of Mt. Kilimanjaro, at 5895 m asl, is the highest point in Africa. Between Mt. Kilimanjaro and the Usambara Mountains, along the Kenyan border, are the North Pare and Pare Mountains.

South of the Rufiji Valley the coastal plain rises more gently to another plateau, 500-700 m asl, but with isolated outcrops reaching 1500 m, and even higher peaks along the shores of Lake Malawi. The altitudinal range in Tanzania, from sea level to the summit of Kilimanjaro, is greater than in any other African country, while the bottom of Lake Tanganyika, 697 m below sea level, is the lowest point in Africa.

Drainage

Drainage is complex. Because of the general declination from the western highlands towards the Indian Ocean, much of the country drains to the ocean. This is accomplished by a series of rivers and numerous small streams. The principal watercourses are, from north to south, the Umba, Pangani, Msangasi, Mligasi, Mandera, Ruvu, Rufiji, Matandu, Mavuji, Mbwemburu, Lukuledi, Mambi and Ruvuma Rivers. All these drain the eastern margin and slopes of the interior plateau exclusively, except for the Rufiji and Ruvuma Rivers, which are much larger and rise in the west of the country. The Rufiji has sources in the Kipengere Mountains at the head of Lake Malawi and drains a huge basin in central

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southern Tanzania, while the Ruvuma rises farther south, but even closer to Lake Malawi. This latter stream marks the border with Mozambique for most of the way between Lake Malawi and the sea.

The northwestern highlands, along the Burundi border, drain either to Lake Victoria via the Kagera River, or to the endorheic Lakes of Burigi and Ikimba. Farther south the western slopes of the highlands along the Western Rift Valley drain by short streams to Lake Tanganyika. In the northern half of the country the eastern slopes of these mountains also drain to Lake Tanganyika via the Malagarasi River, which turns west and cuts through the highland range to enter the lake. However, in the southern half of the country these eastern slopes drain either to the endorheic Rukwa Basin, or to the Indian Ocean via the Rufiji and Ruvuma Rivers.

In addition to the Rukwa Basin, there are two other important regions of internal drainage. One is the trough of the Eastern Rift Valley, where streams draining the internal slopes discharge into a series of soda lakes. The other is near Dodoma (6°09'S/35°41'E), close to the geographic centre of Tanzania, where streams flow into a swampy basin which is flooded seasonally.

Land peripheral to Lake Victoria drains directly to that lake by short streams, but the watershed between the Lake Victoria and Malagarasi catchments approaches to within 25 km of the southwestern lakeshore. The western slopes of Mt. Meru drain into the Eastern Rift Valley, while the eastern slopes, and the slopes of Mt. Kilimanjaro, drain to the Indian Ocean via the Pangani River, or through Kenya via the Tsavo/Galana System.

Climate

The climate is dominated by three major wind systems, the SW Monsoon which intrudes into the country from the Zaire Basin, the moist SE Trade Winds which sweep in from the Indian Ocean, and the dry NE Trade Winds which blow down from Ethiopia and Somalia. The principal rains occur between January and May, but northwestern regions have an additional peak in October-November. The SE Trades predominate between the March and September equinoxes, but once the moist air stream reaches the interior it veers southerly or southwesterly. Mean annual rainfall declines southwards along the coast, from some 1300 mm in the Tanga District, to 1110 mm at Dar es Salaam (6°47'S/39°17'E) and 936 mm at Lindi (9°59'S/39°42'E). The offshore islands of the north are wetter however, with mean annual falls of 1964 mm at Wete (5°03'S/39°44'E) on Pemba Island. Similarly the coastal hills of the north experience high annual falls and precipitation exceeds 2250 mm/yr in the Usambara Mountains, and is generally over 1900 mm/yr on the lower seaward flanks of this range.

Where there are no mountains rainfall tends to decrease away from the sea, and the northern and central interior plateaux are comparatively dry, with falls below 600 mm/yr in the north. The southern and western thirds of the country are wettest, with falls exceeding 1400 mm/yr along the hills northwest of the Rufiji Valley and around the head of Lake Malawi, and between 950 1400 mm/yr over most of the southern interior and in the lands adjacent to the Western Rift Valley. Rainfall is 1130 mm/yr at Sonega (10°40'S/35°39'E) and 2300 mm/yr at Tukuyu (9°16'S/33°38'E). Sonega is situated on

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the plateau, 96 km north of the Mozambique border and 112 km east of Lake Malawi, at an altitude of 1153 m asl. Tukuyu is 1450 m asl in the Western Rift Valley north of Lake Malawi, and is more strongly influenced by the SW airstream than is Sonega.

The western side of the Lake Victoria basin is much wetter than the eastern side. Mean annual rainfall at Bukoba (1°20'S/31°48'E), 1144 m asl on the western shore, is 2025 mm, while it is 1010 mm at Mwanza (2°32'S/32°56'E), 1133 m asl on the southern shore, and 752 mm at Musoma (1°32'S/33°48'E), 1148 m asl on the eastern shore at the mouth of the Mara River.

Temperatures are moderated by altitude, and by onshore breezes at the coast. The mean annual temperature at Wete is 26.2°C, while the mean maximum of the warmest month is 31.9°C and the mean minimum of the coldest month is 20.7°C. Absolute maxima and minima are 35.9 and 18.1°C. The corresponding figures for Dar es Salaam are 25.7, 31.4 and 18.7°C, with absolute recordings of 34.4 and 15.0°C. At Lindi the figures are 26.1, 31.2 and 18.8°C, with absolute recordings of 35.2 and 12.3°C. At altitudes of approximately 1100 m around Lake Victoria the corresponding temperatures for different centres are; Bukoba, 21.1, 25.7 and 15.2°C, with absolute values of 30.6 and 10.0°C; Musoma, 23.4, 29.4 and 17.2°C, with absolute values of 35.0 and 12.2°C; Mwanza, 23.4, 29.7 and 11.4°C, with absolute values of 35.0 and 6.5°C. In the south the figures are 21.0, 28.4 and 12.7°C, with absolute values of 33.0 and 7°C at Sonega. Frosts are not uncommon over 4000 m asl and there is permanent snow on Mt. Kilimanjaro.

Vegetation

The total forested area of Tanzania is small and is largely confined to the major highland areas. However, a type of coastal forest occurs sporadically within a zone, 30-60 km wide, along the Indian Ocean. The southern and central interior plateaux support miombo woodland dominated by *Brachystegia*, *Isoberlinia* and *Julbernardia* spp, often associated with *Pterocarpus angolensis*. This occurs where rainfall is typically 800-1200 mm/yr with a single wet season, but it seldom has a continuous distribution and usually occurs in catenary associations. It is present on the best drained red and grey soils of the central plateau, but gives way to *Combretum* spp. in less well drained sites, and to deciduous *Acacia-Commiphora* bushland on hard-pan soils. This latter vegetation dominates much of the arid northern interior. The mountains support evergreen Afromontane vegetation. Within these broad vegetational zones there are large areas of edaphic vegetation, including the dense Itigi thicket (*Baphia massaiensis* and *Bussea massaiensis*) on duricrust soils in central Tanzania, and pure stands of *Borassus aethiopum* where the water table is always high. Most rivers carry galleries of forest or woodland, some dominated by a *Syzygium guineense-Ficus* spp. association, as in the Tabora district, and there are extensive grasslands on river floodplains. 'Mbugas' develop on boggy sites with *Digitaria regularis*, *Setaria holstii* and *Themeda triandra*, while secondary grass/fernlands, with *Pteridium aquilinum*, occur in the southern hills.

Wetlands

It has been estimated that there are some 5 439 000 ha of lakes and swamps in Tanzania, representing 5.8% of the total land surface, but this does not include seasonally inundated floodplains. Some 25% of the country is now protected in National Parks or Game Reserves,

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and these tend to be centred on wetland systems, thus a high proportion of the country's wetlands are protected. The principal wetland systems comprise the lakes of the Western and Eastern Rift Valleys, Lake Victoria, numerous minor lakes, riverine floodplains and permanent swamps, tidal swamps at the coast, and a number of artificial impoundments.

List of Wetlands Described

1. Tidal Wetlands
2. Riverine Wetlands
   a) The Kagera River
   b) The Moyowosi/Malagarasi System
   c) The Mara River
   d) The Pangani River
   e) The Wami River
   f) The Ruvu River
   g) The Ruaha/Rufiji System
3. Basins of Internal Drainage
   a) The Rukwa Basin
   b) The Bahi Swamp
   c) The Eyasi & Yaida Basins
   d) The Lake Natron Basin
   e) The Lake Manyara Basin
   f) The Burigi & Ikimba Basins
4. Natural Lakes
   a) Lake Victoria
   b) Lake Tanganyika
   c) Lake Malawi
   d) Minor Lakes & Swamps
5. Artificial Impoundments
   a) Nyumba ya Mungu Reservoir
   b) Mtera Reservoir
   c) Other Reservoirs

1. Tidal Wetlands

General: There were approximately 196 000 ha of mangrove swamps at the coast in 1982. Mangroves are present in all sheltered creeks on the mainland and offshore islands. They are well developed in creeks of the Tanga District, between latitudes 4°42' and 5°13'S, and on Pemba and Zanzibar Islands. In the delta of the Wami River (6°05'-6°15'S) and in the estuary of the Ruvu River (6°22'S) they have transitions with fresh water swamps. Then, in passing south, mangroves occur at the mouth of the Mzinga

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River at Dar es Salaam and in creeks sheltered by offshore islands between Ras Buyuni (7°10'S/39°30'E) and Kisiju (7°24'S/39°20'E). However, they attain their best development on the entire East African coast in a stretch between Mohungu (7°42'S/39°16'E), north of the Rufiji Delta, and Samanga (8°23'S/39°17'E), south of the delta. Here the swamps cover offshore mudflats and encompass small coral islands, and extend seaward for a maximum distance of 26 km immediately north of the main river mouth and opposite Mafia Island. Other good and floristically diverse mangrove stands occur in several large sheltered inlets farther south, e.g. in the bay at Miteja (8°32'-8°38'S/39°17'-39°23'E), in the Matandu Estuary (8°39'-8°46'S/39°18'-39°24'E), in the bay at Kilwa Masoko (8°51'-9°01'S/39°20'-39°30'E), at the head of Mtandura Bay (9°11'-9°14'S/39°30'-39°34'E) and at the Ruvuma River Mouth on the Mozambique border (10°24'-10°31'S/40°20'-40°26'E).

Flora & Fauna: The flora and fauna of these swamps is as indicated in the regional introduction. There are many transitions with coastal dune forest and fresh water swamp forest. *Lepidochelys olivacea* nests near large river mouths in the south of Tanzania and both it and other turtles visit mangroves.

Human Impact & Utilisation: Mangroves have been intensively exploited for firewood, poles, and masts for Arab dhows.

Conservation Status: Currently unprotected.

2. Riverine Wetlands

(A) THE KAGERA RIVER

General: The wetlands on the Kagera River are described more fully in section 2.6.11. The Kagera forms the border between Rwanda and Tanzania for a distance of about 210 km, and for 180 km it traverses a shallow swampy valley (1°19'-2°11'S/30°33'-31°01'E) at altitudes between 1270 and 1300 m asl. In this sector it flows sluggishly, almost due north, through permanent swamps which reach 18 km in width, but which are generally only 1-2 km wide on the Tanzanian side of the border. Very locally they extend 10 km into Tanzania. There are many papyrus fringed lakes in depressions on either side of the river, and those in Tanzania are, from north to south, Lakes Gwelu (1°20'S/30°39'E), Nyakatale (1°22'S/30°39'E), Nyaruwale (1°23'S/30°41'E), Lubuga (1°26'S/30°47'E), Ishaka (1°27'S/30°47'E), Duko (1°30'S/30°46'E), Kashani (1°34'S/30°49'E), Twamwala (1°36'S/30°50'E), Mujunju (1°36'-1°44'S/30°51'-30°55'E), Kashanga (1°53'S/30°51'E), Lweru Kwa Kalambi (1°59'S/30°52'E), Katabi (1°59'S/30°57'E), Kazinga (2°01'S/30°56'E) and Bisongo (2°08'S/30°58'E).

The river rises and floods, following rains over the catchments along the Western Rift Valley in Rwanda and Burundi. About 35 000 ha of the wetland is situated in Tanzania. The swamps are dominated by papyrus, but there are patches of swamp forest, and seasonal floodplains outside parts of the permanent swamp system. There is a rich fauna including frogs, crocodiles, terrapins, monitors, snakes, birds, otters and rodents, but *Hippopotamus amphibius* is now scarce. The lakes and river are fished intensively by artisans, and there is some hunting. The area is unprotected in Tanzania, but most of the wetland on the Rwanda side of the border is included in the Kagera National Park.

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(B) THE MOYOWOSI/MALAGARASI SYSTEM

General: The Malagarasi River, with its tributaries, drains a large part of northwestern Tanzania. Wetlands occur on the upper Malagarasi and its headwater tributaries, but these are very largely situated in Burundi and are dealt with in section 2.1.3d. The principal tributary, the Moyowosi and its major affluent, the Nikonga, both rise in low hills close to the southern shore of Lake Victoria and both flow south, away from the lake. Their gradients flatten as they reach a plain and they overtop their banks seasonally in traversing a vast zone of permanent swamps (3°55'-5°05'S/30°50'-31°35'E) oriented roughly N-S. Here the Moyowosi divides into a network of channels into which the Nikonga flows on the eastern side. The permanent swamp zone is 160 km long, reaches 36 km in width, and covers some 320 000 ha. Seasonal floodplains extend along two other affluents, the Kigosi and Gombe Rivers, which join these swamps from the east.

The Kigosi Floodplain is 35 km long and occupies about 14 000 ha, while that on the Gombe River is 60 km long, 4-6 km wide, and covers 32 000 ha. However, other floodplains occur on tributaries of the Gombe. The largest of these covers a large area beset with low hills, producing a mosaic of dryland and wetland at high water (3°50'-4°34'S/32°16'-33°02'E). This wetland drains to the Gombe by two streams, the Mtoni which leaves the southwestern corner and the Igombe which leaves the southeastern corner. The area of wetland here varies from year to year, but during wet cycles it approaches 250 000 ha.

There are two small lakes at the southern extremity of the permanent Moyowosi swamps, and just above them the flow swings westwards, and the network of Moyowosi channels reunite, before a confluence with the Malagarasi River. A belt of permanent swamps with a peripheral floodplain continues below this confluence for 40 km, approaching the point where the Ugalla River joins the Malagarasi on its south bank.

The Ugalla and its several tributaries drain the plateau and some low hills to the south and east, and many of the rivers of this subsystem have seasonal floodplains. The floodplain on the Ugalla develops 20 km above its confluence with the Malagarasi and extends for 40 km, past the mouth of the Ziuwe River, a right bank tributary. Thereafter it is discontinuous for nearly 60 km, but then widens again and extends up the Wala River to its headwater basin, a distance of 200 km. In total there are about 90 000 ha of seasonally inundated land on the Ugalla/Wala Rivers. An extensive floodplain/lake/swamp system occurs on the Ziuwe River, reaching 24 km in width above Lake Sagara (5°14'S/31°07'E) which the river both feeds and drains. There is a total of about 85 000 ha of wetlands on the Ziuwe, including nearly 8000 ha of permanent swampland along the river to the east and west of Lake Sagara.

Flora & Fauna: This is essentially as described in the regional introduction for the western districts of Equatorial East Africa. All the headwater streams carry gallery forest or woodland containing *Acacia spp.*, *Borassus aethiopum* and *Phoenix reclinata* among others. Substantial sections of the galleries are flooded for short periods each year. The permanent swamps are dominated by papyrus, which detaches from the banks of rivers and lakes to produce islands of floating vegetation, and in the Moyowosi/Nikonga Swamp these frequently cause channel blockages. Shallow depressions on the floodplains and the fringes of permanent swamps carry swamp forest, while the floodplains

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proper carry grassland. The surrounding country is covered by *Brachystegia spiciformis-Julbernardia globiflora* miombo woodland, but there are patches of groundwater forest at sites where the water table is always near the surface, e.g. in the area (5°02'-5°12'S/31°00'-31°16'E) between the Moyowosi Swamp and the swamp around Lake Sagara.

Noteworthy animals include *Crocodylus niloticus*, *Hippopotamus amphibius*, and *Tragelophus spekei* in the swamps, and *Damaliscus lunatus*, *Equus burchelli*, *Kobus ellipsiprymnus*, *Panthera leo* and *Syncerus caffer* on the floodplains. Almost the whole spectrum of small mammals cited in the regional introduction for this district is present in these wetlands, and there are several hundred species of birds.

Human Impact & Utilisation: Fishing is practised by artisans on the rivers, lakes and floodplains, and some crops are cultivated on the floodplains when the waters recede. Hunting occurs almost throughout the system.

Conservation Status: A substantial proportion of the wetland is protected in the Moyowosi Game Reserve which extends between the Moyowosi and Malagarasi Rivers above their confluence.

(C) THE MARA RIVER

General: The Mara rises on the western slopes of the Mau Escarpment in Kenya and flows to Mara Bay on the mid-western shore of Lake Victoria in Tanzania. It traverses the Masirori Swamp (c. 1°27'-1°37'S/34°11'-34°38'E) some 45 km long and up to 14 km wide on the lacustrine plain. This is a permanent papyrus swamp of some 30 000 ha, situated 30 km east of Musoma. The flora and fauna are essentially as described in the regional introduction. The swamp is fished and is unprotected.

(D) THE PANGANI RIVER

General: The Pangani drains Mts. Meru and Kilimanjaro. Its headwater tributaries are the Kikuletwa and the Ruvu. The Kikuletwa rises on the eastern slopes of Mt. Meru and receives 4 affluents from the southern slopes of Mt. Kilimanjaro en route to Lake Pangani (Nyumba ya Mungu), an impoundment (3°41'S/37°27'E). The Kikuletwa flows into the northwestern corner of the reservoir through a swamp with a mean area close to 4200 ha, but which fluctuates with the water level. The Ruvu rises as the Lumi on the eastern slopes of Mt. Kilimanjaro and flows into Lake Jipe (3°31'-3°40'S/37°45'E), half of which is in Kenya, and much of which is encompassed by papyrus swamps. This overflows into the Ruvu, and this river, having traversed a stretch of permanent swamps, joins the Kikuletwa in the Lake Pangani Impoundment. From here the combined stream issues southwards as the Pangani River.

Below the dam this river flows through dry deciduous *Acacia-Combretum* bushlands, but at about 750 m asl, it crosses the flat floor of a trough between the Martin Escarpment in the west and the Pare Mountains in the east. Here (4°07'-4°34'S/37°26'-37°44'E), between Marue and Mbuyuni, it spreads its waters over a broad belt of permanent swamps, surrounded by a seasonal floodplain. The swamps extend 80 km along the foot of the Martin Escarpment on the western side of the trough. The eastward spread of floodwaters is limited by a ridge along the centre of the trough from which 4 conical

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hills rise to just over 1300 m asl. However, the swamps reach 26 km in width along an affluent stream from the Pare Mountains, which enters the system between two of the hills on the central ridge. There are several minor channels through the swamps, which are dominated by papyrus, but the main stream of the Pangani maintains its integrity throughout. This wetland covers about 90 000 ha. The permanent swamps are fished by artisans at all seasons. The floodplain is fished in the wet seasons and grazed and cultivated in the dry seasons. The system is unprotected.

The Kitwai Swamp and Floodplain (4°51'S/37°11'-37°36'E) is situated at the head of a broad shallow valley, 795-810 m asl, 40 km southwest of the previous system. It occupies an E-W depression containing close to 15 750 ha of wetland in a strip 50 km long and up to 6 km wide, and drains from its eastern end towards the Pangani at high water. South of this there are numerous permanent waterholes scattered over a large area (5°04'-5°22'S/37°00'-38°00'E) drained by right bank affluents of the Pangani.

The principal left bank tributary is the Mkomazi. This river rises on the northeastern slopes of the Pare Mountains and then flows through permanent swamps along the northeastern flank of the range, before passing through a narrow valley between the southern tip of the Pare Mountains and the northern tip of the Usambara Mountains. The swamps (4°12'-4°24'S/38°04'E) are dominated by papyrus and occupy some 4000 ha in a strip 24 km long and 2 km wide. Northeast of these swamps, and hard against the Kenyan border and the Tsavo National Park, is the Kifuka Swamp (4°05'-4°15'S/38°11'-38°24'E), centred on Kifuka Spring (4°08'S/38°14'E). This swamp drains to the NW and appears to be included in the Mkomazi National Reserve, but is not mentioned in accounts we have of that reserve.

Flora & Fauna: The permanent swamps with fluctuating water levels are dominated by papyrus. Small patches of groundwater forest occur near springs and some waterholes, and the watercourses are fringed by gallery forests, parts of which are subject to seasonal inundation. The usual grasses grow on the floodplains, together with species of *Acacia* in the less deeply flooded places. The fauna is as described in the regional introduction for Equatorial East Africa. *Crocodylus niloticus* and *Hippopotamus amphibius* persist in the system but are now uncommon.

Human Impact & Utilisation: The area is intensively used. The rivers, swamps and floodplains are fished, and the floodplains are heavily grazed during the dry season. Some cultivation is carried out when the floods recede, and the gallery forests are exploited for timber and firewood. Lake Pangani is used to produce hydroelectric power and is fished, but is dealt with in more detail in section 2.9.5.

Conservation Status: Unprotected, except for Kifuka Swamp, but even here poaching of large animals and birds is serious.

(E) THE WAMI RIVER

General: The principal headwater tributary of the Wami, the Mkata River, has sources (7°25'S/37°04'E and 7°25'S/37°08'E) at the head of a valley aligned SW-NE, between the Uluguru Mountains in the east and the Rubeho Mountains in the west. The river flows NE, draining the opposing flanks of these ranges, and spreads over an extensive swamp on the Mkata Plain (6°26'-7°22'S/37°04'-37°25'E). This covers some 80 000 ha and is

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almost unbroken for 104 km along the river, with a maximum width of 20 km in the north where the Wami and Tomi Rivers are received on the left bank. Papyrus swamps form a central strip along the river throughout this system, and extend away from it on tributaries, backwaters and around ponds. Outside the papyrus swamps there are seasonally inundated floodplains.

The Wami has sources (6°27'S/36°58'E and 6°32'S/36°55'E) in the Kaguru Mountains, farther north on the western side of the valley. From them it flows SE to reach the Mkata in the swamps at the northern end of the Mkata Plain, sometimes called the Lukwatu Plain at this end. Beyond this the combined stream is called the Wami, and another permanent swamp/floodplain is situated (6°16'-6°25'S/37°32'-37°42'E) between the left bank of the river and an affluent which drains the Nguru Mountains. This latter wetland covers about 13 500 ha. Below this the Wami flows due east to reach its delta on the Indian Ocean. Here swamps spread up and down the coast in a floodplain and swamp zone (6°03'-6°16'S/38°45'-38°52'E) which grades into tidal swamps along distributaries.

Flora & Fauna: The upstream swamps are dominated by papyrus with *Miscanthidium violaceum*, *Phragmites mauritianus*, *Typha domingensis* and other typical associates. *Phoenix reclinata* is common on levées in the swamps, with, in places, *Borassus aethiopum*, *Hyphaene coriacea* and species of *Ficus*. The rivers carry gallery forests with a typical East African flora. The floodplains support grasses, and patches of groundwater forest at the back of the delta are dominated by *Chlorophora excelsa*. Swamp forest occurs in the delta and grades into tidal forest along the distributaries. *Barringtonia racemosa*, *Heritiera littoralis* and *Hibiscus tiliaceus* dominate the freshwater/saltwater transition. The fauna is as described in the regional introduction for the eastern districts of East Africa.

Human Impact & Utilisation: The wetlands are fished and hunted, and recession agriculture occurs locally after the floods have subsided. Areas of the delta are used for agriculture and some swamps have been drained.

Conservation Status: The headwaters of the Mkata River are situated in the Mikumi National Park, but none of the major wetlands is protected.

(F) THE RUVU RIVER

General: The Ruvu and its headwater tributaries rise on the eastern slopes of the Uluguru Mountains at altitudes close to 1500 m asl. They descend steeply to a plain 200 m asl, at the eastern foot of the massif, and spread their waters over a swamp (7°16'-7°29'S/37°51'-38°01'E) of 36 000 ha which measures 22 km from SW-NE. The southernmost tributary, the Mgeta, joins the Ruvu about 15 km east of the swamp, and the combined stream then flows ENE to traverse another swamp (7°07'-7°17'S/38°15'-38°23'E) of 7200 ha, 20 km downstream. Thereafter the river meanders NE to reach the coast in a swampy estuary north of Bagamoyo (6°27'S/38°58'E), opposite the southern tip of Zanzibar Island.

The flora and fauna are as described in the regional introduction, with papyrus swamps, grassy floodplains and gallery forests. The system is exploited for floodplain agriculture, hunting and fishing, and is unprotected.

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(G) THE RUAHA/RUFIJI SYSTEM

General: The Rufiji is the largest river of Tanzania. Its headwater tributary farthest from the sea is the Hagafira, which with an affluent, rises on a flat seasonally inundated plain (9°26'-9°33'S/34°32'-34°38'E) 2300 m asl. This plain is just 38 km NW of Lake Malawi, and it straddles a watershed from which the Nkiwe River flows SW to that lake. However, the Hagafira, having united with its affluent, becomes known as the Ruhudji. This river winds eastwards, losing height quite rapidly, to the head of a great floodplain (7°44'-9°26'S/35°33'-36°56'E) 250 km long and up to 52 km wide, covering 626 500 ha at high water. The floodplain occupies the flat floor of Kilombero Valley, 210-250 m asl. The valley is oriented SW-NE, between a densely forested escarpment, which rises to 2576 m asl (7°47'S/35°36'E) on the northwestern side, and the Mahenge Mountains on the southeastern side. This latter group rises to 1516 m asl (8°45'S/36°39'E) and is grass covered on its upper western flanks.

The Ruhudji receives several important tributaries at the head of the valley and then divides, on the floodplain, into a number of channels which produce an anastomosing network in the central part of the floodplain. Other affluents, draining the mountains on opposing sides of the valley, join the network so that in the central part there are ten major channels flowing roughly in parallel. A zone of permanent swamps, 45 km long, extends up to 4 km away from the west bank of the Kihanse River, which comes down from the high escarpment at the southern end of the floodplain to form the most westerly of the major channels. Otherwise, permanent swamps are closely restricted to the vicinity of the channels and some lagoons. The southern and central parts of the floodplain descend 40 m over a distance of 210 km, i.e. with a mean gradient of 1:5250.

About two thirds of the way along the floodplain the channels reunite and the main stream is joined on its left bank by the Msolwa River. This stream comes down from the high escarpment and traverses the northern third of the floodplain, skirting another large zone of permanent swampland to the west. It flows SW to its confluence, from which point the main stream, now called the Kilombero River, swings sharply southeastwards, and leaves the floodplain. The Kilombero then continues for 65 km to a confluence with the Luwegu, a large river from the south which has extensive but narrow floodplains. Below this confluence the river is referred to as the Rufiji.

Some 80 km downstream, the Rufiji receives the Great Ruaha River on the left bank. The Great Ruaha rises farther west than the Rufiji, having six major sources in the Kipengere Mountains at the head of Lake Malawi. These streams issue northeastwards from the mountains and unite on the Usangu Flats, a plain about 1300 m asl. Most of the plain, which is 140 km long and oriented SW-NE, is inundated during the rainy season. Like the Rufiji Floodplain, its effluent stream leaves it about two thirds of the way along its length. Other affluents enter the plain from the north and join the main river, which on leaving the plain is known as the Great Ruaha. The zone of inundation extends the full length of the flats, reaching 42 km in width in the SW and 32 km in the NE. At high water over 150 000 ha are inundated, to depths of 3-4 m. A zone of permanent swamps, covering about 4000 ha, lies at the lowest part of the system, 1020 m asl, above the point where the Great Ruaha leaves the flats.

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From here the river flows NE to another floodplain (7°12'-7°19'S/35°17'-35°28'E) of 10 000 ha, generated jointly by the Ruaha and Lufugwa Rivers. The zone of inundation extends for 26 km between the two streams and terminates at their confluence. Then, some 32 km farther downstream, the Ruaha receives the Kisigo on the left bank. The Kisigo rises on a swampy floodplain (20 000 ha) near the town of Itigi, to the north (5°33'-5°53'S/34°22'-34°39'E), from where, flowing SE, it skirts a small floodplain (6°15'S/34°53'E) before receiving the waters of the Tame River. This river also rises from a floodplain area (6°35'-6°50'S/35°12'-35°32'E).

A further 10 km downstream the Great Ruaha receives the Bubu, again on the left bank, and this river also traverses a floodplain (6°48'-7°05'S/35°43'-35°59'E) on its way to the Ruaha. This wetland is 34 km long from N-S, up to 18 km wide from E-W, and covers 24 000 ha at high water. To the south of the Great Ruaha another seasonally inundated plain occupies 20 000 ha (7°31'-7°40'S/35°47'-35°55'E). It is surrounded by mountains on three sides, the south, east and north, but it drains to the Great Ruaha from the NW via the Mbungu River.

Below the Mbungu confluence the Great Ruaha flows SE through a narrow valley in the Rubeho Mountains to an impoundment at Mtera and finally emerges on the eastern side of the mountains just north of the Rufiji (Kilombero) Floodplain. This it skirts at a distance of less than 5 km before joining the Rufiji on its left bank a few kilometres above Lake Mkalinzu (7°52'S/37°49'E). The Rufiji then veers eastwards and becomes broad and sluggish; its channel reaches more than a kilometre in width in its lower reaches, and locally it encompasses islands. Over the final 180 km above its delta the Rufiji receives numerous tributaries on both banks. Many of the affluents traverse lakes, and some terminate in lakes, from which overspill to the Rufiji is diffuse and occurs only during the rains. A number (e.g. the Lambo River) rise in swampy valleys in the undulating coastal lowlands. The Lambo, which joins the Rufiji on its right bank, drains the southern end of a large and partly forested swamp (7°22'-7°44'S/38°15'-38°24'E), while the Ruhoi also drains this same swamp, but flows independently from the northern end to the Rufiji Delta.

Flora & Fauna: The Rufiji and Ruaha Floodplains are dominated by grasses, including *Echinochloa pyramidalis* and *Oryza* spp. The permanent swamps along the rivers are *Cyperus papyrus* swamps, with the normal associate species. Upstream the rivers carry gallery forests, with zones of inundation and pockets of swamp forest. These include some Zambezian elements and in southwestern districts comprise such species as *Aporrhiza nitida*, *Ficus congensis*, *Garcinia smeathmannii*, *Gardenia imperialis*, *Ilex mitis*, *Mitragyna stipulosa*, *Raphia* sp., *Syzygium cordatum*, *S. owariense*, *Uapaca guineensis*, *Xylopia aethiopica* and *X. rubescens*, while the galleries contain *Acacia albida*, *A. polyacantha* var. *campylacantha*, *A. xanthophloea*, *Adina microcephala*, *Anthocleista schweinfurthii*, *Canarium schweinfurthii*, *Dacryodes edulis*, *Erythrophleum suaveolens*, *Newtonia buchananii*, *Treculia africana* and *Trichelia emetica*. In the coastal section, and at the back of the delta, swamp forests are well developed, but have more typically equatorial and coastal species. Other patches of swampy forest, subject to varying degrees of inundation, occur in and around some of the floodplains, e.g. that on the Lambo.

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The fauna is as described in the regional introduction. *Crocodylus niloticus*, terrapins, *Varanus niloticus*, and some snakes occur throughout most of the system. Among interesting birds *Scotopelia peli* is locally very common along the more densely wooded banks of the Great Ruaha. Several species of bat frequent the riverine woodlands, including fruit bats and false vampires. *Nandinia binotata* also occurs here, as do genets, mongooses, otters and cane rats. *Hippopotamus amphibius* is widespread, and *Tragelaphus spekei* occurs in the permanent reed swamps.

Human Impact & Utilisation: All the floodplains are utilised, but the small ones, and the Usangu Flats, are situated in sparsely populated areas. However, a railway runs along the northwestern side of the Rufiji Floodplain, and there are roads on both sides, with villages scattered along them and across the southwestern end of the plain. The large floodplains are fished intensively and there are commercial fisheries on the Rufiji Floodplain. Cattle are grazed on the grasslands and crops are cultivated when the floods recede. The Great Ruaha was impounded 968 m asl at Mtera (7°06'S/35°55'E) in 1980, where the lake surface will be 61 000 ha at capacity (Bernacsek, 1984), and also at Kidatu (7°47'S/37°01'E) in 1975, where the lake covers 1000 ha. Both reservoirs are used to generate electricity, and both support fisheries.

Conservation Status: The left bank of the Great Ruaha is protected for 143 km where it forms the southeastern boundary of the Ruaha National Park, but this sector includes no important wetlands. The NE corner of the Rufiji Floodplain is situated in the Selous National Reserve, as is a 106 km section of the Great Ruaha River above its confluence with the Rufiji, a 270 km section of the Luwegu River above its confluence with the Rufiji, and a 162 km section of the Rufiji. In addition a part of the headwater floodplain on the Lambo River is included in this reserve.

3. Basins of Internal Drainage

(A) THE RUKWA BASIN

General: Lake Rukwa (7°33'-8°25'S/31°46'-32°51'E) is divided into two basins by a central swamp zone, ranging from 5-20 km wide. The lake occupies much of the floor of a rift valley, the mean level of the water surface in the south basin being 820 m asl. The Rukwa Rift Valley is entirely isolated from the Western Rift Valley, which holds Lake Tanganyika in the west, and from the Malawi Rift Valley to the south, although it represents a northerly extension of the latter. The lake is endorheic and varies in size during wet and dry cycles. It has a mean length of about 140 km and reaches maximum widths of 36 km in the north basin and 22 km in the south basin. It is fed by 17 rivers. These drain the plateau country to the east, the Rungwe Volcano complex at the head of Lake Malawi to the south, and the highlands between Lake Tanganyika and the Rukwa Rift in the west. Seven rivers enter the south basin and 10 discharge to the north basin. The steep escarpment of the Mbizi Mountains lies along the western side of the Rukwa Rift, rising to 2664 m asl (7°24'S/31°19'E) in the north and 2236 m asl (8°27'S/32°06'E) in the south, but the lake is separated from the western wall by broad alluvial plains, in places 38 km wide. On the eastern side the lake lies close to, and even abuts, the escarpment, so that in places rocky cliffs rise 60 m out of the water, but above this the slopes are more gentle, reaching altitudes of 1600-1700 m asl.

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A floodplain at the northern end of the lake is either partly or totally inundated at the height of the rains in wet cycles. This measures 38 km wide and 34 km long, and covers 129 000 ha, of which 53 000 ha close to the lake is a semi-permanent swamp. Other permanent or semi-permanent swamps occupy a strip 50 km long and 5 km wide along the southwestern margin of the north basin, and also cover the intervening section between the north and south basins. These swamps occupy at least 39 000 ha.

An extensive wetland system occurs to the north, on the Katavi Plains, which drain to Lake Rukwa via the Kafufu or Kavu River. This system begins with the Katuma River which has a source on the plateau, on an isolated hill (6°05'S/30°38'E) rising to 2015 m asl. The river flows south to a confluence with another stream, above which they develop a joint floodplain (6°23'-6°33'S/30°44'-31°00'E) of 43 000 ha, and below which the Katuma traverses a belt of permanent swamps, 20 km long, to Lake Katavi (6°43'S/31°00'E). This is a small lake, 5.2 km long and 2 km wide. There is a swampy floodplain on the western shore of the lake, which drains northeastwards, the river now being called the Kafufu. This flows NE to the village of Sitalike (6°39'S/31°08'E), where it swings through 135° to flow SW through another zone of permanent swamps (6°42'-7°00'S/31°08'-31°11'E), 1000 m asl and covering 24 000 ha, before entering Lake Chada (6°58'S/31°15'E).

Lake Chada is situated just below the 1000 m contour. It too is a small lake, 5x3 km, but receives another affluent, the Msaginya River which flows in from the Mlala Hills to the east, through a 22 000 ha floodplain (6°46'-7°02'S/31°16'-31°35'E). This is aligned SE-NW and is 44 km long and up to 12 km wide. The Kafufu leaves Lake Chada at its southwestern extremity and flows south to more permanent swampland (7°05'-7°17'S/31°19'-31°32'E), which is additionally fed by hot springs (7°15'S/31°23'E). In these swamps the river receives tributaries from both sides of the Rukwa Rift Valley, before flowing 50 km to enter the swamps at the northern end of Lake Rukwa.

The Rungwa River enters the northeastern end of Lake Rukwa and has a large catchment on the plateau to the east. It rises at about 1580 m asl and flows north to traverse a permanent swamp (7°01'-7°07'S/33°46'-33°59'E) about 1350 m asl, from where, after receiving many affluents, it reaches Lake Rukwa. It is not a perennial river.

The Mtemba River rises high in the mountains separating Lakes Rukwa and Tanganyika, and flows south to a swamp/floodplain 1400 m asl (8°43'-9°07'S/32°02'-32°24'E). The southern tip of these swamps reaches the Zambian border, but they drain northeastwards via the Mtembwa River, which becomes the Mfafia above the point at which it enters Lake Rukwa.

Hydrology & Water Quality: The catchment of Lake Rukwa exceeds 85 000 km^2, and direct precipitation over the lake is close to 930 mm/yr. The principal inflows to the south basin are from the Lupa and Songwe Rivers, both of which drain the Rungwe Volcanoes, although the Lupa also has an extensive catchment on the plateau to the east. The Mfafia River, which drains part of the western escarpment, enters the central swamps between the two basins, while the Kafufu enters at the northern extremity. These are all perennial rivers, but the other inflows are seasonal, or seasonal in most years. The water is saline with comparatively high levels of sodium and carbonate.

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The lake floor slopes from west to east so that maximum depths occur close to the eastern shore. The north basin is shallow and may dry completely in some years, while the south basin has maximum depths of about 6.5 m, reducing to c. 3 m in dry cycles. At high water the two basins become continuous but the water depth over the barrier seldom exceeds 1 m and is not sufficient to engulf the emergent macrophytes.

Flora & Fauna: The floodplain grasslands around Lake Rukwa are short, and are dominated by the salt tolerant species *Diplachne fusca* and *Sporobolus spicatus*. Papyrus grows in the permanent swamps around the lake, where there is a supply of fresh water from affluent streams, and is dominant in the swamps on the Kafufu River. In most sites it is associated with *Phragmites mauritianus* and other typical species. The small lakes, Cahada and Katvi, have a dense submerged flora and support carpets of waterlilies inside the fringe of emergent macrophytes. All the watercourses of the system carry galleries of woodland, similar in character to those described in the previous section for the western parts of the Rinaha/Rufiji system.

Twenty-four species of fish have been identified in Lake Rukwa, the most important being *Alestes imberi*, *Clarias mossambicus*, *Hydrocynus lineatus*, *Schilbe mystus* and *Oreochromis rukwaensis*, the latter being both endemic to the lake and the most abundant species. This fish is better able, than the others present, to survive drastic phases of drying such as have occurred several times within the last hundred years. Other species include *Barbus* spp., *Gnathonemus macrolepidatus*, *Haplochromis bloyeti*, *Lates fulleborni*, *Mormyrus longirostris*, *Oreochromis esculentus* and *Synodontis* sp. *Crocodylus niloticus* is present on the lake margins and along the affluent streams. Among the birds large numbers of *Pelecanus onocrotalus* are present, nesting at the northern end of the lake. Other birds include *Ardea melanocephala*, *Grus carunculatus*, *Nycticorax leuconotus* and *Plegadis falcinellus*. *Hippopotamus amphibius*, *Redunca arundinum* and *Tragelaphus spekei* are found in the swamps, the latter being common along southwestern shores of the north basin. Large mammals found at the lakeside, i.e. on the short-grass floodplain, are *Damaliscus lunatus*, *Equus burchelli*, *Kobus ellipsiprymnus*, *K. vardoni*, *Loxodonta africana* and *Syncerus caffer*. A race of zebras marked with spots instead of stripes is present.

Human Impact & Utilisation: The system is isolated and the population scant, but it has been increasing in recent years. There has long been an artisanal fishery using dugout canoes in shallow water, but commercial fisheries have had a chequered history, having been started and abandoned on several occasions. *Oreochromis rukwaensis* has always been the principal species in the commercial catches, and in the past was smoked and sun-dried for market. The yield has varied from 30-40 kg/ha/yr.

Conservation Status: The Uwanda Game Reserve, established in 1971, protects much of the southwestern and central shores of the north basin and is contiguous with the North Rukwa Controlled Game Area which covers the north end of the lake. Some 50% of these areas, i.e. about 250 000 ha, are subject to seasonal inundation. The North Rukwa Controlled Game Area is contiguous with the Katavi National Park, gazetted in 1974. This contains most of the Katavi Plains wetlands including Lakes Katavi and Chada.

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(B) THE BAHI SWAMP

Location: 5°51'-6°16'S/34°59'-35°19'E
Area: 125 000 ha
Altitude: 796-804 m asl
Nearest Towns: Dodoma (44 km E); Dar es Salaam (440 km ESE)

General: This seasonally inundated semi-permanent endorheic swamp is situated west of Dodoma and receives affluent streams in radial fashion from the surrounding plateau country, and from hills in the northeast and north. Its boundary is almost exactly delimited by the 800 m contour. It is 54 km long and 30 km wide and supports salt-tolerant grasses such as *Sporobolus spicatus*, and some sedges and reeds. The main road from Dar es Salaam to Mwanza on Lake Victoria runs along the northern side of the swamp. Some hunting takes place here and the area is unprotected. One of the southern affluents is impounded at Nondwa (6°21'S/35°20'E) to produce a reservoir of about 500 ha.

(C) THE EYASI & YAIDA BASINS

General: The Nyahua River rises on the interior plateau (5°52'S/33°21'E) and flows SW-NE. It develops a floodplain 1-5 km wide for 60 km (5°19'-5°38'S/33°09'-33°28'E) with an area of about 11 000 ha, before reaching a confluence with the Wembere. Immediately below this confluence the Wembere traverses a large floodplain, 105 km long and up to 20 km wide, covering more than 140 000 ha (4°12'-5°01'S/33°47'-34°11'E) before entering the southern end of Lake Kitangiri (4°00'-4°12'S/34°10'-34°24'E), c. 1150 m asl. This lake is 30 km long, has a maximum width of 8 km at the northern end, and an open water area of 11 500 ha. Another river, the Manoga, also feeds Lake Kitangiri, which is a fresh water lake with a conductivity of about 780 µSiemens/cm and a sodium ion concentration of 156 mg/l. It has an outflow from its northern extremity into the Sibiti River.

The Sibiti receives 6 major affluents above Lake Eyasi (3°24'-3°49'S/34°43'-35°21'E), but it carries water to the lake only in wet years. It enters the southern extremity of Lake Eyasi, which is oriented SW-NE, and is 80 km long, with a mean width of 14.5 km, and an area of 116 000 ha. When the Sibiti does flow, its waters are often quickly dissipated over the lake bed which is usually dry. Two other affluents enter the lake directly, but even during wet cycles the depth of water in the lake is generally less than 1 m. A number of permanent springs exist around the lake margin, but their waters also evaporate quickly on the lake floor. Direct precipitation in this part of Tanzania is generally in the vicinity of 600 mm/yr.

An entirely separate endorheic wetland, the Yaida Swamp, is situated immediately east of Lake Eyasi (3°52'-3°58'S/34°56'-35°08'E) on the floor of the Eastern Rift Valley, but separated from Lake Eyasi by a low ridge. This system is fed by a stream from the north, draining the mountainous eastern rim of the Eastern (Gregory) Rift Valley above Lake Manyara.

Flora & Fauna: The affluent streams carry gallery woodlands, the floodplains are dominated by grasses, and the freshwater swamps by papyrus. The immediate margins

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of Lake Eyasi are bare, but at a distance they carry short grasslands containing *Diplachne fusca* and *Sporobolus spicatus*, with *Cyperus laevigatus* in boggy sites.

Since Lake Eyasi is dry for much of the time it contains no fish other than *Oreochromis amphimelas* which lives in the springs around the lake. However, the fish faunas of Lake Kitangiri and the Wembere River are representative of the western equatorial part of the region, with species of *Alestes*, *Clarias*, *Hydrocynus*, *Lates*, *Mormyrus*, *Schilbe* and *Synodontis*. The amphibian population of the rivers and swamps is abundant, and the system supports crocodiles, monitors and snakes, as well as a rich avifauna. In total nearly 400 species of birds have been recorded here. The spectrum of mammals in the galleries, swamps and floodplains is as described in the regional introduction.

Human Impact & Utilisation: Lake Kitangiri supports a fishery with an annual yield of 600-4000 tonnes. There were 500 fishermen operating on the lake in the period 1971-1975, when *Oreochromis amphimelas*, *O. esculentus* and *Tilapia rendalli* formed the bulk of the catch. The last two species having been introduced from Lake Victoria. The gallery forest trees are exploited for timber and firewood and there is some cultivation of the Wembere Floodplain.

(D) THE LAKE NATRON BASIN

General: Lake Natron is a shallow endorheic soda lake, situated (2°05'-2°36'S/ 35°53'-36°08'E) on the floor of the Eastern (Gregory) Rift Valley, reaching the Kenyan border in the north. It is 57.5 km long, has a maximum width of 22 km, a mean width of 15 km, and an open water surface of 85 500 ha at an altitude of 610 m asl. It has a maximum depth of 50 cm and is fed by seasonal streams from the Ngorongoro Highlands in the south, from Mt. Gelai (2942 m asl) in the southeast, the Nkito Hills in the east and the highlands along the western margin of the valley. However, the principal affluent, the Ewaso Ngiro River, is perennial. This rises on the western slopes of the Mau Escarpment in Kenya and flows southwards along the western side of the Rift Valley, under the Nkuruman Escarpment, passing 12 km west of Lake Magadi, before entering Lake Natron through the Ngare Ngiro Swamp (2°01'-2°11'S/35°59'-36°09'E). This wetland comprises a permanent herb swamp of some 4000 ha upstream, and a seasonal floodplain of about 8000 ha, which extends down to the lake and along the eastern lakeshore. Lacustrine sediments above the level of the present Lake Natron suggest that it was at one time continuous with Lake Magadi, 21 km north. The water is highly saline, with chloride concentrations reaching 65 000 mg/l.

Flora & Fauna: The lake is endorheic and highly saline and has no macrophyte flora, but the herb swamp is a fresh water system with a typical spectrum of tall species including *Cyperus papyrus*, *Phragmites mauritianus* and *Typha domingensis*. Stands of *Hyphaene coriacea* and *Raphia farinifera* have been reported here. There is a rich vertebrate fauna in the swamps with an abundance of birds. *Oreochromis alcalicus* is found in springs and creeks around the lake in waters with salinities exceeding 40‰.

Human Impact & Utilisation: The swamp is virtually unutilised.

Conservation Status: Unprotected.

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(E) THE LAKE MANYARA BASIN

General: Lake Manyara is oriented almost due N-S and lies in a trough, 960 m asl, in the line of the eastern margin of the Eastern (Gregory) Rift Valley. The lake has an area of 41 300 ha at high water and a maximum depth of 3.7 m. An escarpment rises steeply, 200-900 m above the level of the lake, along its western shore, and the Ngorongoro Highlands rise to 3658 m asl, some 45 km to the north. Several perennial streams flow to the lake. The Simba River enters the north end from the Ngorongoro area, and there is a substantial swamp to the east of the river mouth. The Makayuni River drains the plateau lands to the east, while other, semi-perennial streams descend the escarpment and have built alluvial fans into the lake, e.g. the Ardi, Enoobash, Bosayo, Ndala, Chem Chem and Masasa Rivers. The area of the lake is very variable; during dry cycles it contracts to reveal expanses of alkaline mud-flat. The waters are saline, and conductivities as high as 94 000 µSiemens/cm have been recorded, while the pH is usually in the vicinity of 9.5. Sodium is the dominant cation, with mean concentrations of 2510 mg/l, with calcium the next most abundant at 1.5 mg/l. Chloride ion concentrations reach 1168 mg/l.

On the plateau below the eastern rim of the Gregory Rift Valley is the Shuriro Swamp (4°32'-4°58'S/36°08'-36°14'E), 50 km long and up to 12 km wide, with a wet season area of 36 000 ha. This drains northwards via the Tarangire River. Some 20 km WNW of the Shuriro Swamp the Kisaki River rises in another swamp (4°19'-4°38'S/35°48'-35°57'E). This is situated close to the mountains of the rift valley margin and covers 19 000 ha at high water. On leaving it the Kisaki reaches a confluence with the Tarangire 30 km below Shuriro Swamp, and the river, then flowing due north, enters the Tarangire National Park through yet another swamp (3°50'-4°31'S/36°08'-36°13'E). This is 61 km long and 10 km wide and has an area of 60 000 ha in wet years. All these swamps are situated very close to 1200 m asl, and flow in the connecting watercourses is sluggish. Yet farther north the Tarangire receives the overspill from Lake Burungi, a small fresh water lake 23 km west of the river. Below this confluence the Tarangire swings NW to reach Lake Manyara. However, another, apparently endorheic swamp, is situated to the east of this system (4°21'-4°35'S/36°16'-36°26'E) at Oljoro, 1100 m asl, and is fed by several short seasonal streams.

All the rivers and streams of the Tarangire system contract to a series of pools during the dry season, and much of the swampland dries out revealing hard black cracking clay soils, especially during prolonged dry cycles. Lake Burungi, however, is perennial.

Flora & Fauna: The low lying alkaline flats around Lake Manyara are covered by short grasses including *Diplachne fusca*, *Odyssea jaegeri* and *Sporobolus spicatus*, with *Cyperus laevigatus* in permanently wet spots. The vegetation is generally zoned according to depth and duration of flooding, but fresh water species become dominant at river mouths, and in these places there are large stands of *Typha domingensis*. Wherever fresh water influence is high there are patches of groundwater forest and *Cynodon dactylon* swards. The plateau is covered by *Acacia-Commiphora* bushland, but the Tarangire and its affluents support sparse gallery woodlands. The swamps through which they flow contain *Phragmites mauritianus* and *Typha domingensis*, together with sedges and some short grasses. There are patches of dense groundwater forest which contain *Acacia tortilis* among other species.

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Oreochromis amphimelas lives in springs around the lake, which is its type locality. Over 400 species of birds have been identified in the basin. At times *Phoeniconaias minor* is present in large numbers, while *Charadrius venustus, Oxyura maccoa* and *Thalassornis leuconotus* are other important species. *Hippopotamus amphibius* is present on the lake margins and at the mouths of affluent streams, with several large mammals on the surrounding plains and in the gallery forests. These include *Damaliscus lunatus, Kobus ellipsiprymnus, Loxodonta africana* and *Syncerus caffer*. Small mammals include *Atilax paludinosus, Aonyx capensis, Lutra maculicollis* and civets, genets and mongooses.

Human Impact & Utilisation: The basin is an important tourist area and there is an hotel just outside the park a few kilometres from the northwest end of the lake. The indigenous population is quite dense to the north, around the town of Arusha, and settlement is increasing on the plateau to the east of the lake, but the wetlands *per se* are not heavily exploited.

Conservation Status: The northwestern part of the Manyara lakeshore and the northern two-thirds of the lake itself is protected in the Lake Manyara National Park. A large sector of the Tarangire Swamps is contained in Tarangire National Park.

(F) THE BURIGI & IKIMBA BASINS

General: These two small lakes are situated in northwestern Tanzania, between the Kagera River and Lake Victoria, being isolated from both, and from each other, by hill ridges rising 1300-1715 m asl. Lake Burigi (2°01'-2°12'S/31°14'-31°20'E) is 18 km long, 4 km wide and has an area of about 7000 ha. It is fed by run-off from its immediate surroundings, and by rivers from hills to the south. The largest of these, the Ruiza, is 108 km long, with a broad, often indiscrete course. It is swampy in its lower reaches, and carries gallery forest. Papyrus swamps occur around the lake, and there are patches of groundwater forest on the flats about the lake. The northwestern part of the lake and lakeshore are situated within the Burigi Game Reserve. *Kobus ellipsiprymnus* and *Hippopotamus amphibius* occur here.

Lake Ikimba has an area of some 12 500 ha. It is situated almost due north of Burigi (1°24'-1°35'S/31°30'-31°36'E) and is also fed by a southern affluent. It is 18 km long and has a maximum width of 12 km. Both lakes are about 1200 m asl, and neither has an outflow. There is little information regarding the biology, hydrology and water quality of these lakes, but the flora and fauna are expected to be typical of western equatorial districts. Lake Ikimba is not protected.

4. Natural Lakes

(A) LAKE VICTORIA

Location: 0°30'N-3°12'S/31°37'-34°53'E
Area: 6 889 000 ha (c. 3 375 600 ha in Tanzania)
Altitude: 1134 m asl
Nearest Towns: Mwanza (on S lakeshore); Musoma (on E lakeshore)

General: In terms of surface area, Lake Victoria is the 3rd largest lake in the world, with 49% of its area in Tanzania. It has a maximum recorded depth of 85 m and a mean depth

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of 40 m. It stretches 412 km from north to south between latitudes 0°30'N and 3°12'S, and 355 km from west to east between longitudes 31°37' and 34°53'E. It contains numerous islands and has a highly indented shoreline which Welcomme (1972) estimates as 3460 km long. However, published shoreline measurements are notoriously variable, since they depend absolutely upon the scale of map used for their determination and how far each indentation is measured. Welcomme's estimate appears conservative, especially if island shores are included. The innumerable bays and inlets of the lake margin occupy valleys of the pre-lake system, and they differ in ecology from inlet to inlet, and from inlets to the main lake. Much of the margin is swampy, being fringed by dense papyrus stands. Mean monthly air temperatures over the lake range from 21.0-25.0°C. February and March are the warmest months, while December and January are the coolest ones.

The lake occupies the shore of a vast shallow basin formed by the upwarping of the eastern and western margins. The geological history of the lake is not agreed, but interpretations of modern data are given by Bishop (1969), Kendall (1969) and Temple (1969), while Greenwood (1965a) and Worthington (1954) deal with the history and development of the fish fauna. It is clear from fossil evidence that an earlier lake, or system of lakes, with a Soudanian fauna, occurred in the area in the early Miocene and persisted until at least 16 million years BP, but when and why this lake declined is obscure. That its fauna was different is clear from the fact that it contained *Lates* and *Polypterus* which are not indigenous to the modern lake. Between the disappearance of the old lake and the development of the present lake it seems that rivers from western Kenya flowed across the area to Lake Edward, and thence it would seem, to the Nile. With the upwarping of land in the west, to create that side of the present basin, these rivers reversed their directions of flow. Although today the pattern of their tributaries, as seen on a map, suggests that they flow to Lakes Edward and Albert, they actually flow eastwards to Lake Victoria. The important rivers in this context are the Katonga and Kafu Rivers, both of which have swampy watersheds close to the Western Rift Valley, from which they flow sluggishly eastwards, as swampy water courses rather than rivers, to Lake Victoria. From the western sides of these watersheds the Katonga still flows to Lake Edward and the Kafu flows to Lake Albert.

It seems that the present Lake Victoria is about 750 000 years old, but because of the slowness of the upwarping along the western margin, it may have continued to discharge to Lake Edward, via the Katonga, until about 20 000 years ago, whether or not the present northern exit had been forged at that time. A series of three raised beaches, 18, 10 and 1 m above present lake level, indicate past periods of higher water level and stability, the last dated at 3700 BP. The causes of these higher levels and the comparatively sudden drops are not known. They could have been due to climatic changes, or to the opening of new effluents at successively lower levels, or a combination of these factors. Certainly the climatic events which led to the disappearance of the great Pleistocene water bodies from the Sahara cannot have failed to have influenced Lake Victoria. It seems that the modern lake shrank below its outflow level at least twice, once between 14 500 and 12 000 BP, and again for a period around 10 000 BP. This is deduced from dated sediments rich in precipitated carbonates, and from the analysis of pollen in cores, which indicate dry conditions contemporary with low lake levels. The lake was high in 1876, possibly close to the level of the lowest raised beach, but had fallen to almost 4 m below it in 1900. From that time until 1961, the level of the lake was stable with inter-annual

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fluctuations of about 1 m, but in 1961-64 the level rose sharply to the present level, 1 m below the lowest raised beach. High water was then maintained into the early 1980s. The dramatic rise of the water level between 1961-64 has had profound consequences for the marginal habitats of the lake.

A fossil cichlid, provisionally asigned to *Oreochromis spilurus*, which is now confined to the Bivaso Ngiro and the rivers flowing to the Indian Ocean, occur in deposits east of the lake. Again the interpretation of this is not certain, but it may be that the eastern side of the Lake Victoria basin was once farther west than it is now. However, there seems no reason to doubt that the fish fauna of the present lake was derived from that of the old rivers flowing west across the area, which would have undergone 'ponding' prior to the development of the lake. This was followed by a burst of speciation in the cichlid stock with the advent of true lacustrine conditions, as has occurred in the great lakes of the Western Rift Valley. Beadle (1981) gives a good introductory account of the history of the lake and its fauna.

Hydrology & Water Quality: The principal affluent is the Kagera River which drains the highlands of Burundi and Rwanda along the eastern rim of the Western Rift Valley. Thereafter the Nzoia River, which enters the northeastern corner, is the most important affluent. This river drains parts of the Mt Elgon Massif and the Cherangany Hills in Kenya, but it is far more seasonal in its discharges than is the Kagera. Other important inflows are from the other rivers of the northeastern and northwestern quadrants. Those of the northeast are very seasonal and comparatively swift flowing, while those of the northwest are less seasonal and very sluggish. The southeastern affluents are of comparatively little importance and drain areas of rather arid plateau country, including the Serengeti Plains. Direct precipitation contributes more water to the lake than riverine inflows. It decreases from west to east across the lake, being 2000 mm/yr on the central western shore near Bukoba, but just over 1100 mm at the southwestern corner and only 750 mm in the southeast. The northern shores receive rather more than 1100 mm/yr. The lake is generally well oxygenated, at least to depths of 30 m, with concentrations ranging from 4.6-9.4 mg oxygen/l, although stratification does occur. Water temperatures range from 23.6-30.0°C, the highest readings being made in shallow bays. Secchi depths range from 35-300 cm. The concentrations of the principal ions, as given by Talling & Talling (1965) are: sodium 10.4 mg/l; potassium 3.8 mg/l; calcium 5.6 mg/l; magnesium 2.6 mg/l; chloride 3.9 mg/l; silicate 4.2 mg/l; and sulphate c. 1.0 mg/l.

Flora & Fauna: The phytoplankton is dominated by cyanophytes. Islands of *Cyperus papyrus*, with its typical associates, detach from the fringing swamps. The lake itself contains submerged species such as *Ceratophyllum demersum* and *Potamogeton* spp. around the margins, while waterlilies and *Pistia stratiotes* are found floating in quiet spots. Copepods and rotifers are abundant in the zooplankton. Enormous swarms of lake flies, mainly chaoborids (especially *Chaoborus anomalus*) and chironomids, rise from the lake surface from time to time, generally a few days after a new moon, and at these times the waters may be churned up by fish struggling to eat the pupae as they rise to the surface to emerge. The fly swarms, which may be over a kilometre long and up to 100 m high, are often attacked by flocks of birds. The total biomass of these flies in the lake is prodigious.

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The fish fauna is essentially nilotic, but there are many endemics, including nearly 200 endemic cichlid species and 4 endemic genera. More than 150 of the cichlids belong to the genus *Haplochromis* according to Greenwood (1974a). Many species leave the lake to spawn in the affluent streams. There have also been some introductions, e.g. *Lates albertianus*, *Oreochromis niloticus*, *O. leucostictus* and *Tilapia zillii* were introduced before 1962 and are now widely distributed.

Crocodylus niloticus has been intensively hunted on the lake and is now nearly extinct there. Many of the Equatorial East African animals cited in the regional introduction occur in, or on the shores, including water turtles, aquatic snakes, monitor lizards, a wealth of birds, rodents, otters, *Hippopotamus amphibius*, *Kobus ellipsiprymnus* and *Tragelaphus spekei*.

Human Impact & Utilisation: The shores of the lake are fairly densely populated. The lake is fished commercially by trawling, and by artisans using seines and lines from beaches and canoes. The total annual catch is difficult to estimate but is probably in the region of 130 000 tonnes, with as much as 51 000 tonnes being taken from Tanzanian waters in 1969, when 2600 canoes were operating with gill nets. Yields from Tanzanian waters subsequently went into a decline, despite an increased number of canoes. It is therefore noteworthy that Welcomme (1972) cites the estimated maximum sustainable yield from Tanzanian waters as 21 000 tonnes/yr. The introduced *Lates niloticus* now comprises between 40-55% of the commercial catch, with individual fish weighing as much as 45 kg. Other important fish caught commercially include species of *Bagrus*, *Engraulicypris*, *Haplochromis*, *Mormyrus* and *Oreochromis*.

The lake has long been important for communications, but the construction of a railway and good roads around the northern shore, linking Uganda with the coast has lessened the amount of cargo and the numbers of passengers carried across the lake.

Conservation Status: A very small length of lakeshore in the SW is protected in the Biharamulo National Reserve, and Rubondo Island in the SW (2°25'S/31°50'E) is a National Park. Otherwise the lake is unprotected in Tanzania.

(B) LAKE TANGANYIKA

Location: 3°21'-8°51'S/29°04'-31°12'E
Area: 3 294 480 ha (c. 1 350 736 ha in Tanzania)
Altitude: 773 m asl
Nearest Towns: Kigoma (on lake); Tabora (340 km E)

General: Lake Tanganyika is 659 km long with a maximum width of 85 km at the parallel 5°55'S. It is slightly brackish and the second deepest lake in the world at 1470 m, at which point its bottom is 697 m below sea level. It lies in the Western Rift Valley and down most of its western side the escarpment plunges straight into the water. In the south basin it continues underwater to the maximum depth of 1470 m, which is reached just 4 km offshore. Only at the northern and southern ends is the underwater slope moderate, and even in these places the 100 m contour is reached inside 10 km. The adjacent mountain ranges exceed 3000 m in altitude at the northern end of the lake, which is fed by several large rivers and countless small streams. These enter all round the periphery, from Zambia, Tanzania, Burundi and Zaire. 41% of the lake surface is situated in Tanzania. The Ruzizi River, draining Lake Kivu, descends the Panzi Falls before

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entering Lake Tanganyika so that the two lakes are faunally isolated. The Ruziri has formed a substantial delta at the north end of Lake Tanganyika. The other principal affluent is the Malagarasi River, which drains much swampy land to the south of Lake Victoria and enters from Tanzania. The lake drains from the middle western section, in Zaire, via the Lukuga River to the Lualaba. Water levels fluctuate over long time periods, much as they do in Lake Malawi to the south, a matter discussed by Camus (1965).

The lake is ancient and was long isolated, which accounts for the fact that it contains a higher proportion of endemic species than any other African lake. It seems clear that in pre-rift days, rivers such as the Malagarasi flowed west across the region to the Zaire Basin, and that rifting interrupted their flow and produced the lake. The original fauna of the lake would have been derived from that of the rivers concerned, but there have been subsequent arrivals from the Zaire Basin via the Lukuga. A good introductory account of the history of the Lake is given by Beadle (1981).

Hydrology & Water Quality: Although it is a freshwater lake the salinity is elevated, 0.5‰, and this may in part reflect the salinity of the input from the Ruzizi which is 0.65‰. Direct precipitation makes a significant contribution to the annual inputs, but the bulk of the inflow is riverine. During the rainy season most of the streams draining the escarpments are torrential. Far more water, probably 80-85%, evaporates from the lake surface than leaves by the Lukuga River (15-20%). There is a vast mass of anoxic, stagnant, sulphide charged water in the lake below a depth of 200 m. The concentrations of the principal ions are sodium, 57 mg/l; potassium, 35 mg/l; calcium 9.8 mg/l; magnesium 43.3 mg/l; chloride 26.5 mg/l; sulphate 5.0 mg/l and silicate 0.4 mg/l. Carbonates are present in a concentration of 6.7 meq/l (Talling & Talling, 1965).

Flora & Fauna: *Ceratophyllum demersum* is abundant in the vicinities of affluent river mouths, while in the deltas of several rivers *Azolla pinnata* may form immense floating mats, green or red-brown in colour, and there are great submerged beds of *Myriophyllum spicatum*, *Najas marina*, *N. pectinata*, *Ottelia ulvifolia*, *Potamogeton pectinatus* and *P. schweinfurthii*. *Potamogeton* spp. are the predominant macrophytes around much of the shoreline, with occasional rafts of *Nymphaea caerulea* and *N. capensis* in shallow sheltered bays. *Cyperus papyrus*, *Phragmites mauritianus* and *Typha domingensis* dominate the delta swamps, with *Vossia cuspidata* as the principal low growing associate.

The lake contains a large fish fauna comprising some 193 species from 13 families. Although 98% of the cichlids and 57% of the non-cichlid species are endemic, similar proportions to those found in the faunas of Lakes Malawi and Victoria, it is the degree of speciation here, which distinguishes Lake Tanganyika from the others. It contains no less than 8 endemic genera, and some endemic species reveal distinct subspecific forms between the north and south ends of the lake. Zaire Basin species have invaded the lake comparatively recently, presumably by way of the Lukuga River, the most recent effluent. These include *Distichodus fasciatus*, *Hydrocynus goliath* and *Labeo lineatus*. Other interesting species include *Polypterus congicus*, *Protopterus aethiopicus* and *P. ornatipinnis*, also Zaire Basin species which live in lagoons and deltas around the lake, especially the Malagarasi Delta. These are ancient fish and their presence has probably been continuous from the time when the Malagarasi flowed directly into the Zaire basin, before the faulting which led to the development of the Rift Valley and its lakes. There are two fully aquatic piscivorous snakes in the lake. *Boulengerina annulata*

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lies up in the rocks during the day and fishes nocturnally, while *Glypholycus bicolor*, hunts pelagic fish, chiefly shoals of *Stolothrissa tanganicae*. A general account of the vegetation is given by van Meel (1952), while Poll (1950; 1952) discusses the fish and Leloup (1952) the invertebrates.

Human Impact: The lake is fished from ports in all four countries which border the lake, but Kigoma is the main port in Tanzania. Historical surveys show that the fishery yields from the lake have varied considerably this century. A sardine fishery (*Stolothrissa*) operates, but is concentrated on ports in Zambia and Burundi, and indeed fishing intensity for all species is higher at the southern and northern extremities than at other parts of the lake. The annual landings of sardines in Burundi ranged from 3500-8900 tonnes during the period 1972-76, while figures for Zambia over the same period were slightly lower. The total catch for the lake in 1971 was 73 268 tonnes, with 44 468 tonnes being landed in Tanzania. Estimates of the total fish biomass in the lake, made by acoustic methods, have varied between 500 000-2 600 000 tonnes, and estimates of the maximum sustainable yield for all species range from 22-100 kg/ha (Smart, 1978). A comprehensive bibliography of fisheries and limnology for Lake Tanganyika is available (FAO, 1982).

There is an important network of steamer services on the lake, the shoreline being unsuitable for the construction of good roads. Only around the northern end of the lake, in Burundi and Zaire, are there roads of importance.

Conservation Status: A small area, which includes a 1 km stretch of lakeshore south of Kigoma, was declared a National Park in 1985, largely to protect the chimpanzees which still occur in the area. This is the only section of the entire lakeshore which is protected.

(C) LAKE MALAWI

Location: 9°30'-14°27'S/33°58'-35°19'E
Area: 2 975 000 ha (none in Tanzania)
Altitude: 475 m asl
Nearest Towns: Mbeya (90 km NW); Dodoma (425 km NE)

General: Lake Malawi is situated in the southern part of the Western Rift Valley. Tanzania has 305 km of shoreline, but none of the lake surface is in Tanzania. The lake is 565 km long in a N-S direction, has a maximum recorded depth of 706 m, and is the second deepest lake in Africa. In the north, the Kipengere Mountains fall steeply to the lake surface and continue into the depths of the northern basin. To the east and west, other escarpments form sheer cliffs at the water's edge. Much of the shoreline is rocky, giving rise to sheltered bays in places, but where the escarpments do not descend directly into the lake, there are coastal plains of varying widths, which are subject to flooding when water levels are high. In the south of the lake the topography is less rugged. The lake is of sufficient size to modify the climate locally. Annual rainfall reaches 2500 mm at the northern extremity of the lake but riverine inputs are more important than direct precipitation. The lake level fluctuates by 70-180 cm/yr. The principal water loss (80-90%) is through evaporation, with the remaining 10-20% leaving the southern extremity via the Shire River. Details of the biology, hydrology, water quality and history of the lake are given in section 5.4.6.

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Small deltas with fresh water swamps occur at the mouths of some streams entering the lake on the Tanzanian shore. The lake is covered by a network of steamer routes which connect Tanzanian ports with others in Malawi and Mozambique. The lake is fished both commercially and by artisans from Tanzanian ports. The annual catch landed in Tanzania had reached 21 000 tonnes in 1971, and at that time exceeded the joint catch landed in Mozambique and Malawi (Welcomme, 1972). The lakeshore is unprotected in Tanzania.

(D) MINOR LAKES & SWAMPS

The Balangida/Singida Lakes: Southeast of Lake Eyasi, in the highlands along the eastern rim of the Gregory Rift Valley, there is a collection of small endorheic lakes and swamps. The largest of the lakes are Lakes Balangida (4°22'S/35°18'-35°24'E) and Balangida Lelu (4°40'S/35°09'-35°16'E). Lake Balangida is 14 km long, up to 3.5 km wide and covers 6000 ha. It is situated in a deep trough close to the 1800 m contour in forested country, and is surmounted by steep rock walls which rise abruptly to 2000 m. Immediately above these cliffs, on the southeastern side, the perfect volcanic cone of Mt. Hanang rises to 3418 m asl. Lake Balangida Lelu, to the south, is 10 km long and about 4 km wide at the northern end. It is close to 1400 m asl, and the northern end is set in forested country.

Ten kilometres west of Lake Balangida Lelu, swamps develop in the wet season in an area 30 km from N-S and 10 km from E-W (4°28'-4°48'S/34°57'-35°06'E), covering about 25 000 ha. At the northeast corner of these swamps is a semi-permanent lake (4°33'-4°38'S/34°56'E) which is fed by two short seasonal streams and seepage from the swamp. A further 18 km west there is another swampy trough, about 15 km long and 4 km wide, oriented SW-NE, with Singida Lake (4°49'S/34°44'E) at its southern end. Two other very small lakes lie immediately south of this.

The surrounding plateau supports *Acacia-Commiphora* bush, but the streams carry sparse gallery woodlands, and although there are patches of groundwater forest in some of the swamps, these are dominated by reeds, sedges and *Typha* sp. The area is comparatively densely populated and the unprotected areas are heavily grazed.

Ngorongoro Crater: The crater, or more properly caldera, is situated (3°05'-3°14'S/35°29'-35°37'E) on a volcanic massif, rising to 3648 m asl at Mt. Loolmalasin, in the Eastern Rift Valley between Lakes Eyasi and Natron. The rim of the caldera, 2270-2700 m asl, is nearly 15 km across, and on the floor 610-760 m below, there is a series of fresh and brackish-water lakes and swamps, and some dense *Acacia* woodlands, all protected in the Ngorongoro Crater Conservation Area. The caldera floor supports an abundance of wildlife, including many aquatic and semi-aquatic species, and others which visit the wetlands regularly. A great many of the animals listed in the regional introduction for Equatorial East Africa occur here.

Arusha National Park: This park includes a series of little crater lakes, some less than a kilometre long and only a few hundred metres across. The two largest are the Big and Small Momela Lakes, the small one being 3 km long and 900 m wide. The big one has an equivalent area but is shorter and wider. The other lakes are Lakes Kasare, Lekandiro, Longil, Sanjo and Tulusia. The Momela Lakes are a haunt of flamingoes.

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Serengeti Plains: There are two saline lakes on the Serengeti Plains. Lake Logaria (3°00'S/35°01'E) and Lake Magadi (approximately 2°40'S/35°50'E). These are important to flamingoes. Both are situated within the Serengeti National Park.

5. Artificial Impoundments

General: The total surface area of impoundments in Tanzania is 84 813 ha, if all reservoirs are at capacity. The largest reservoir is at Mtera, where the dam was closed in 1980. The second largest is at Nyumba ya Mungu, where the dam was closed in 1965. This latter reservoir has been intensively studied.

(A) NYUMBA YA MUNGU RESERVOIR

Location: 3°41'S/37°27'E
Area: 18 000 ha (at capacity)
Altitude: 670 m asl
Nearest Towns: Moshi (50 km N); Dar es Salaam (390 km SE)

General: This reservoir, otherwise known as Lake Pangani, is a multipurpose impoundment of the Pangani River, which was completed in 1965. It is used for the generation of electricity and for irrigation, and supports a fishery. It is 25 km long and 15 km wide at maximum, with a maximum recorded depth of 41 m and an estimated storage capacity of 1.12 billion m^3. Retention time is currently close to 9 months. Although Denny (1978) states that it is situated 670 m asl, several maps place it above the 800 m contour. It is situated in a low rainfall zone, c. 500 mm/yr, and is fed by the Kikuletwa River which rises on Mt. Meru, but receives four affluents from Mt. Kilimanjaro, and the Ruvu River which originates at Lake Jipe, but receives three affluents from Mt. Kilimanjaro. Lake Jipe is fed by the Lumi River from Mt. Kilimanjaro. There is a swamp 5.2 km wide and 8.4 km long at the northeastern corner of the reservoir where the Kikuletwa enters.

Denny (1978), Welsh & Denny (1978) and Bailey & Denny (1978) have made detailed studies of the reservoir and its biology.

(B) MTERA RESERVOIR

General: This is a recent impoundment on the Great Ruaha River, just below its confluence with the Bubu River (approximately 7°06'S/35°55'E). According to Bernacsek (1984) this reservoir will have a surface area of 61 000 ha, which will make it by far the largest impoundment in Tanzania, and currently the tenth largest in Africa. This is a new reservoir and we have no information regarding either its hydrology or biology.

(C) OTHER RESERVOIRS

General: There are reservoirs at Hombolo on the Wami River (1500 ha), and at Kidatu on the Great Ruaha River (1000 ha). Other reservoirs are at Igombe (1300 ha), Dobola, Ikowa, Kalimawe, Kerenge, Kisaki, Malya, Manda, Mianje, Muchlur, Nhimbu, Nondwa and Uchama. Taken together these 15 reservoirs account for only 7% of the national area.

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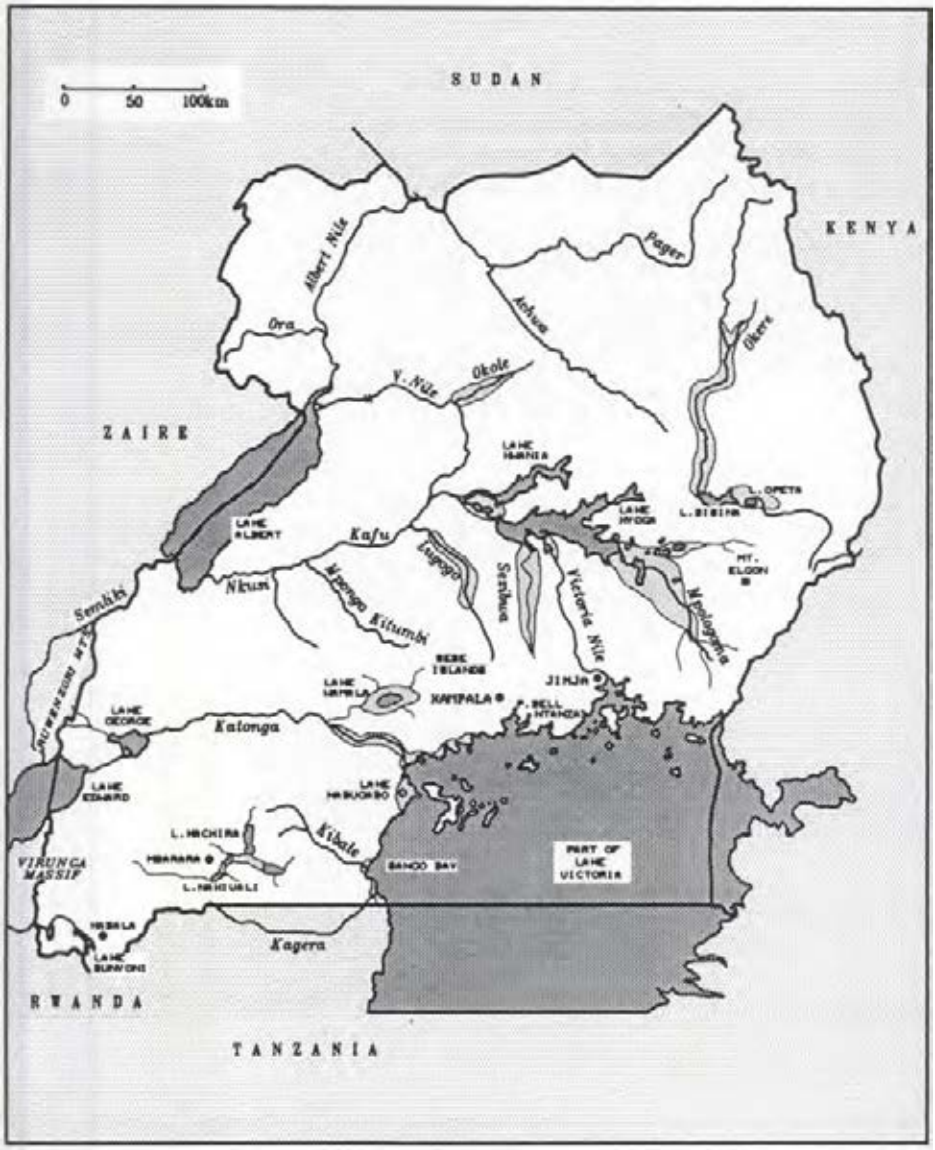

Map of Uganda

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2.10 UGANDA

Introduction

Uganda had a population of 12 639 076 in 1982, as determined by a census. It has an area of 236 580 km^2 and therefore, in 1982, had a mean population density of 53.4 persons/km^2, but subsequent trends in population development are not clear. Uganda is landlocked, being bounded by Tanzania and Rwanda in the south, by Zaire in the west, by Sudan in the north and by Kenya in the east. The country stretches approximately 627.5 km from north to south between latitudes 3°14'N and 1°29'S, and 607 km from west to east between longitudes 29°34' and 35°01'E.

In the main Uganda comprises a plateau of low relief, 1100-1300 m asl, but with four principal highland areas, and some lower land in the northwest, in the valley of the Albert Nile. The highlands are all peripheral. A broken chain of mountains lies along the northeastern border with Kenya in the Karamoja District, with peaks of 2750 m asl at Mt. Morungale (3°49'N/34°01'E), 3083 m asl at Mt. Moroto (2°31'N/34°46'E) and 3068 m asl at Mt. Kadam (1°46'N/34°43'E). In the southeast the great volcanic cone of Mt. Elgon (1°07'N/34°32'E) rises to 4321 m asl astride the border with Kenya, the summit being just inside Uganda. In the southwest the Ruwenzori Mountains on the Zaire border rise to 5110 m asl at Mt. Stanley (0°24'N/29°55'E) providing the highest land in Uganda, and in the extreme southwest the largest highland block in the country rises to 4127 m asl at Mt. Muhavura (1°24'S/29°40'E), one of the Virunga Volcanoes on the border with Rwanda. The lowest land in Uganda is 610 m asl near Nimule (3°37'N/32°03'E).

Around Lake Victoria the landscape is characterised by flat-topped hills, about 1300 m asl, with forested valley sides, and papyrus swamps along the thalwegs leading down to swampy inlets on the lakeshore. Very nearly 18% of the total national land surface is lake or permanent swamp. Lake Victoria has an open water surface of 3 100 060 ha in Uganda, while in the west Lakes Albert, Edward and George have a combined surface area in Uganda of 405 170 ha, and in the centre Lakes Kyoga and Kwania cover 317 300 ha.

Drainage

All of Uganda drains to the Nile. The land between Lake Victoria and the Western Rift Valley drains either into the rift or to Lake Victoria, but the Katonga River is continuous between Lake Victoria and Lake George in the Western Rift, and the Kafu River is continuous between the Victoria Nile and Lake Albert in the Western Rift. This is due to the fact that since the upwarping of the western side of the Lake Victoria basin, rivers crossing it have in part reversed their directions of flow. Thus swampy watersheds now occur on the Katonga (0°13'N/30°39'E) and Kafu (1°11'N/31°09'E) Rivers from which the rivers flow sluggishly in opposite directions. The greater part of the Katonga flows eastwards to Lake Victoria, and the greater part of the Kafu flows northeastwards to the Nile, despite the fact that the angles of their tributaries suggest that they flow westwards throughout their courses.

The Virunga Massif is also beset with swampy watersheds from which rivers flow in different directions. The northwestern slopes in Uganda drain to Lake Edward via the

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Ishasha, Chirurima, Nchwera and Nyamweru Rivers, and also by several streams which enter the western flowing part of the Katonga River. The northeastern part of the Virunga Range however, drains directly to Lake Victoria via a series of swampy lakes and streams culminating in the Kibale River, which enters Lake Victoria through the swamps at Sango Bay.

The Ugandan slopes of the Ruwenzoris drain to the westward flowing section of the Katonga, and thence to Lakes George and Edward, while the plateau immediately to the north of the Ruwenzoris drains to Lake Albert via the Muzizi River. The Ugandan slopes of Mt. Elgon and the central highlands along the Kenyan border drain via rivers with swampy valleys or seasonal floodplains to Lake Kyoga, while the northeastern highlands and most of the northern plateau drain directly to the Bahr el Jebel in Sudan via the Achwa River.

Climate

The climate is largely determined by the interplay of three major airstreams, the SE Trade Winds, the NE Trade Winds and the SW Monsoon. The latter chiefly influences western districts bringing humid air from the Zaire Basin as the intertropical convergence zone moves northwards. The SE Trade Winds are also humid and blow in from the Indian Ocean, but this airstream tends to veer southerly or southwesterly over Kenya and Tanzania. The western slopes of Mt. Elgon, like those of Mt. Kenya, are wetter than the eastern slopes, where mean annual falls just exceed 2000 mm. The Ruwenzori Mountains are wetter, with falls in excess of 3000 mm/yr on the western slopes, and 2250 mm/yr on the eastern Ugandan slopes. However, the largest area of high rainfall is over Lake Victoria where there is no harsh dry season. Rainfall is highest during March-May and October-November, with comparatively dry periods during December-February and June-July, but thunderstorms occur in these latter months producing intense precipitation. Mean annual rainfall is 1250-1500 mm on the lakeshore, with some 160-170 rainy days/yr, but precipitation exceeds 2250 mm over the Sese Islands and much of the open lake. The Karamoja District, in northeastern Uganda, is the driest part of the country with mean annual falls in the region of 625 mm, but precipitation is higher on the mountains there, and increases to the west. Most of interior Uganda receives 1000-1500 mm rain/yr, the north being more humid than the south, but there is an arid area bewteen Lake Victoria and the Ruwenzoris where falls are only 700-1000 mm/yr.

The figures for some specific centres given below confirm these gross patterns. Kaabong (3°30'N/34°09'E) in the northeast has a mean annual rainfall of 737 mm with one rainy season from August to September. Tororo in the southeast (0°42'N/34°10'E) receives 1396 mm/yr, with a major peak in March-April, but receives more than 50 mm in all months. Jinja (0°25'N/33°12'E) on the northern shore of Lake Victoria receives 1340 mm/yr, with peaks in March-May and October-November, but again all months receive more than 50 mm. Fort Portal (0°34'N/30°17'E) at the foot of the Ruwenzoris receives an average of 1524 mm/yr with a similar monthly distribution to Jinja, while Gulu (2°46'N/32°18'E) in the central north receives 1546 mm/yr. At this centre it rains for most of the year but with peaks in May and August, although January is dry with a mean receipt of only 17 mm. All other months receive more than 50 mm.

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The central northern districts are warmest with mean annual maxima over 35°C and mean annual minima of 17-20°C. Around Lake Victoria mean annual maxima are in the vicinity of 27-30°C, with mean minima between 16-17°C. Corresponding figures for the highlands are 22-24°C and less than 10°C. Permanent snow occurs on the highest peaks of the Ruwenzori Mountains, where small glaciers and icefields cover about 500 ha, while frosts are common on Mt. Elgon and the Virunga Volcanoes. Potential evaporation is about 1250 mm/yr in the mountains, about 1550-1650 mm/yr over the southern half of the country, but over 2000 mm/yr in the far north, e.g. at Kitgum (3°18'N/32°53'E).

Vegetation

Alpine vegetation, dominated by species of *Alchemilla*, *Helichrysum*, *Lobelia* and *Senecio*, occurs on the highest and wettest mountains, below which there is *Hagenia-Rapanea* evergreen forest. *Arundinaria alpina* often occurs at a transition between this and a more luxuriant forest type dominated by *Pygeum* spp. At lower levels this grades into medium altitude moist ever-green forest or semi-deciduous forest, or into a mosaic of forest and savanna. Here grasses such as *Pennisetum purpureum* or *Hyparrhenia rufa* are important. The southern plateau areas are largely covered by dry *Acacia* or *Combretum* savannas, while in the north, there are large areas of moist well wooded savanna with abundant *Isoberlinia* spp. Palm savannas indicate a high water table and have a scattered distribution in the north. Areas of tree and grass steppe occur along the Kenyan border in the northeast. Edaphic vegetation includes herbaceous swamp and swamp forest.

Wetlands

Swamps have developed on several rivers which have been tilted back eastwards by the upwarping of the western margin of the Lake Victoria basin, and these are mainly dominated by papyrus. In the Virunga Massif a number of lakes have formed where valleys have been blocked by volcanic activity, and others have developed on valley floors where upwarping has raised the lower end of the valley so that it has flattened out. Many river valleys carry large strips of papyrus swamp along their thalwegs, especially those entering Lake Kyoga, while some rivers draining the northeastern districts have seasonal floodplains. There are many lacustrine swamps, and some seasonal floodplains at the heads of the rift valley lakes, and several small lakes in the Virunga Mountains.

List of Wetlands Described

1. Natural Lakes & Lacustrine Swamps
    (a) Lake Victoria
    (b) The Kyoga/Kwania Lake/Swamp Complex
    (c) Lake George
    (d) Lake Edward
    (e) Lake Albert
    (f) The Bunyoni Lake/Swamp Complex

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(g) The Kijanebalola Lake/Swamp Complex

(h) Lakes Bisina & Opeta

(i) Lake Wamala

(j) Minor Lakes

2. Riverine Swamps & Floodplains

(a) The Okere System

(b) The Kafu System

(c) The Nile

1. Natural Lakes & Lacustrine Swamps

(A) LAKE VICTORIA

Location: 0°30'N-3°12'S/31°37'-34°53'E
Area: 6 889 000 ha (c. 3 100 060 ha in Uganda)
Altitude: 1134 m asl
Nearest Towns: Entebbe (on N lakeshore); Kampala (13 km N)

General: In terms of surface area, Lake Victoria is the 3rd largest lake in the world, with 45% of its area in Uganda. It has a maximum recorded depth of 85 m and a mean depth of 40 m. It stretches 412 km from north to south between latitudes 0°30'N and 3°12'S, and 355 km from west to east between longitudes 31°37' and 34°53'E. It has a highly indented shoreline some 3460 km long (Welcomme, 1972), of which about half is in Uganda. The innumerable bays and inlets of the lake margin occupy valleys of the pre-lake system, and they differ in ecology from inlet to inlet, and from inlets to the main lake. Much of the margin is swampy, especially in the northwest in Uganda. Mean monthly air temperatures over the lake range from 21.0-25.0°C. February and March are the warmest months, while December and January are the coolest ones. A more detailed account of the lake is given in section 2.9.4a, but a brief account is given here as it applies to Uganda.

There are numerous islands off the northwestern lakeshore in Uganda, notably the 18 Sese Islands and 5 Kome Islands, 5 islands in Roseberry Channel, Buvuma and Bugaia Islands, Siguli and Lolui Islands, and the 3 Sagitu Islands. Permanent papyrus swamps with some patches of swamp forest occur around the Ugandan lakeshore. Such swamps are well developed around the mouths of the Kagera and Kibale Rivers, for example, in an area along and inland of Sango Bay immediately north of the Tanzanian border (0°37'-1°00'S/31°27'-31°42'E). Other swamps occur on the lakeshore (0°20'-0°30'S/31°50'-31°58'E) encompassing Lake Nabugabo, and at the Katonga River mouth in two major blocks (0°08'-0°19'S/31°51'-31°57'E and 0°02'S/31°55'-32°04'E), and farther east along Salisbury Channel where many short streams enter the lake through a deltaic zone (0°10'N-0°02'S/32°06'-32°20'E). Smaller swamps are situated (0°16'N/32°41'E) near Port Bell and (0°09'N/32°45'E) near Ntanzi. An extensive seasonal floodplain is situated behind the swamps at Sango Bay, extending 30 km up some of the affluent streams.

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Lake Nabugabo (0°20'-0°23'S/31°53'-31°57'E) is 9 km long from SW-NE and 5 km wide. It occupies about 3600 ha at high water and has a maximum depth of 5 m. It is separated from Lake Victoria by a sand bar 1.2 km wide at its narrowest point. The lake is fringed by dense swamps, but the northwestern shore is forested with areas of sandy beach. This lake has been isolated only since the last fall in water levels some 3700 BP, but may have been in contact with the lake for short intervals during this period, possibly even in the late 1890s.

Hydrology & Water Quality: More water enters the lake from direct precipitation, which is heaviest over the Ugandan sector, than from riverine influxes. The most important affluents are situated in Tanzania and Kenya. The Katonga, the largest Ugandan affluent, is an extremely sluggish stream, more a swamp-course than a river in its lower reaches. For further details see section 2.9.4a.

Flora & Fauna: Lake Nabugabo contains 9 species of *Haplochromis*, 4 of which are endemic according to Greenwood (1965b) and must have evolved over the last 3700 years. The other 5 are also found in Lake Victoria. Other fish from this lake include *Alestes nurse*, *Bagrus docmac*, *Clarias mossambicus*, *C. werneri*, *Gnathonemus longibarbis*, *Protopterus aethiopicus*, *Schilbe mystus* and *Synodontis afrofischeri*. *Oreochromis leucostictus*, *O. niloticus* and *Tilapia zillii* were introduced to this lake in the 1950s.

The lacustrine swamps of Lake Victoria are dominated by papyrus, but in places there are arborescent associates, chiefly *Bridelia micrantha*, *Ficus verruculosa* and *Phoenix reclinata*. On the fringes of the papyrus, in areas less deeply inundated, there are strips and patches of swamp forest, as described in the regional introduction. For more detail see section 2.9.4a.

Human Impact & Utilisation: The shores of the lake are fairly densely populated. The lake is fished commercially using trawlers, and by artisans using seines and lines from beaches and canoes. The effluent river, the Victoria Nile, is dammed at Owen Falls (0°26'N/33°11'E).

Conservation Status: Small sanctuary areas have been set aside at Entebbe (5200 ha) and Jinja (800 ha), otherwise the lake and its shore are unprotected in Uganda. Nkosi Island, south of Entebbe, is protected as a Sitatunga Sanctuary, but there is a lot of poaching.

(B) THE KYOGA/KWANIA LAKE/SWAMP COMPLEX

Location: 0°33'-1°56'N/32°18'-34°00'E
Area: 560 000 ha (total wetland)
Altitude: 1033-1060 m asl
Nearest Towns: Kampala (112 km SSW of Kyoga); Mbale (50 km E of Kyoga)

General: This wetland occupies a shallow dendritic valley system, part of which is permanently flooded to form a series of shallow lakes, which have a combined maximum open water surface of 341 600 ha, and 218 400 ha of permanent swamps. The system is tributary to the Victoria Nile which flows through the southwestern end of Lake Kyoga, and then receives the discharge of Lake Kwania 32 km downstream. The system owes its existence to the upwarping of the western edge of the

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Lake Victoria basin, which has reduced the gradient and rate of flow in rivers flowing west, causing 'ponding' and turning them into sluggish swampy tracts.

Lake Kyoga (1°13'-1°47'N/32°33'-33°29'E) is the largest lake in the system. At high water its surface is 1034 m asl and covers 263 600 ha. The maximum depth is then 10.7 m and the mean depth about 3 m, and the surface level fluctuates by as much as 3.8 m during a year. The lake discharges at the western end into the Victoria Nile, and is oriented roughly E-W for 55 km immediately above the confluence, at which point it divides into two arms. The northeastern arm continues up the valley of the Omunyal River for a further 53 km, while the southeastern arm extends up the valley of the Mpologoma River for some 34 km. Many tributaries enter the Omunyal Arm the valley of which carries only minor swamps. By contrast, a vast permanent swamp extends up the Mpologoma Arm for 102 km above the lakehead, including many minor lakes, the largest of which are Lakes Adois (1°20'-1°25'N/33°30'-33°37'E), Kiando (1°23'N/33°24'E), Naragaga (1°23'N/33°27'E), Nyaguo (1°20'-1°22'N/33°41'-33°45'E), Nyasala (1°17'-1°22'N/33°34'-33°40'E), Namasajeri (1°21'N/33°22'E), Nakuwa (1°05'-1°17'N/33°24'-33°30'E), Nawampasa (1°16'N/33°22'E), Kawi (1°12'N/33°37'E) and Lemwa (1°07'N/33°41'E). The swamp belt reaches widths of 20 km and extends up several side valleys, covering more than 106 000 ha if the very variable lake surfaces are included.

The Victoria Nile enters Lake Kyoga on its southern shore through a swampy valley, with a continuous block of swampland extending upstream for 21 km above the lake, while to the west another large swamp belt extends southwards from the lake, up the valley of the Sezibwa River. Here the swamps are continuous for 80 km above the lake, and thereafter, following the bifurcation of the valley, for a further 25 km SSW up the Lwajali Valley and for 27 km SSE up the Sezibwa. There are close to 16 000 ha of swamps on the Victoria Nile above Lake Kyoga and 47 000 ha on the Sezibwa system. Other extensive swamps (approximately 44 000 ha) occur at the northwestern end of the lake, between it and Lake Kwania, and also along the south bank of the Victoria Nile between Lakes Kyoga and Kwania, and along the north bank of the effluent channel joining Lake Kwania to the Nile. In addition there are numerous small swamps around the lakeshore, and a seasonal floodplain of some 5000 ha on the Mukate River immediately above its mouth on the southwestern shore of Lake Kyoga.

Lake Kwania (1°35'-1°55'N/32°20'-33°02'E) is situated northwest of Lake Kyoga. It is 66 km long above the 25 km channel which connects it to the Victoria Nile. It is oriented roughly SW-NE and branches into two short arms near its northeastern end. At high water the lake surface is 1033 m asl and covers some 54 000 ha if the effluent channel is included. The maximum recorded depth is 5.4 m at high water and mean depth is estimated as 4 m. There are several small swamps around the lake margin.

Hydrology & Water Quality: The catchment of the complex is enormous. The principal inflow to Lake Kyoga is from the Nile which drains Lake Victoria and contributes an average of 25.6 billion m^3 of water each year. The other affluents are much smaller, the most important being the Mpologoma, which brings some 610 million m^3 of water from southeast Uganda each year, and the Okere which contributes an average of 373 million m^3 water/yr, and drains much of the north and central eastern parts of the country. The Sezibwa discharges some 217 million m^3 of water to Lake Kyoga each year, while the Omunyal contributes a further 40 million m^3/yr, and the Adip and Abalang

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Rivers jointly discharge a similar volume into Lake Kwania. Direct precipitation over the major lakes amounts to about 6 billion m^3/yr, while the mean annual outflow from the system is 27 billion m^3.

The water temperatures vary from 26-30°C and oxygen concentrations are moderate, but may fall to 3.8 mg/l in some of the small lakes. The pH values of Lake Kyoga range from 7.6-9.0, and conductivities from 210-365 µSiemens/cm. Concentrations of the principal ions are sodium 10.8 mg/l; potassium 9.6 mg/l; calcium 21.7 mg/l; magnesium 13.8 mg/l; carbonates 2.2 meq/l; chloride 12.0 mg/l; sulphate 31 mg/l and silicate 34 mg/l.

Flora & Fauna: The lake margins are fringed by *Cyperus papyrus*, which often detaches to produce floating islands, because of the substantial changes in water levels. There are extensive and dense carpets of floating macrophytes along the fringes of the open water, and beds of submerged macrophytes throughout the lakes. The swamps are dominated by papyrus, but seasonal floodplains carry grasses with some trees in less deeply inundated areas.

The fish fauna is nilotic. There was no effective barrier separating the fish faunas of Lakes Kyoga and Victoria until the Owen Falls Dam was completed in 1954, thus the fish fauna of the lakes in the complex is imilar to that of the inshore waters of Lake Victoria. By contrast the Murchison Falls have always been a barrier to interchange between these lakes and Lake Albert. *Oreochromis variabilis* is endemic to this system and Lake Victoria. *Oreochromis esculentus* occurs in Lake Kyoga, while *O. leucostictus*, *O. niloticus* and *Tilapia zillii* were introduced. *Lates niloticus* was introduced in 1954 and was the most important commercial species by 1970.

Crocodylus niloticus is now scarce around the lakes, having been systematically killed as the human population has increased around the lakeshores. There is an abundant avifauna which includes many piscivorous species. Among mammals the semi-aquatic species *Aonyx capensis*, *Atilax paludinosus*, *Hippapotamus amphibius* and *Lutra maculicollis* are present, together with the swamp dwelling *Tragelaphus spekei*.

Human Impact & Utilisation: The lakes of the complex support important commercial fisheries, in which *Lates niloticus* comprises 60-70% of the total annual catch, which amounted to 48 900 tonnes on Lake Kyoga in 1969. The small lakes are however, fished only by artisans. Crocodiles have long been shot for their skins and are in consequence now on the point of extinction in the large lakes.

Conservation Status: Unprotected.

(C) LAKE GEORGE

Location: 0°05'N-0°05'S/30°02'-30°18'E
Area: 22 850 ha (including islands)
Altitude: 914 m asl
Nearest Towns: Fort Portal (64 km N); Kampala (255 km E)

General: This lake, which straddles the equator, is situated on the floor of the Western Rift Valley. It has a maximum E-W length of 30 km, a N-S width of 16 km, a maximum depth of 7 m and a mean depth of 2.4 m. It is fed by several rivers and drains from the southwestern end by the Kazinga Channel which leads to Lake Edward. This is 36 km long with a mean width of about 1 km. The principal affluent streams (Nyamwamba,

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Rukoki, Mubuku, Ruimi Rivers) drain the eastern slopes of the Ruwenzori Mountains and enter the lake through extensive swamps (0°03'-0°16'N/30°09'-30°19'E) on the north shore. These swamps are 21 km long, up to 14 km deep, and occupy some 26 00 ha. The Mpanga also enters these swamps from the eastern edge of the Rift Valley Escarpment, while two other affluents enter on the southern shore, from the Virunga Massif, and the westward flowing section of the Katonga River enters the eastern extremity of the lake. Other swamps occur to north and south of the small western basin of the lake, and another is situated on the central southern lakeshore. There are three large islands close to the western shore, one of which almost blocks the channel connecting the main basin with a smaller basin in the northwest.

The Lake George area has seen much volcanic activity over the past 12 000 years and a small crater lake is connected to the main lake by a narrow channel just south of the beginning of the Kazinga Channel. There are 4 isolated crater lakes north of the Kazinga Channel and a dozen south of it, all discussed in section 2.10.1i.

Hydrology & Water Quality: Direct precipitation over the lake is about 820 mm/yr and produces 12% (240 million m^3) of the annual influx. Rainfall over the Virunga and Ruwenzori catchments is much higher, exceeding 2000 mm/yr in the latter. The total catchment is 9705 km^2 yielding an estimated 1948 million m^3 water to the lake each year. Evaporation is estimated as 456 million m^3 and discharge via the Kazinga Channel at 1697 million m^3/yr (Burgis, 1987). The Kazinga Channel is essentially lacustrine in character, there being only 1 m difference in altitude between Lakes George and Edward.

Lake George is fresh, and its water chemistry is known to have remained fairly constant over the last 40 years, suggesting that the residence time of water in the lake is short, and that evaporation does not lead to the concentration of solutes. The surface water temperature of the lake varies considerably with a range conceivably in excess of 25-36°C, but the bottom water is always close to 25.5°C. The water is quite turbid with Secchi depths of only 24-46 cms. The pH range is 8.5-9.5, but an extreme reading of 10.4 has been obtained, and conductivities range from 210-240 µSiemens/cm through the year, being highest in the dry seasons. The lake water exhibits a diurnal pattern of stratification, but is generally very well oxygenated. When mixing fails to occur during occasional periods of exceptionally calm weather the bottom water becomes deoxygenated, which may result in fish mortalities. Viner (1969) gives an account of the water chemistry.

Flora & Fauna: The phytoplankton is dominated by cyanophytes, 29 out of 58 species and 70-80% of the biomass, but diatoms (11 spp.) and chlorophytes (18 spp.) are important. The greatest phytoplankton density is in the centre of the lake. The zooplankton is dominated by a cyclopoid copepod, *Thermocyclops hyalinus*, but cladocerans (3 spp.) and rotifers (15 spp.) are present.

The peripheral swamps are dominated by *Cyperus papyrus*, rich in climbers such as *Cayratia ibuensis*, *Ipomoea rubens* and *Melanthera scandens*, but there are dense patches of arborescent species including *Ficus verruculosa* and *Phoenix reclinata*. *Vossia cuspidata* is common along the outer fringe of *papyrus*, and the lake surface supports dense carpets of floating vegetation containing much *Pistia stratiotes*. Some muddy shallowly flooded shores sustain communities of *Cyperus articulatus* and *C. latifolius* with sprawling *Commelina diffusa* and *Spilanthes oleracea*. Elsewhere, *Hy-*

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drocotyle ranunculoides is common in shallow water. Submerged aquatics occur at the mouths of affluent streams where the incoming water sweeps floating vegetation away. *Paspalidium geminatum* occurs on the sandy eastern shores of the islands.

Some 32 species of fish have been identified to date. Of these 21 are cichlids and 17 belong to the genus *Haplochromis*. *Oreochromis niloticus* comprises 20% of the fish biomass and is the basis of the commercial fishery. Other common species include *Aplochellichthys* spp., *Bagrus docmac*, *Clarias lazera*, *Haplochromis angustifrons*, *H. spamipinnis* and *Protopterus aethiopicus*. Crocodiles survive in the affluent rivers and there are large numbers of piscivorous birds including *Haliaeetus vocifer*, *Pelecanus onocrotalus*, *Phalacrocorax carbo* and various herons and kingfishers. There are also many storks and ibises. Important mammals include *Atilax paludinosus*, *Hippopotamus amphibius*, *Kobus ellipsiprymnus*, *Loxodonta africana*, *Lutra maculicollis*, *Redunca arundinum*, *Syncerus caffer* and *Tragelaphus spekei*.

Human Impact & Utilisation: The lake supports an important fishery which produced 4264 tonnes in 1970. Fish were both frozen and salted at Kasenyi by the Uganda Fish Marketing Corporation until 1973, which exported frozen fish to Zaire or sent frozen or salted fish by road to Kampala. Although this operation has ceased, the fishery continues, fish being sold directly to buyers with lorries who cart the fish to market. There is a ferry service across the lake from Kasenyi to Mayhoro, and a road runs down to Kasenyi, where there is also an airstrip. The railway crosses the swamp on the north side of the lake, and since the embankment inhibits drainage, it has led to the development of open water areas in the swamp on the north side, with *Cladium mariscus* and *Nymphaea* sp.

Conservation Status: The Ruwenzori National Park abuts most of the western and northern shores of the lake, while the south shore is included in the Kyambura Game Reserve. The Kazinga Channel is protected in the Kazinga Sanctuary. The Ruwenzori Park was established as the Queen Elizabeth National Park in 1952 with an area of 198 600 ha, encompassing all the land between Lakes Edward and George. Heavy poaching has occurred in the park, reducing the elephant population to 150 in 1981.

(D) LAKE EDWARD

Location: 0°05'-0°56'S/29°16'-29°56'E
Area: c. 234 200 ha (63 750 ha in Uganda)
Altitude: 912 m asl
Nearest Towns: Fort Portal (100 km NNE); Kampala (305 km E)

General: Lake Edward is 76 km long with a maximum width of 39 km. Just over 29% of its surface is situated in Uganda. It is connected to Lake George, effectively a bay of Lake Edward, by the Kazinga Channel, 36 km long and about 1.5 km wide. Lake Edward reaches a maximum depth of 112 m, just 5 km from the western shore, above which the land rises precipitously to a high plateau, over 2000 m asl, carrying mountain peaks over 3000 m. By contrast the lake floor slopes up gradually to the Ugandan shore. There are extensive swamps at the mouths of the Ishasha and Chirurumu Rivers covering about 14 000 ha.

Hydrology & Water Quality: Lake Edward has numerous affluent streams, the most important being the Nyamugasani River from the Ruwenzori Mountains and the Ishasha, Rutshuru and Rwindi Rivers from the Virunga Massif and the Rwanda Highlands.

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Further inflow, estimated at 1650 million m^3/yr, comes from Lake George, which also drains the Ruwenzori Range, and to the east shares a watershed with Lake Victoria. However, flow through the Kazinga Channel is very sluggish, along a gradient of 1:80 000 over the first 24 km. The junction of the waters between Lakes Edward and George is indicated by a change in colour and chemistry, and can usually be seen in the Kazinga Channel. The position of this boundary oscillates up and down the channel over a distance of about 3 km. Precipitation over Lake Edward is only 500-650 mm/yr, but is much higher in the adjacent mountains, e.g. approaching 3000 mm/yr on the western slopes of the Ruwenzori Massif. Lake Edward discharges into the Semliki River, and thence to Lake Albert and the Nile. Water spills over a rock shelf at the northern extremity of the lake, which functions as a natural weir.

Water leaving the lake has a temperature of 25-26°C and a pH close to 9.1. The concentrations of the major ions are sodium 110 mg/l; potassium 9 mg/l; calcium 12 mg/l; magnesium 48 mg/l; carbonates 9 meq/l; chloride 36 mg/l; sulphate 31 mg/l; silicate 6 mg/l (Talling & Talling, 1965). Total dissolved solids amount to 521 mg/l.

Flora & Fauna: *Potamogeton pectinatus* is the dominant submerged macrophyte, in association with *Najas marina* and *Vallisneria aethiopica*. Some *Potamogeton schweinfurthii* and *Najas pectinata* occur along the Ugandan shores. *Vallisneria* and *Najas* are best developed in the vicinity of river mouths where waters are better aerated. *Cyperus papyrus* and *Phragmites mauritianus* form swamps at the mouths of the Ishasha, Chirurema and Nchwera Rivers in Uganda on the northeastern shore.

The present fish fauna comprises about 23 cichlids and 30 non-cichlid species. However, the fauna is impoverished, with certain widespread families being entirely absent, e.g. Centropomidae, Characidae, Malapteruridae, Mastacembalidae, Mochokidae and Schilbeidae. Further, *Citharinus*, *Distichodus*, *Hydrocynus*, *Polypterus* and *Lates* which are found in Lake Albert and the Nile are also absent, although both *Hydrocynus* and *Lates* are known to have been present in the middle Pleistocene. From palaeontological studies a picture emerges of Lake Edward being in a phase of recolonisation, its fauna having been partially eliminated at least twice during the late Pleistocene. Although the lake once contained crocodiles, as well as the Nile fish cited, they are also now absent. The rapids prevented their re-introduction from the lower Semliki where they persisted until the middle of this century, before they were finally eliminated by hunters. However, it appears that fish have entered from the east, where there is now a watershed with Lake Victoria, and these have begun speciating. Among the cichlids there are several species with close relatives in Lake Victoria, e.g. *Haplochromis guiarti*, *H. ishmaeli* and *H. macrops*, and two common species, *Astatoreochromis alluaudi* and *Haplochromis nubilis*. Two species present in the Nile have either re-entered or survived, *Bagrus docmac* and *Oreochromis niloticus*. *Oreochromis leucostictus* is confined to Lakes Edward and Albert, perhaps having originated in Lake Edward and passed downstream. Considering the history of the lake the invertebrate fauna is surprisingly rich.

The avifauna of the lake and associated river valleys and swamps is very diverse and includes herons, ibises, egrets, bitterns, ducks, geese, darters, cormorants, skimmers, shoebills, openbills, ospreys, gulls, francolins, warblers and weavers. Species of interest include *Acrocephalus schoenobaenus*, *A. scirpaceus*, *Anas querquedula*,

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Ardeola ralloides, *Calidris ferruginea*, *C. minuta*, *Charadrius hiaticula*, *Chlidonias leucoptera*, *Gelochelidon nilotica*, *Hirundo rustica*, *Philomachus pugnax*, *Riparia riparia*, *Tringa glareola*, *T. nebularia* and *T. stagnatilis*.

Human Impact: The area is sparsely populated and there has been relatively little disturbance since the proclamation of the Ruwenzori National Park in Uganda in 1959 and the Virunga National Park in Zaire in 1969, but illegal fishing and poaching are chronic problems. Growing tourism could prove a threat, and the proposal to dam the Rutshuru River (in Zaire) would almost certainly have a major, and adverse, impact upon the riverine wetland ecosystem.

Conservation Status: Almost the entire Ugandan shore of the lake is protected in the Ruwenzori National Park, as is the lower course of the Rutshuru and several other tributary rivers.

(E) LAKE ALBERT

Location: 1°01'-2°20'N/30°23'-31°26'E
Area: 565 915 ha (318 570 ha in Uganda)
Altitude: 619 m asl
Nearest Towns: Masindi (45 km E); Kampala (220 km SE)

General: Lake Albert lies between two parallel escarpments in the Western Rift Valley, at an altitude of 619 m, with an extreme length of 180 km and a maximum width of 43 km. Just over 56% of its surface is in Uganda. Its deepest point, 56 m, lies 7 km off the western shore, from where the land rises steeply to a high plateau more than 2000 m asl. The lake floor slopes gently upwards towards the east, but the eastern escarpment rises abruptly just a few km from the east bank in Uganda. The lake is subject to violent windstorms which cause the upwelling of bottom waters, but even without these happenings, the lake is generally well mixed. During calm periods, which frequently occur between November and February, a degree of stratification develops and dissolved oxygen levels fall, but not deleteriously for the fauna.

Hydrology & Water Quality: The principal affluent streams are the Semliki, which enters at the southern end from Zaire, and the Victoria Nile, which enters in Uganda very close to the northern end. Both rivers have built deltas into the lake, that of the Semliki is the larger and 90% of it is in Uganda. Although the Nile carries more water than the Semliki, it has little influence on the ecology of the lake, other than to maintain water levels. The Nile water is fresh, with a salinity of 0.1‰, while the main body of the lake water, up to 10 km from the delta which the Victoria Nile has built into the lake, has a salinity of 6‰. Lesser streams entering the lake from Uganda are, from south to north, the Waiga, Waisoke, Waki, Waisembe, Wambabya, Nkusi, Muzizi and Wasa Rivers. However, all these, and numerous small streams from Zaire, are highly seasonal and of only minor importance to the hydrology of the lake. Much periodically inundated land occurs around the southern margin of the lake in the Semliki Delta, and also at isolated sites along the eastern shore, most notably in the delta of the the Victoria Nile.

The surface temperature is usually within the range 26-29°C and the pH between 8.4 and 9.5. Total dissolved solids amount to 565 mg/l and the concentrations of the principal ions are sodium 96 mg/l; potassium 65 mg/l; calcium 10 mg/l; magnesium 32 mg/l; carbonates 7.3 meq/l; chloride 31 mg/l; sulphate 32 mg/l and silicate below 1 mg/l

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(Talling & Talling, 1965). The results of detailed hydrobiological surveys were published by the Institut Royal des Sciences Naturelles de Belgique (Brussels) between 1957-1962. General information is provided by Bishop (1965; 1969) and Livingstone (1976).

Flora & Fauna: *Potamogeton schweinfurthii* is the dominant submerged macrophyte over most of the lake, by contrast with Lakes Kivu and Edward where *P. pectinatus* is most common. However, the latter species is present in Lake Albert. The principal associate species are *Najas marina* and *Vallisneria aethiopica*, and as in the other lakes, they are most abundant in the vicinities of river mouths, but this phenomenon is not so pronounced as it is in the two other lakes, possibly because Lake Albert is shallower and its waters are generally well oxygenated. There are extensive stands of *Cyperus papyrus* and *Phragmites mauritianus* in the river deltas, with flowering culms up to 5 m high. Aquatic meadows of *Vossia cuspidata* flourish on the lakeward side of the papyrus swamp, with twining thickets of *Cyclosorus striatus* on the landward side. In ponds in the swamps, and in sheltered coves around the lake, there are floating-leaved and free floating associations, notably a *Lemna paucicosta-Pistia stratiotes-Azolla nilotica* association, and a *Nymphaea calliandra* association. In the latter, *Najas marina*, *Nymphaea lotus* and *Vallisneria aethiopica* are usually to be found, together with free floating plants of *Ceratophyllum demersum* and *Utricularia thoningii*. Species of *Nitzschia* and *Stephanotis* are the chief planktonic diatoms, undergoing periodic fluctuations in density. Blooms of the blue-green alga, *Anabaena* sp., occur from time to time, and lead to the mass mortality of fish, especially *Lates nilaticus*.

The fish fauna comprises 46 species, of which 22 are also found in the Nile. Some genera, e.g. *Bagrus*, *Heterobranchus* and *Lates*, have long histories in the lake, having been recognised from mid-Pleistocene sediments, while *Clarotes*, which was present in the Pleistocene, is no longer there. *Alestes baremose*, *Citharinus citharus*, *Lates niloticus* and *Oreochromis niloticus* form the basis of the present fishery. Two distinct populations of *Lates niloticus* are present, one which breeds in the lake, and another which migrates into rivers to spawn. In Lake Albert this species is an inshore form, and is largely piscivorous, whereas another species, *Lates microphthalmus*, is pelagic and feeds mainly on *Caradina* (a freshwater prawn). Among the other piscivores, both *Hydrocynus vittatus* and the smaller *H. forskalii* occur in the lake, but the latter, here, tends to be pelagic and also feeds very largely upon *Caradina*. Of 36 non-cichlid species, 3 are endemic, while of 10 cichlids, 4 are endemic. These are all species of *Haplochromis*. The cichlid fauna is poor compared with that of most other East African lakes, including some other 'nilotic' lakes, such as Lake Edward. Accounts of the fish fauna are given by Worthington (1929) and Holden (1967; 1970). The invertebrate fauna is discussed by Green (1967a,b; 1971) and Verbeke (1957).

Crocodylus nilaticus survives on the affluent streams, and is quite dense on the Albert Nile below the lake in the Kabalega National Park. Birds of interest found along the lakeshore are *Buteo buteo*, *Chlidonias leucoptera*, *Ciconia ciconia*, *Crex crex*, *Cuculus canorus*, *Gallinago media*, *Gelochelidon nilotica*, *Lanius collurio*, *L. minor*, *Lymnocryptes minimus*, *Merops apiaster*, *Muscicapa striata*, *Pernis aprivorus*, *Phylloscopus trochilus*, *Porzana porzana*, *Riparia riparia*, *Tringa glareola* and *T. ochropus*. Many of the mammals cited in the regional introduction are present around the lake and in its

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swamps, including *Artlax paludinosus*, *Hippopotamus amphibius*, *Kobus ellipsiprymnus*, *K. kob*, *Loxodonta africana*, *Lutra maculicollis*, *Phacochoerus aethiopicus* and *Syncerus caffer*.

Human Impact & Utilisation: There are important fisheries on the lake, which by 1970 were producing some 28 000 tonnes fish/yr, the Ugandan catch amounting to 17 530 tonnes in 1970.

Conservation Status: The northern extremity of the lake on the Ugandan side is protected in the Kabalega (Murchison Falls) National Park. The park is bisected by the Victoria Nile and the river delta and the Kabalega Falls (where the Albert Nile leaves the lake) are included. About 25 km of the lakeshore is included in the Bugungu Game Reserve, a buffer zone on the south side of the national park. A similar stretch is included in the Toro Game Reserve at the southern extremity of the lake, where there are grassy lakeshore flats, lacustrine swamps, and heavily wooded affluent streams.

(F) THE BUNYONI LAKE/SWAMP COMPLEX

Location: 1°05'-1°28'S/29°39'-30°02'E
Area: 18 000 ha (total wetland)
Altitude: 1798-1990 m asl
Nearest Towns: Mbarara (112 km NE); Kampala (340 km NE)

General: Lake Bunyoni (1°13'-1°24'S/29°49'-29°58'E) was formed when a steep-sided dendritic valley system was blocked by volcanic activity about 18 000 BP. It covers about 6100 ha, 1974 m asl, and is fed at its southern end by the Kabirita River from Rwanda, and by numerous affluents from the surrounding hills which rise to heights of 2200-2478 m asl. The lake is 25 km long, 7 km wide at maximum, and oriented roughly SE-NW. It has a maximum depth of 44 m and contains 23 small islands. Swamps extend back up the Kabirita for 8 km, and are present at the heads of 25 of the little arms of the lake. In total these cover about 1500 ha. Upwarping in the area has led to the curious situation where streams in steep-sided mountain valleys flow very sluggishly, sometimes with the creation of watersheds midway along rivers. Thus Lake Bunyoni drains sluggishly from its northern end to the Ruhuhuma (Ruvuma) Swamp (1°07'-1°12'S/29°48'-29°52'E) which lies on a watershed from where streams flow both east and west.

The Ruhuhuma Swamp is 10 km long from E-W and covers a little more than 4000 ha at an altitude of 1940 m asl. The eastern part of the swamp drains by a short stream to the swampy upper course of the Ishasha River, which rises in Rwanda and flows north and northwest to Lake Edward and the Nile. A strip of permanent swamp, 40 km long and about 1 km wide, accompanies the Ishasha from the Rwanda border northwards to a point just beyond the confluence with the effluent from the Ruhuhuma Swamp, so that a permanent wetland of 4000 ha is situated here. The western part of the swamp drains to Lake Mutanda (1°10'-1°16'S/29°39'-29°42'E), 1798 m asl. This lake is 9 km long and 2.5 km wide and contains one large island. It has an open water surface of 1600 ha and is fed by short streams which enter the northern end. It discharges from the southwestern corner via the Kako River and the Tahengere Swamp (1°14'S/29°32'E) in Zaire, to the Rutshuru River and thence to Lake Edward and the Nile.

Lake Muanga or Muhele (1°13'S/29°44'E) is situated about 1800 m asl, just to the east of Lake Mutanda. It has a maximum depth of 7.5 m, a length of 3 km and a width of

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1 km. It is ringed by high hills, but drains to Lake Mutanda through a papyrus swamp at its southwestern corner.

Hydrology & Water Quality: The water level of Lake Bunyoni fluctuates about 75 cm during the course of a year, but the mean level rose some 2 m after the 1962-63 season, c.f. Lake Victoria. Lake Bunyoni is stratified and apparently remains so for many years at a time without mixing. The bottom temperature remains close to 19°C, but the surface temperature rises to 25°C. Oxygen concentrations reach 8 mg/l, but the bottom water is anoxic, while pH values range from 7.4 at the bottom to 8.6 at the surface. The water is clear with Secchi depths of up to 2.9 m. Denny (1972) gives an account of the chemistry of this lake.

Flora & Fauna: There are floating swamps of *Cyperus papyrus* and *Cladium mariscus* in the shallow sheltered bays of Lake Bunyoni, with *Phragmites australis* present in a narrow strip on steep exposed shores. *Potamogeton* and *Nymphaea* spp. dominate the floating leaved vegetation in front of the papyrus swamps, and *Ceratophyllum demersum* is the commonest submerged species, often with *Hydrilla verticillata*. Floating islands of papyrus have as associates *Hydrocotyle ranunculoides*, *Polygonum salicifolium*, *Pycnostachys coerulea*, *Thelypteris squamigera* and *Utricularia* sp. *Typha domingensis* is present along affluent streams. Denny (1973) gives an account of the vegetation of this lake.

Oreochromis niloticus was introduced and still persists in the lake. The most common fish however, is a species of *Haplochromis* and local fishermen take a species of *Clarias*.

Human Impact & Utilisation: The lake was stocked with fish earlier this century, but recently there have been mass fish mortalities. These have been attributed to violent mixing. There is an artisanal fishery.

Conservation Status: Unprotected.

(G) THE KIJANEBALOLA LAKE/SWAMP COMPLEX

Location: 1°10'-1°34'N/30°50'-31°25'E
Area: 25 950 ha
Altitude: 1226-1250 m asl
Nearest Towns: Mbarara (33 km WNW); Kampala (180 km ENE)

General: This complex has, as its principal affluent, the Ruizi River which rises from a headwater swamp (0°46'S/30°11'E) and flows eastwards to a central swamp (0°32'-0°45'S/30°51'-31°16'E) oriented E-W, which has a number of peripheral lakes. These latter are situated at the lower ends of valleys which run down to the swamp from both north and south. The largest are from west to east, Lakes Nakivali (0°45'-0°50'S/30°53'E), Mburo (0°39'S/30°55'E), Kachira (0°30'-0°40'S/31°06'E) and Kijanebalola (0°43'S/31°19'E). Other small lakes, also from W-E, are Lakes Kiretwa, Kasasa, Mutukura, Kazuma, Mishera, Ruma, Karitima, Bwara and Karunga. The swamp drains from Lake Kijanebalola at the eastern end of the system to Lake Victoria via the Kibale River which reaches the lake in an extensive swamp at Sango Bay, north of the mouth of the Kagera River.

The central swamp occupies a tract of land 44 km long and up to 15 km wide, covering 15 000 ha. Lake Nakivali is 14 km long and 3 km wide, and has an area of 3080 ha at high water, when the maximum depth is 3.5 m. Lake Mburo, to the north, is 6.2 km long

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and 3 km wide at maximum, and has a mean area of 1190 ha at high water. Lake Kachira is the largest lake, 22.8 km long and up to 3.4 km wide, with a maximum depth of 4.1 m. It has an area of 3960 ha. However, Lake Kajanebalola is the best known lake of the complex. It is 17 km long and up to 4.3 km wide, and has a maximum depth of 4.8 m. It contains two large islands at its western end.

Hydrology & Water Quality: The chief inputs are from the Ruizi River and from direct precipitation. There is little information as to water quality, but lake water temperatures generally range from 23-26°C, with pH values of 7.5-8.5. The pH of Lake Kachira is close to 8.4 and that of Kijanebalola is usually 8.3. The waters of the lakes are turbid with Secchi depths of 40-50 cm. The depth and size of the lakes varies considerably from year to year. Lake Kijanebalola overflows into the Kibale River about once every decade, otherwise the system is endorheic.

Flora & Fauna: The central swamp is a papyrus swamp, but with some *Ficus verruculosa* and other woody species, and prairies of aquatic grasses. There are extensive grasslands subject to seasonal inundation on the periphery of the swamp and around parts of the lakes which support much free-floating and floating-leaved vegetation.

Among fishes *Clarias mossambicus*, *C. werneri*, *Haplochromis* spp., and *Protopterus aethiopicus* are indigenous, while *Oreochromis* spp. have been introduced. There are crocodiles and many piscivorous birds, and almost all the small semi-aquatic mammals cited in the regional introduction. Among the larger mammals using the wetlands are *Damaliscus lunatus*, *Hippopotamus amphibius*, *Panthera pardus*, *Phacochoerus aethiopicus*, *Redunca redunca*, *Syncerus caffer* and *Tragelaphus spekei*.

Human Impact & Utilisation: The lakes were first stocked with commercial species of fish in 1935, but catches, which include *Clarias mossambicus*, *Haplochromis* spp., *Protopterus aethiopicus*, *Oreochromis esculentus*, *O. niloticus* and *O. variabilis* have declined since 1971. About 1000 canoes are employed on the four major lakes, almost 500 on Lake Kijanebalola. The area is heavily grazed by domestic cattle.

Conservation Status: An area including Lake Mburo, some small lakes, and much of the western shore of Lake Kachira are protected in the Mburo National Park, gazetted in 1983.

(H) LAKES BISINA & OPETA

Location: 1°28'-2°01'N/33°49'-34°26'E
Area: 120 000 ha (25 000 ha open water)
Altitude: c. 1040-1060 m asl
Nearest Towns: Jinja (150 km SSW); Kampala (205 km SW)

General: These lakes are situated on drainage lines leading from the Karasuk Hills in Kenya, and from Mts. Elgon and Kadam, to the Okere Valley and Lake Kyoga. The Ukutat, Muchilmakat and Kelim Rivers all enter Lake Opeta (1°39'N/34°09'-34°14'E) through a zone of permanent swamps east of the lake, above which each river has a seasonal floodplain. Lake Opeta is 10 km long, 5 km wide and has an open water area of 4000 ha. The entire lake is fringed by wide swamps, except along parts of the southern shore. The Kamirya and Siroko Rivers from Mt. Elgon also enter Lake Opeta, but do so through the swamps on the southern shore, and neither stream has an important flood-

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plain. Water then passes west for 5 km from Lake Opeta, through a dense swamp, to Lake Bisina (1°35'-1°44'N/33°49'-34°06'E). This lake (formerly Lake Salisbury) has few affluents, the largest being the seasonal Apedura River which rises to the north on the slopes of Mt. Akim. Lake Bisina is oriented E-W and is 30 km long and up to 9 km wide, with a maximum surface area of 21 000 ha at high water. It drains from its western end through swamps, to the Okere system which leads in diffuse fashion to the swamps at the head of the Mpologoma Arm of Lake Kyoga.

The permanent swamps around Lake Opeta cover about 30 000 ha. The floodplain on the Ukutat is 40 km long and up to 7 km wide with an area of 20 000 ha at high water, that on the Muchilmakat is 25 km long and about 5 km wide with an area of 11 000 ha, while that on the Kelim is 25 km long and up to 10 km wide with a high water area of 17 500 ha. The Apedura River has a floodplain 30 km long and up to 6.5 km wide, which at high water covers 16 500 ha.

Flora & Fauna: Permanent swamps are dominated by papyrus, but there are areas of *Typha* and *Phragmites*, and strips of swamp forest. The fish fauna of the lakes is essentially nilotic, but with some species characteristic of the Lake Victoria Basin. *Clarias* spp., *Haplochromis* spp., *Labeo victorianus*, *Mormyrus macrocephalus*, *Oreochromis esculentus*, *O. variabilis*, *Protopterus aethiopicus* and *Schilbe mystus* are important species. However, *Barbus* and *Bagrus* spp. are absent and probably have not been able to cross the swamp barrier from Lake Kyoga. There is an abundance of piscivorous birds and almost all the semi-aquatic mammals cited in the regional introduction are present.

Human Impact & Utilisation: There was a thriving crocodile skin industry on Lake Bisina up until the late 1950s, with the result that these animals are now very scarce. A gill net fishery was started on Lake Bisina in 1950 for *Oreochromis* spp., but the state of this is not clear. Both lakes are still fished by artisans however, using long lines and baskets, and the floodplains are grazed and cultivated locally.

Conservation Status: The Pian-Upe National Reserve includes the western ends of the floodplains on the Muchilmakat and Kelim Rivers, immediately above Lake Opeta.

(I) LAKE WAMALA

Location: 0°12'-0°25'N/31°41'-32°02'E
Area: 51 000 ha (25 000 ha open water)
Altitude: c. 1290 m asl
Nearest Towns: Kampala (58 km E); Masindi (138 km N)

General: Lake Wamala is surrounded by swampland, the whole system occupying some 51 000 ha. The lake has a mean length of 27 km and a mean maximum width of 10 km. It has a variable area of 16-25 000 ha. The peripheral swamp is 44 km long, oriented WSW-ENE, and has a maximum width of 16 km. The system receives numerous minor affluent watercourses and drains via the Kibimba River to the Katonga River. However, the Kibimba is almost permanently dry and only occasionally does it carry overspill from Lake Wamala, and when it does, this may not be sufficient to reach the Katonga. The Wamala Basin (2654 km^2) is therefore usually quite separate from the Katonga Basin. Direct precipitation over the lake is estimated as 1200 *mm/yr*, and this, plus the

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contribution of the affluents, is lost by evapo-transpiration. The inflow of the largest affluent, the Mpamujugu, is 97 million m^3/yr.

Flora & Fauna: The swamps throughout the system are dominated by *Cyperus papyrus*, but there is much swamp forest and riverine forest along the Katonga. The fish fauna has many species common to the shallow waters and inlets of Lake Victoria. Bird life is prolific, and the river and its swamps are important to a range of mammals, including *Hippopotamus amphibius*, *Kobus ellipsiprymnus*, *Loxodonta africana*, *Redunca redunca* and *Syncerus caffer*.

Human Impact & Utilisation: Lake Wamala supports an important fishery. 250 canoes were licensed in 1975, at which time no outboard motors were permitted. *Oreochromis niloticus*, which was introduced in the 1950s, provides the bulk of the catch, but other important species are *Clarias mossambicus*, *Protopterus aethiopicus*, *Oreochromis leucostictus* and *Tilapia zillii*.

Conservation Status: A section of the north bank of the river is protected in the Katonga Game Reserve.

(J) MINOR LAKES

General: Several small lakes are situated high in the hills near Bunyoni Lake, but are not in connection with that system. The largest are Lakes Mugisha (1°20'S/29°47'E), 1894 m asl, and Tshahafi (1°21'S/29°46'E), 1894 m asl. These lakes are swamp-fringed.

A dozen small crater lakes are situated immediately south of Lake George in an area 0°06'-0°19'S/30°01'-30°11'E. They are, from N-S, Lakes Mosoche, Bagusa, Mshenyi, Chibera, Kyamwiga (0°11'S/30°08'S), Bugwagi, Katinda, Mirambi, Niamsigeri (0°17'S/30°01'E), the largest, Mugogo, Kyasanduka and Mununuli. Four other crater lakes, Kikorongo, Kitagata, Mununuli and Nyamunuka, are situated west of Lake George, just north of the Kazinga Channel and between Lakes George and Edward. There are said to be no less than 87 crater lakes in the Rift Valley south of the Ruwenzori Mountains, many of which are saline and shallow.

2. Riverine Swamps & Floodplains

(A) THE OKERE SYSTEM

General: The most northern source of this system is the Dopeth River which rises in a small swamp (3°35'N/34°23'E) 2000 m asl near the Kenyan border. From this swamp the Dopeth flows west and south and the Napass River, which also rises here, flows northeast across Kenya to Lake Turkana. This river joins the Longira, which also rises in a swamp near the northeastern border, at a point (2°46'N/34°00'E) below which a seasonal floodplain develops. Other floodplains occur on two other tributaries flowing in parallel to the east, and the streams unite (2°24'N/34°00'E) to form the Okok River.

The Okere River has numerous sources in the highlands along the Kenyan border, including several streams which drain Mt. Moroto. These unite to form the Okere (2°31'N/34°17'E), some little distance below which this river also develops a floodplain. The Okok and Okere Rivers reach a confluence at a point 2°05'N/33°54'E, where their

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joint floodplain is 7.5 km wide. The river flows south from here, but quickly loses its integrity in a swampy floodplain which encompasses the western end of Lake Bisina, towards the swamps at the northern end of the Mpologoma Arm of Lake Kyoga. Water from Lake Bisina passes this way to reach Lake Kyoga. The lower floodplain of the Okere is studded with lakes, and merges into permanent swamps at its southern extremity. The floodplain is continuous for 110 km below the Okuk/Okere confluence, and above it for a further 29 km up the Okuk and 46 km up the Okere. It has a total high water area of approximately 80 000 ha, including the numerous lakes of the lower reaches.

Flora & Fauna: *Cyperus papyrus*, *Phragmites mauritianus* and *Typha domingensis* all occur along the river, with various arborescent species in shallowly inundated places. These include *Acacia tortilis*, *Borassus aethiopum*, *Ficus* spp., *Phoenix reclinata* and *Syzygium guineense*.

The floodplains are important grazing areas for wildlife during the dry seasons when they may be visited by a variety of large mammals as discussed in the regional introduction. *Acinonyx jubatus* and *Panthera leo* are found here.

Human Impact & Utilisation: Cattle are grazed on the floodplains during the dry seasons.

Conservation Status: Unprotected.

(B) THE KAFU SYSTEM

General: The Kafu River flows east from a swampy watershed to the Nile, and west from the same watershed as the Nkusi to Lake Albert. Along the eastward flowing section it receives two tributaries on its right (southeastern) bank, both of which flow through extensive permanent swamp systems. These are the Mayanja, which traverses a 30 km papyrus swamp (1°45'-1°57'N/31°59'-32°15'E) with an area of 13 500 ha, and the Lugogo which flows through a continuous strip swamp (1°00'-1°29'N/31°57'-32°24'E) for 82 km above its confluence with the Kafu. This latter swamp has an area of 24 600 ha.

(C) THE NILE

General: The Okole River, a right bank tributary of the Victoria Nile, traverses a continuous swamp belt (2°03'-2°19'N/32°19'-32°45'E) of 16 000 ha for 52 km above its confluence. Farther downstream the delta swamps in Lake Albert occupy some 6500 ha, and below Murchison Falls the Albert Nile traverses a swamp 115 km long and some 5-10 km wide (2°30'-3°35'N/31°16'-31°58'E), with an area of about 52 000 ha.

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REGION 3

WEST AFRICA

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Introduction

This region comprises the eleven maritime countries of West Africa, plus the land-locked states of Burkina Faso, Mali and Niger, thus encompassing the entire Niger drainage basin. Chad is included for reasons of geographical integrity. The region extends some 4510 km from east to west, from the eastern border of Chad (24°E) to Cape Vert in Senegal (17°31'W), and close to 2330 km from north to south from the northern border of Mali (25°N) to the southernmost point of the Niger Delta (4°17'N). It has a total area of 6 275 782 km^2 of which the three Sahelian countries, Chad, Mali and Niger comprise 59% (3 710 550 km^2). In the west, 85% of the total land surface of Senegal, Gambia and Guinea Bissau, amounting to some 215 000 km^2, lies below the 100 m contour, but most of the regional land surface is situated 200-500 m asl. Only in Guinea and Nigeria in the south, and in Chad and Niger in the north, are there substantial areas above 500 m. In the south the so-called Guinean Dorsale comprises several long mountain ranges, some massifs, and high plateaux dissected by wide valleys. It stretches from the Fouta-Djallon buttresses in Guinea to the Man Heights in Côte d'Ivoire and is oriented NW-SE, about 250 km inland. The highest points in the dorsale are the Tingi Hills (1835 m) in the west and the Nimba Mountains (1752 m) in the east. Farther east, a chain of mountains runs from south to north in Togo, reaching a maximum altitude of 986 m at Bauman Peak. In Nigeria, the Jos Plateau (1200 m) is surmounted by a number of high peaks, e.g. Shere Hill (1871 m) and Wadi Hill (1698 m), and along the border with Cameroon, mountains rise above 2000 m in several places, the highest being Chappal Wade (2419 m) and Vogel Peak (2042 m). In the far north, Mt. Greboun (20°00'N/8°37'E) rises to 2000 m in Niger, and in the Tibesti Mountains of Chad, Mt. Emi Koussi (18°52'N/18°33'E) rises to 3415 m and several other peaks exceed 3000 m.

The northern coast of Senegal is sandy, having evolved under the influence of prevailing swells from the NW and a southerly coastal drift. However, from Dakar (14°38'N/17°27'W) southeastwards to Monrovia (6°20'N/10°46'W) the coast is one of submergence with many drowned valleys and offshore islands. It is highly indented, but has a

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deltaic nature in parts of Guinea and Sierra Leone. From southern Guinea to Liberia, longshore drift is towards the NW, while east of Cape Palmas (4°25'N/7°50'W), on the Liberia/Côte d'Ivoire border, it is easterly towards the Niger Delta. Between Monrovia and Cape Palmas, and also in Ghana, the coast is rocky and of relatively high relief, but elsewhere along the Gulf of Guinea it is low lying and sandy. In these latter regions it is characterised by a series of large and comparatively deep lagoons, separated from the sea by dune covered barriers. The far eastern coastal sector is dominated by the delta of the Niger River, which, with an area of 36 260 km^2, is the second largest delta in the world. Excluding offshore islands, and inlets with mouths less than 1 km wide, the coast of this region exceeds 5300 km in length.

Drainage in the region is dominated by a series of inland watersheds from which streams flow directly to the sea, or northwards to the Niger River. The Niger receives the great bulk of its water from right bank tributaries, since the lands situated north of the river are remarkably arid, while those to the south are mostly very wet. The Niger is one of the four major rivers of Africa, and rises just over 800 m asl at a point 9°07'N/10°41'E in the Fouta Djallon Highlands in Guinea, close to the border with Sierra Leone. It flows northeastwards into Mali where it breaks into a network of channels and lakes in the so called 'internal delta'. On leaving the delta at Tombouctou, it swings sharply southeastwards and flows through Niger to Nigeria and thence to the sea where it has built the largest delta in Africa covering 36 260 km^2. However, in the early Pleistocene the Niger was a tributary of the Senegal River. It followed its upper course for a short distance into Mali, but then veered westwards into Senegal, depositing a great deal of alluvium in the low lying valleys of what is now the Baoulé system. Then, in the middle Pleistocene, arid conditions produced a barrier of sand dunes, the Erg Ouagadou, which diverted the river so that it discharged into a series of endorheic lakes southwest of Tombouctou in Mali. Eventually, with the resumption of pluvial conditions, the lower Niger cut back and captured the waters of these lakes so that they drained, and the river now flows southeastwards from the point of capture to its delta at the coast. The present 'internal delta' has been built on the bed of the Pleistocene lakes. The history of the river thus explains the great similarity between the fish faunas of the Senegal and Niger Rivers.

A number of major tributary streams, notably the Tinkisso, Bala, Milo, Gbanhala, Baoulé and Bagoé also rise in the humid Fouta Djallon Mountains and flow roughly northwards to the upper Niger, draining the northern parts of the countries lining the Guinea coast. The other major tributaries of the Niger enter along the lower course, below the 'internal delta'. The Sokoto (or Kebbi), Mariga/Kaduna and Gurara Rivers drain the Jos Plateau, while the Benue drains parts of Cameroon and the wet mountains along the Cameroon/Nigeria border.

In the far west, the whole area of Senegal, Gambia and Guinea Bissau drains directly to the Atlantic Ocean. In the far east of the region, southern Chad, eastern Niger and northeastern Nigeria drain to Lake Chad. The Komadougou, Ngadda, Yedseram and El Beid Rivers come from Nigeria, but are extremely seasonal in their flows, and contribute only a small fraction of the total inflow to the lake, the great bulk of which comes from the Chari, which enters from Chad. With its tributaries this river drains humid highlands to the south, mostly out of the region in Cameroon and the The Central African Republic.

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The watercourses which enter Lake Chad from the desert regions of Niger and Chad are ephemeral, and their influence upon the hydrology of the lake is insignificant.

Climate

The distribution of rainfall, and the patterns of temperature and humidity, are determined by the seasonal movements of high pressure zones. Two masses of air are in opposition over the region, a dry stable continental mass to the north, and a humid, less stable, oceanic mass to the south. These meet along an intertropical convergence zone, which lies along the parallel 8°N in January, but which pushes north to 22° in August. During the boreal winter, only the southern coastal zone receives rain, but as the front moves farther inland, rain extends over the interior. To the north of the intertropical front, trade and harmattan winds are accompanied by drought and intense heat and as the front never reaches the very north of the region in Mali, this area is true desert.

The north of the region encompasses part of the Sahara Desert and is extremely dry and hot, while the south is wet and less hot. Away from the coast, mean temperatures always increase towards the north. On the coast the mean annual temperature is 24.3°C at Dakar with mean monthly maxima of 27.5°C in October (the warmest month), and 20.4°C in February (the coolest month). Corresponding figures for Conakry are 26.2°C; 27.5°C (April) and 24.6°C (August), while for Port Harcourt they are 25.9°C; 26.9°C (March) and 24.8°C (August).

Precipitation is greatest at the coast throughout the region, declining progressively in passing inland. Rainfall is 380 mm/yr on the coast at Saint Louis (16°01'N/16°30'W) at the mouth of the Senegal River, but it increases quickly in passing southwards along the coast, reaching 572 mm at Dakar, over 1000 mm at Banjul (13°28'N/16°39'W) at the mouth of the Gambia River, and 1547 mm at Ziguinchor (12°35'N/16°20'W) on the estuary of the Casamance River. A very wet pocket extends from near Bentimodia (10°32'N/14°28'W) in Guinea to Cape Palmas (4°25'N/7°50'W) in Liberia where the direction of the trade winds is perpendicular to the coast. Throughout this sector, in a belt extending up to 100 km inland, precipitation exceeds 3000 mm each year, and at the coast, from Conakry (9°31'N/13°43'W) to Greenville (5°01'N/9°03'W) it tends to exceed 4000 mm/yr, reaching 5200 mm at Cape Mount (16°44'N/11°25'W). In passing eastwards from here it declines to 2000 mm, but rises again to more than 2500 mm between Abidjan (5°19'N/4°01'W) and Takoradi (4°55'N/1°45'W). Thereafter it falls to a bare 800 mm on the coast near Accra (5°33'N/0°15'W), rising again to 1000 mm at Lomé (6°10'N/1°21'E), and eventually to more than 3500 mm over the southern part of the Niger Delta. Northern Burkina Faso receives some 500 mm rain/yr, while northern Mali and Niger are the driest parts of the region, with mean annual falls of less than 20 mm, and since rainfall is so variable, some entirely rainless years. The 100 mm isohyet lies between 17-18°N across much of the region.

The seasonal distribution of rainfall is similar throughout the region (except for the coastal sector between Ghana and Nigeria) with one dry season in the northern winter and one wet season in the northern summer. The dry season decreases in severity from north to south. It is virtually continuous in the far north and nearly 10 months long in Saint Louis, decreasing to 8-9 months at Dakar, 7 months at Ziguinchor, 4-5 months at Conakry, 3 months at Lungi, while there is no dry season at Greenville. July and August

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are the wettest months throughout the region, except on the coast between 4°W and 4°E. Dakar, with a mean annual rainfall of 572 mm receives 90% of its precipitation during the 3 months July-September, with a mean monthly maximum of 275 mm in August. By contrast, Freetown (8°30'N/13°17'W), which has a mean annual rainfall of 3639 mm, receives 850 mm in both July and August, and only January and February are really dry. Both Freetown and Greenville have more than 180 rainy days/year. On the southern coast from 4°W-4°E, rainfall has a bimodal pattern and there is a short dry season in August. However, towards the Niger Delta the SW monsoon again becomes important and effectively eliminates this minor dry season. Here, Port Harcourt (4°43'N/7°10'E) with a December-January dry season, has 170 rainy days/yr, and Calabar (4°56'N/ 8°22'E) on the Cross River, which has a less pronounced dry season, has more than 190 rainy days/yr.

It is convenient to recognise a southern, Guinean zone, in which the rainy season persists for 7-9 months and the dry season is mild, an inland Soudanian zone, with a 4-6 month wet season and a comparatively severe dry season, and a dry Sahelian zone in the north, the southern limit of which corresponds roughly with the 600 mm isohyet. This zone grades imperceptibly into the Sahara Desert.

Vegetation

There are five principal vegetational zones, occupying broad belts, roughly oriented in parallel from east to west across the region, corresponding with these climatic zones. In the north, adjacent to the Sahara, a belt of Sahelian *Acacia tortilis* savanna and deciduous scrub woodland extends from Lake Chad to the coast of Senegal, encompassing the mouth of the Senegal River. Below this is a broad belt of Soudanian savanna woodland, which at the coast, reaches as far south as Dakar. The coastal lowlands along the Gulf of Guinea are covered by high rain forest in the wettest regions, but this grades into a mosaic of rain forest and secondary grassland where disturbance has been intense. This mosaic extends to the coast in the far west in Gambia, Guinea Bissau and Sierra Leone, and again in the central part of the region in Togo and Benin, in the so-called 'Dahomey Gap' which separates a western rain forest block from the eastern block. In Gambia, Togo and Benin, where the coasts are comparatively dry, receiving 1000-1500 mm rain/yr, the mosaic is different in specific composition from that in Guinea Bissau and Sierra Leone, and trends towards true savanna. Across the centre of the region, sandwiched between this mosaic and the Soudanian woodland belt, on the higher ground of the interior watershed, there is a broad belt of *Isoberlinia* woodland. Montane vegetation occurs in the highest regions along the border with Cameroon, but hardly constitutes a major vegetational zone.

Wetlands

Mangrove (tidal) forests occur on all coasts but are best developed on those of Gambia, Guinea Bissau, Sierra Leone and Nigeria, where they may reach 50 km in depth between the landward and seaward faces. Rivers are tidal for many kilometres in some countries, especially Senegal and Gambia, and in these places mangroves occur 190 km up-river. On the Niger Delta the mangrove forest is backed by a belt of freshwater swamp forest

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occupying 1 760 000 ha and stretching 440 km across the delta with a maximum depth of 110 km. Most of this forest is flooded only during the rainy season, when the more seaward parts may be tidal, although inundated by freshwater. During the dry season most of the forest floor becomes dry, but there are pockets of permanent inundation. Extensive freshwater swamp forests also occur behind the mangroves in Guinea Bissau, Sierra Leone and Liberia, and to a lesser extent in Côte d'Ivoire. However, freshwater swamp forests are not exclusively associated with the mangroves, and strips of high swamp forest occur throughout the Guinean forest zone wherever rivers or streams meander through depressions. Some secondary grasslands in the coastal lowlands are also flooded seasonally, e.g. in the vicinity of Accra in Ghana. Swamp lands flank the coastal lagoons and there are numerous coastal lakes. In places, secondary herb swamps have developed where mangroves have been cleared from lagoon margins, e.g. on Lagos Lagoon.

Galleries of forest extend inland, into the savanna zones, and parts of these are subject to seasonal flooding. Seasonal floodplains and permanent swamps occur on rivers in Senegal, northern Guinea, Burkina Faso and Mali, and again in the east on rivers entering Lake Chad. Other wetlands occur away from the rivers in the Soudanian zone. There are many clay based pans and ponds which carry standing water in most years. Firiki are large shallow depressions, almost plains, covered by impervious clay. During the wet season they are flooded and are covered by grasses which emerge above the surface of the water. The clays are black, and crack in the dry season, but lie on top of pervious sands. Such areas may be farmed. Fako or kabe, as they are called in Nigeria, are depressed clay pans from which the surface soil has been stripped. They retain water during the rains and support stunted bushes but virtually no grass. Semi-permanent pools known as tabki in Nigeria, occur throughout the Soudanian parts of the region. Individually they are small, but collectively they provide a large area of wetland in some countries.

Most of Lake Chad is situated within the region and there are several swampy lakes in southern and western Mali and northern Burkina Faso, and others in central and southern Chad. There are numerous impoundments, including Lakes Kainji and Volta, the latter providing the largest artificial water surface in Africa, covering 850 000 ha.

Some oases, with permanent pools and springs occur in the desert regions, in the gullies draining the high massifs, and there are numerous flat saline pans. In some of these the rise of subterranean water may wet the surface after heavy rain on distant catchments, and films of sparkling crystals may be left when the surfaces dry.

Wetland Vegetation

Tidal Swamps: Over almost the entire region, mangrove vegetation is dominated by three species of *Rhizophora*. These grow on open sea coasts, where they are inundated by fully saline sea water, but also in the freshwater tidal zones of estuaries, deltas and lagoons. In the Guinean zone, the seaward mangrove comprises *Rhizophora racemosa*, which is size graded on rapidly prograding shores, the canopy increasing in height away from the sea. This species reaches 45 m in height in the Niger Delta and 40 m in Guinea Bissau. It may form monospecific zones more than 1 km wide. Behind this high frontal forest there is usually a lower zone of *Rhizophora harrisonii*, which to landward in drier areas, and upstream, gives way to yet lower (5-10 m) *Rhizophora mangle* scrub

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woodland. All three of these species occur in the Caribbean and on the Atlantic coasts of South America, but having said this, there is some confusion as to the taxonomy of *Rhizophora* in West Africa. Both Savory (1953) and Keay (1953) recognised three species in West Africa, but Rosevear (1947) held that there was only one. More recently, some authors have recorded only the first two of these species, e.g. Boyé *et al.* (1975), and Bretzler (1969) regarded *R. harrisonii* as a hybrid between *R. mangle* and *R. racemosa*. Certainly some populations of *R. harrisonii* exhibit very low fertility.

In the most landward sites the tidal forest comprises pure stands of *Avicennia africana*, or mixed stands of this species and *Laguncularia racemosa*. The driest, and least frequently inundated fringes may be occupied by *Conocarpus erecta*. These three species, and the three *Rhizophora* species, occur throughout the region. Both *Conocarpus erecto* and *Laguncularia racemosa* are also common in neotropical mangroves, but *Avicennia africana* is now regarded as distinct from the American species, *A. germinans* and *A. nitida*, to both of which the African material has at times been referred.

Mudbanks along tidal creeks may be colonised by 'sea grasses', and then by *Crinum natans* when the banks first become emergent, while the aquatic grasses, *Anadelphia* spp., frequently precede mangroves on young alluvial banks in lagoons. Open lagoons are fringed by *Rhizophora* spp., often with *Acrostichum aureum* and *Hibiscus tiliaceus* in zones of shallow inundation, and *Paspalum distichum* (= *P. vaginatum*) in open glades. *Pandanus candelabrum*, *Phoenix reclinata* and *Paullinia pinnata* are common associates in brackish zones, and a *Pandanus-Phoenix-Rhizophora* association may grade into a pure *Raphia vinifera* swamp in the vicinity of river mouths. *Echinochloa stagnina* is locally abundant in openings in these swamps and also along channels in the brackish parts of tidal forests.

Closed lagoons which become highly saline in the dry season, or which dry up periodically, are fringed by *Avicennia africana*, while their floors become covered by swards of *Philoxerus vermicularis* and *Sesuvium portulacastrum* when they are dry. *Scirpus littoralis*, *Fimbristylis obtusifolia* and *Sporobolus virginicus* are also common around these lagoons, on open sandy ground subject to infrequent shallow inundation.

Mangroves extend far upstream on many rivers in the region. In the drier countries, e.g. Senegal and Gambia, tidal rivers and creeks are bordered by low galleries of *Rhizophora mangle* (5-9 m high) or *R. racemosa*, with *Avicennia africana* dominant on the tidal flats behind. *Avicennia* is more important in Senegal than it is in the wetter, more equatorial countries. On the Senegal and Gambia Rivers, and on the Casamance estuary, the landward *Avicennia* flats are highly saline and give way to herbfields dominated by *Sesuvium portulacastrum* with, on the landward side, herbs such as *Eleocharis geniculata*, *E. mutata*, *Scirpus littoralis* and *Sporobolus virginicus*. Trees usually occur at the very limit of inundation, notably *Mitragyna inermis*, and locally *Avicennia africana* and *Conocarpus erecta*. Some of the flats are flooded only during the rainy season when river water backs up behind spring tides, and at these times annuals, e.g. *Heleochoris* spp., may bloom on the flats. Farther upstream on these western rivers, where tidal flooding is less important than freshwater flooding during the rains, the rivers are fringed by stands of *Cyperus* spp., *Phragmites mauritianus* and *Typho australis*.

By contrast, in the ever-wet zones of Guinea Bissau, Sierra Leone, Liberia and Nigeria, the riverine mangroves are tall and contain several species characteristic of the fresh-

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water swamp forests into which they grade, e.g. *Anthocleista vogelii, Carapa procera, Chrysobalanus orbicularis, Crudia klainei, Cynometra mannii, Lophira procera, Manilkara obovata, Oxystigma mannii, Phoenix reclinata* (= *P. spinosa* of older authors) and *Raphia vinifera. Raphia palmapinus* and *Podococcus barteri* occur on the Cross River and in the eastern part of the Niger Delta. Epiphytes are common in the mangroves of the perhumid zones and include several orchids, e.g. *Bulbophyllum falcipetalum, Cyrtorchis aschersonii, Genyorchis pumila, Polystachya* sp. and *Tridactyle anthomaniaca*, the ferns *Nephrolepis biserrata, Phymatodes scolopendria* and *Platycerium stemaria* and the cactus, *Rhipsalis cassytha. Tapinanthus belvissi* is a common mangrove parasite. Epiphytes are uncommon in the mangroves of drier areas.

Caesalpinia bonduc, Cynometra megalophylla, Dalbergia ecastaphyllum, Drepanocarpus lunatus, Hibiscus tiliaceus, Laguncularia racemosa and *Ormocarpum verrucosum* occur on shallowly flooded levées throughout the coastal parts of the region. Where the trees or bushes are well spaced, a dense herbaceous layer develops, in which *Acrostichum aureum, Eleocharis geniculata, Fimbristylis ferruginea, Paspalum distichum* and *Xyris anceps* are prominent.

Where *Avicennia africana, Hibiscus tiliaceus, Pandanus candelabrum, Phoenix reclinata* or *Rhizophora* spp. have been cleared from the margins of open lagoons, or are highly disturbed, a sedge-grass swamp tends to become established. In these situations *Cyperus articulatus* and *Paspalum distichum* are the most important pioneers, but *Ipomoea cairica, Panicum maximum, Paullinia pinnata, Phragmites karka* and *Typha domingensis* become associates in fresh to lightly brackish water regions.

The freshwater zones of lagoons, and slow flowing waterways, support beds of *Ceratophyllum demersum, Najas marina, Potamogeton* spp., and *Utricularia* spp., with free floating species such as *Azolla* sp. and *Pistia stratiotes* and floating leaved species such as *Nymphaea lotus*. These are succeeded by grasses or papyrus and this often by *Pandanus candelabrum*. Depending upon conditions, this may give way to a *Raphia* swamp, or to a bushy *Alchornea cordifolia* zone, which appears to be the first stage of a freshwater swamp forest.

Freshwater Swamp Forests: Guinean freshwater swamp forests show some variation in floristic content across the region, and several species are common to both swamp and normal, dry ground, rain forests. Among this latter group are species which, in dry ground forest, are characteristic of secondary forest. However, the most common or widespread species in swamp forest are *Alstonia boonei, A. congensis, A. macrophylla, Anopyxis* sp., *Anthocleista nobilis, A. vogelii, Berlinia auriculata, Carapa procera, Irvingia smithii, Manilkara argentea, Mitragyna ciliata, M. stipulosa* (more common towards the interior), *Nauclea diderrichii, N. latifolia, N. pobguinii, Oxystigma mannii, Pandanus candelabrum, Phoenix reclinata* (essentially riparian), *Raphia hookeri, R. vinifera, Spondianthus preussii, Symphonia globulifera, Tarietia utilis* (more common in the west), *Uapaca guineensis, U. heudelotii, U. paludosa, U. staudtii, Voacanga thouarsii* and *Xylopia staudtii. Gilbertiodendron dewevrei* occurs in southern Nigeria, and is present in the drier fringes of periodically inundated valley forests. Typically it forms mono-dominant stands. Pockets of permanent swamp forest are dominated by *Raphia* spp., or by *Sterculia ambacensis* and *Xylopia* spp. *Bequaertiodendron magalismontanum* is a component of riverside swamp forests in the central and western parts of the region

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and develops prominent knee roots, at least in Côte d'Ivoire. Understorey species include the shrub *Leea guineensis*, and the tall herbs *Cyriosperma senegalense* and *Marantochloa* spp. Species of *Ancistrophyllum*, *Calamus* and *Eremospatha* are common lianes in clearings in swamp forests, and also in *Raphia* swamps.

Trees which are common in dry ground secondary forest, but which also appear in swamp forests, especially in the Guineo-Soudanian transition region, include *Annona senegalensis*, *Ceiba pentandra*, *Diospyros mespiliformis*, *Ficus vogelii*, *Macaranga* sp., *Manilkara obovata* and *Musanga cecropioides*.

Seasonally inundated swamp forests occur along rivers in the Guineo-Soudanian transition zone and the Soudanian zone. Common species in this type of forest include *Berlinia grandiflora*, *Cola laurifolia*, *Cynometra vogelii*, *Diospyros elliotii*, *Mitragyna stipulosa*, *Parinari congensis*, *Phoenix reclinata*, *Pterocarpus santalinoides*, *Uapaca heudelotii* and *U. togoensis*, in addition to the secondary forest species listed above. This type of swamp forest is developed on numerous streams flowing north from the Fouta Djallon, e.g. the Tinkisso, Milo and Gbanhala Rivers in northern Guinea, and also on the upper Volta and Oti Rivers. In the far west, in Gambia and Senegal, the spectrum is slightly different. *Cola*, *Cynometra* and *Diospyros* are still common in swamp forest, but *Christiana africana*, *Croton scarciessii*, *Symmeria paniculata*, *Syzygium guineense* and *Ziziphus amphibia* are the commonest associates, often with groves of *Raphia sudanica*.

In the Soudanian zone proper, riparian forests, subject to varying degrees of inundation, contain *Acacia sieberana*, *Afzelia africana*, *Ceiba pentandra*, *Detarium senegalense*, *Diospyros mespiliformis*, *Erythrophleum guineense*, *Ficus glumosa*, *F. sycomorus*, *Khaya senegalensis*, *Syzygium guineense*, *Tamarindus indica*, *Terminalia glaucescens* and *Vitex doniana*. On the Senegal/Mauritania border, in the southern Sahelian zone, *Acacia nilotica* forests occur on the floodplain of the Senegal River, which is otherwise locally dominated by *Vetiveria* grassland, and *Nauclea latifolia* and *Raphia sudanica* forms groves along the river in the riparian forest, which contains many of the above species. Here *Dalbergia saxatilis* and *Landolphia dulcis* are common scandent species.

Levée woodland, or levée scrub, along rivers in the northern Soudanian and southern Sahel zones is generally dominated by *Mitragyna inermis*, associated with species such as *Acacia nilotica*, *A. polyacantha*, *A. sieberana*, *Allophyllus africanus*, *Anogeissus leiocarpus*, *Antidesma venosum*, *Balanites aegyptiaca*, *Bauhinia rufescens*, *Barassus aethiopum*, *Celtis integrifolia*, *Crateva religiosa*, *Dalbergia melanoxylan*, *Diospyros mespiliformis*, *Ficus gnaphalocarpa*, *Morelia senegalensis*, *Parkia biglobosa*, *Phyllanthus muellerianus* and *Ziziphus mucronata*. In some places, *Acacia nilotica* becomes dominant and may occur in almost mono-specific stands.

Grasslands of Hydromorphic Soils: Swampy grasslands occur on the coastal plains in the central and western parts of the region, e.g. on the Accra Plains in Ghana, and also in many places in the west of the region. These are dominated by *Vetiveria fulvibarbis*, together with *Andropogon canaliculatus*, *Brachiaria falcifera*, *Cassia mimosoides*, *Fimbristylis pilosa* and *Polygala arenaria*. Woody thickets occur on termite mounds in these grasslands and in these *Diospyros mespiliformis* is dominant, with *Capparis erythrocarpos*, *Elaeophorbia drupifera*, *Flacourtia indica*, *Grewia carpinifolia*, *Securinega virosa* and *Zanthoxylum zanthoxyloides* as common associates. *Sansevieria liberica* is often present in the field layer.

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Floodplains of the Soudanian zone are dominated by tall grasses and occur in many wide river valleys, but often with widely spaced trees giving an 'orchard-like' appearance, although *Terminalia macroptera* often forms groves in depressions. The other arborescent species, which usually occur upon hummocks, include *Borassus aethiopum*, *Mitragyna inermis* and *Terminalia glaucescens*, while the most widespread grasses in these valleys are *Hyparrhenia cyanescens*, *Pennisetum polystachion* and *P. unisetum*. *Andropogon gayanus* and *Setaria sphacelata* cover great areas in the headwater areas of tributary streams.

Areas of waterlogged grassland occur on peat-filled depressions on high land in the Soudanian zone surrounded by *Isoberlinia* woodlands. They are dominated by *Rhytachne rottboellioides* with an abundance of *Lycopodium affine* and several species of *Bulbine*, *Drosera*, *Utricularia* and *Xyris*.

The floodplains of the northern Soudanian and southern Sahelian zones are also dominated by grasses, e.g. those along the Niger in southern Mali and those draining to Lake Chad. In the zones of deepest and most prolonged inundation, where water depths may exceed 2 m, *Oryza barthii* is dominant, giving way to *Echinochloa pyramidalis* in the middle zones, with *Hyparrhenia rufa* and *Vetiveria nigritana* on the margins. Other species seen on the margins during the rainy season are *Acroceras amplectens*, *Andropogon gayanus*, *Brachiaria deflexa*, *B. mutica*, *Chloris lamproparia*, *C. pilosa*, *Cyperus iria*, *C. longus*, *C. microlepis*, *C. pustulatus*, *C. tenuispica*, *Digitaria acuminatissima*, *D. marginata*, *Dinebra retroflexa*, *Echinochloa colona*, *E. obtusiflora*, *E. stagnina*, *Eleocharis atropurpurea*, *Eragrostis atrovirens*, *Hyparrhenia dissoluta*, *Ischaemum brachyatherum*, *Oryza breviligulata*, *Panicum anabaptismum*, *P. laetum*, *P. subalbidum*, *Paspalidium geminatum*, *Pennisetum ramosum*, *Pycreus albomarginatus*, *Scirpus articulatus*, *S. praelongatus*, *Setaria anceps*, *Sorghum arundinaceum*, *S. bipennatum*, *Sporobolus marginatus*, *S. pyramidalis*, *Thelepogon elegans* and *Urochloa lata*.

In the drainage channels, where water attains semi-permanent depths of a metre or more, and in the lakes and pools, one finds an ephemeral aquatic flora comprising such species as *Aeschynomene crassicaulis*, *Apanogeton subconjugatus*, *Burnatia enneandra*, *Centrostachys aquatica*, *Ceratopteris cornuta*, *Eichhornia crassipes* (among the most abundant), *Eriocaulon bifistulosum*, *Heteranthera callifolia*, *Ipomoea aquatica*, *Limnophyton obtusifolium*, *Lophotocarpus guayanensis*, *Marsilea crenulata*, *Nymphaea lotus*, *N. rufescens* (among the most abundant), *Nymphoides indica*, *Ottelia ulvifolia*, *Scholleropsis lutea* (naturalised) and *Vossia cuspidata*. Among the rooted submerged species, *Ammania auriculata*, *Limnophila barteri*, *Rotala mexicana*, *R. tenella* and *R. welwitschii* are most common. Free-floating submerged species include *Chara zeylanica*, *Najas graminea*, *N. pectinata*, *Nitella acuminata*, and on the surface, *Utricularia benjaminiana*, *U. gibba* var. *exolata* and *U. inflexa* var. *stelloris*.

In the more superficially flooded areas, a mosaic vegetation develops in the rainy season, with patches of different composition, some containing only one gregarious species, others being heterogeneous. Representative species include *Acalypha crenata*, *Aeschynomene nilotica*, *A. uniflora*, *Alternanthera sessilis*, *Ammania auriculata*, *Aspilia helianthoides*, *Borreria radiata*, *Burnatia enneandra*, *Caperonia palustris*, *Cassia mimosoides*, *Celosia argentea*, *Cleome hirta*, *Commelina diffusa*, *C. erecta*, *Crinum pauciflorum*, *C. yuccaeflorum*, *Cucumis melo*, *Cyanotis cucullata*, *Dichondra repens*, *Evolvulus alsinoides*, *Glinus oppositifolius*, *Hibiscus articulatus*, *H. cannabinus*,

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H. esculentus, H. panduriformis, Hygrophila auriculata, Ilysanthes parviflora, Luffa echinata, Melochia corchorifolia, Phyllanthus maderaspatensis, Sesbania leptocarpa, S. pachycarpa, S. sesban, Sonchus exauriculatus, Sphenoclea zeylanica, Stachytarpheta angustifolia, Thalia welwitschii, Withania somnifera and *Zornia glochidiata*. *Acacia nilotica* and *A. seyal* are the only trees on the floodplain proper.

In the west, e.g. on the Gambia and Senegal Rivers, seasonally flooded grasslands may be covered by swards of *Andropogon gayanus, Echinochloa pyramidalis, Panicum anabaptistum, Paspalum orbiculare*, and *Vetiveria* spp., the distribution of species depending upon the depth and duration of inundation, and soil factors.

Lakes & Ponds: The southern shores of Lake Chad are fringed by great stands of *Cyperus papyrus* and *Phragmites mauritianus* with much *Vossia cuspidata* in the water, while on the northern shores these species are replaced by *Phragmites australis* and *Typha latifolia* var. *australis*, and a similar type of vegetation occurs on other lakes and swamps in Chad. However, the absence of papyrus from the rest of the region is one of its more remarkable phytogeographical features. The lakes and swamps of Burkina Faso, Mali and Senegal are dominated by *Phragmites* and *Typha*, together with their typical, lower growing, grass and sedge associates.

Semi-permanent ponds in the Soudanian zone (tabki) are often fringed by a ring of lush grass and trees, the periphery remaining green throughout the dry season even when the ponds dry up. Among the trees present in this situation are *Acacia nilotica, A. polyacantha, A. seberana, Anogeissus leiocarpus, Balanites aegyptiaca, Diospyros mespiliformis, Mitragyna inermis* and *Tamarindus indica*. *Echinochloa* spp., *Ipomoea aquatica, Oryza barthii* and *Vossia cuspidata* are often common in the ponds, as are *Ceratophyllum demersum, Nymphaea lotus, Pistia stratiotes, Potamogeton* spp. and *Utricularia* spp.

The pools and springs of oases may be fringed by *Phragmites mauritianus* and *Typha domingensis*, and there may occasionally be *Ficus* and *Tamarix* trees along the beds of oueds, and quite often *Hyphaene thebaica*. There have been plantings of *Phoenix dactylifera* at many oases.

Wetland Fauna

Most of the savanna species are to be found on the great floodplains of the north of the region during the dry seasons, many moving onto the plain to graze the fresh grasses, closely followed by their predators. They are included in the following lists since they regularly exploit wetlands and are dependent upon them. In much the same way other species visit the closed swamp forests of the Guinean zone during the dry seasons.

Fishes: The fish fauna of the Niger Basin is well known, and is primarily Soudanian in character. Of the 112 species described by Daget (1954) in the upper and middle Niger, 66 are common to the Nile and 52 to the Gambia River, while 33 are common to all three rivers, including *Citharinus citharus, Hydrocynus forskalii, Lates niloticus* and *Oreochromis niloticus*. Some 20 species are apparently confined to the Niger Basin, among them *Gobiocichla wonderi* (middle Niger), *Microthrissa miri* (middle Niger, associated lakes and floodplain), and *Pellonula afzuli* (lower Niger). *Calamoichthys calabaricus* is an eel-like polypteran confined to the Niger Delta. The other rivers of the region have been less well studied, but all have many species in common with the Niger.

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Widespread species which have all been collected from the Niger, and most of which have also been recorded from the Volta, Gambia and Senegal Rivers, include *Alestes baremose, A. dentex, A. leuciscus, A. macrolepidotus, A. nurse, Arius gigas* (on muddy bottoms), *Auchenoglanis occidentalis, Bagrus bayad, B. docmac, Barbus occidentalis, B. punctitaeniatus, B. stigmatopygus, Barilius niloticus, Channa obscura, Chrysichthys nigrodigitatus, Citharinus distichodoides, C. latus, Clarias anguillaris* (swamps), *C. lazera* (swamps), *C. submarginatus* (swamps), *Claroteo laticeps, Distichodus brevipinnis* (swamps), *D. engycephalus* (swamps), *D. rostratus* (swamps), *Eutropius niloticus, Gnathonemus adabii, G. petersii, G. tamandua, Gymnarchus niloticus* (swamps), *Hepsetus odoe, Heterobranchus bidorsalis, H. longifilis, Heteropisus bebe, Heterotis niloticus* (swamps), *Hydrocynus lineatus, H. vittatus, Ichthyborus besse, Labeo pseudocoubie, L. senegalensis, Malapterus electricus, Marcusenius ihuysi, M. psittacus, Mormyrops deliciosus, Mormyrus macrophthalmus, M. rume, Notobranchius walkeri* (floodplains/swamps), *Petrocephalus bane, Phago loricatus, Physalia pellucida, Polypterus ansorgei, P. endlicheri, P. senegalus, Protopterus annectens* (floodplains/swamps), *Schilbe mystus, Siluranodon auritus, Synbranchus afer, Synodontis batensoda* (stagnant pools), *S. clarias, S. eupterus, S. filamentosus, S. gobroni* (lower reaches of rivers), *S. membranaceus, S. nigrita* (swamps), *S. ocellifer, S. sorex, Tetraadon fahaka, Tilapia aurea, T. galilaea* (sandy bottoms), *T. melanopleura* and *T. zillii* (reed beds).

Coastal lakes and lagoons often contain a mixture of estuarine fishes and fishes with more strictly lacustrine or riverine affinities, especially where the lagoons are periodically closed from the sea, yet fed by a river. Common species known to breed in coastal lagoons include *Acanthurus monroviae, Alestes macrolepidotus, Caranx carangus, Chrysichthys nigrodigitatus, Cynoglossus senegalensis, Dasyatis margarita, Distichodus rostratus, Elops lacerta, Ethmalosa fimbriata, Gerres melanopterus, Hemichromis fasciatus, Hepsetus odoe, Hydrocynus forskalii, Labeo senegalensis, Liza falcipinnis, Pellonula afezeliusi, Pristipoma jubelini, Psettus sebae, Sardinella eba, Tilapia melanopleura* and *T. zillii*.

A number of marine fish penetrate the rivers for considerable distances. For example *Pellonula vorax* occurs in the Niger Delta, in the mangroves, and migrates upriver to breed, and a flat fish (*Dagetichthys* sp.) and a stingray (*Potamotrygon garouensis*) have been recorded in the Benue River as far upstream as Cameroon. Daget (1954) distinguished between Guinean and Soudanian species, which live in forest and savanna waters respectively. Many fish exhibit seasonal migrations up and down river. *Alestes leuciscus* for example moves up to 400 km along the middle Niger each year (Daget, 1954), while others move up to 50 km away from the rivers to the edges of floodplains to spawn. A good introduction to recent work on West African fishes is given by Lowe-McConnell (1975), while detailed accounts are provided by Daget (1954; 1957) for the Niger, Daget & Stauch (1963) for the Benue, Daget & Iltis (1965) for the Côte d'Ivoire, Johnels (1954) for the Gambia River and Durand (1970) for rivers entering Lake Chad.

Amphibia: Species more or less confined to the two Guinean rain forest blocks include *Bufo perreti, Phrynobatrachus alticola* and *Xenopus tropicalis*, while *Phrynobatrachus liberiensis* and *P. guineensis* are confined to the western block. *Hymebochirus merlini* is also confined to the western region but extends from the rain forest block into the

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coastal savanna zone of Senegal. *Rana galamensis* is a widespread savanna zone species, reaching the coast in the 'Dahomey Gap' but not extending far west of this, while *Phrynobatrachus francisci* occurs in the savanna zones throughout the region.

Reptiles: Reptiles found in the wetlands include *Crocodylus cataphractus, C. niloticus, Osteolaemus tetraspis* and *Varanus niloticus*. Among the snakes of forest streams and pools *Boithrophthalmus lineatus, Boulengerina annulata, Grayia smithii, Miodon acanthias, Naja melanoleuca, Natrix anoscopus, Pseudohaje nigra* and *Python sebae* are the most common. *Boulengerina* is also found in large lakes and impoundments. In the Soudanian zone, *Philothamnus* spp. occur in herbaceous swamps, rivers and pools, while *Psammophis sibilans* is common in wet, as well as dry, grasslands. *Atheris chloraechis, Boiga blandingii, Dasypeltis fasciata, Dendroaspis viridis, Thelotornis kirtlandii* and *Thrasops occidentalis* have been recorded in swamp forest trees, while *Dasypeltis scabra, Dispholidus typus, Philothamnus* sp. and *Thelotornis kirtlandii* have been recorded from riparian swamp forests in the savannas.

Birds: The avifauna of the mangrove areas is fairly constant throughout West Africa. Most species are piscivorous, or feed on insects, crabs or shellfish. Species which commonly nest in mangroves include *Ardea goliath, Ardea purpurea, Bubulcus ibis, Butorides striatus, Egretta garzetta, Hypsanurgus brachypterus, Melanophoyx ardesiaca, Platysteira cyanea, Ploceus cucullatus, Turtur afer* and *Uraeginthus bengalus*. Other species regularly seen in mangroves include *Acrocephalus scirpaceus, Alseonax aquaticus, Anhinga rufa, Anthreptes gabonica* (confined to mangroves), *A. longuemarie, Ardea cinerea, Ardeola ralloides, Calidris minuta, Casmerodius albus, Ceryle rudis, Chlorophoneus sulphureopectus, Cinnyris coccinogaster, Corythornis cristata, Dryoscopus gambensis, Gypohierax angolensis, Halcyon malimbicus, Haliaeetus vocifer, Himantopus himantopus, Hirundo rustica, Hypergerus atriceps, Lanarius barbarus, Lophoceros nasutus, Macronyx croceus, Numenius phaeopus, Numida meleagris, Nycticorax leuconotus, N. nycticorax, Pandion haliaeetus, Phalacrocorax africanus, Phylloscopus collybita, P. trochilus, Pynonotus barbatus, Spermophaga haematina, Streptopelia semitorquata, Sylvia cantillans, Tringa nebularia* and *T. totanus*.

Other species widely distributed in West African coastal wetlands, including lagoons, lakes and estuaries, are *Anas acuta, A. clypeata, A. querquedula, Casmerodius albus, Dendrocygna bicolor, D. viduata, Egretta garzetta, Euplectes orix, Gelochidion nilotica, Hydroprogne caspia, Larus cirrocephalus, L. genei, Morus bassanus, Nycticorax nycticorax, Otis arabs, Pandion haliaeetus, Phaethon aethereus, Platalea leucorodia, Sterna albifrons, S. anaethetus, S. fuscata, Sula leucogaster* and *Thalasseus maximus*.

Kingfishers occur in wetlands throughout the region. Those with the widest distribution occur right across the Soudanian zone and include *Ceryle rudis, Halcyon chelicuti* and *Halcyon senegalensis. Halcyon fuscopileus* and *Mioceyx lecontei* occur in both rain forest blocks, while *Halcyon badius badius* is confined to the eastern block and *Halcyon badius nigricans* to the western block. *Alcedo quadribrachys* and *Corythornis leucogaster* are found in the southern savanna zones and reach the coast in the 'Dahomey Gap'.

Common species on West African floodplains include *Alopochen aegyptiacus, Anas acuta, A. capensis, A. querquedula, Anhinga rufa, Ardea cinerea, A. goliath, A. melanocephala, A. purpurea, A. ralloides, Balearica pavonina, Bubulcus ibis, Butorides striatus, Calidris minuta, C. temminckii, C. testacea, Chlidonias hiaticula, C. hybrida,*

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C. leucoptera, Ciconia ciconia, Dendrocygna viduata, Egretta garzetta, E. intermedia, Ephippiorhynchus senegalensis, Glareola nordmanni, G. pratincola, Hagedashia hagedash, Haliaeetus vocifer, Himantopus himantopus, Ixobrychus minutus, Larus cirrocephalus, Leptoptilos crumenifera, Limosa lapponica, L. limosa, Nettapus auritus, Pelecanus onocrotalus, Phalacrocorax africanus, P. carbo, Philomachus pugnax, Platalea alba, Plectropterus gambensis, Plegadis falcinellus, Sarkidiornis melanotos, Scotopelia peli, Threskiornis aethiopicus, Tringa glareola, T. erythropus and *T. nebularia.*

Mammals: *Trichechus senegalensis* occurs in rivers and lakes throughout the region, extending several hundred kilometres inland. Large terrestrial mammals found in the swamp forests of the two rain forest blocks comprise *Cephalophus monticola, C. niger, C. ogilbyi, C. sylvicultor, Hyemoschus aquaticus, Loxodonta pumilio, Manis gigantea* (extends into savannas), *M. tetradactyla, Potamochoerus porcus* and *Syncerus caffer nanus.* Others are confined to one or the other block, not crossing the 'Dahomey Gap'. Those restricted to the eastern rain forest block include *Cephalophus nigrifrons, Neotragus batesi* (E Niger Delta only), while those found only in the western block include *Cephalophus dorsalis, C. jentinki, Chloeropsis liberiensis, Neotragus pygmaeus, Tragelaphus euryceros* and *T. scriptus.*

Hippopotamus amphibius is found in the savanna zones and the eastern rain forest block, but is replaced in the western forest block by *Chloeropsis liberiensis.* Other large mammals which visit wetlands throughout the savanna zones are *Cephalophus rufilatus* (S savanna zone), *Loxodonta africana, Lycaon pictus, Ourebia ourebi, Panthera leo* (floodplains), *Panthera pardus, Phacochoerus aethiopicus, Redunca redunca, Sylvicapra grimmia* and *Syncerus caffer brachyceros*, while those with restricted distributions are *Damaliscus lunatus* (Lake Chad and floodplains of Sahel), *Hippotragus equinus* (gallery forest of central zone), *Kobus ellipsiprymnus* (W only), *K. kob* (W only), *Papio papio* (W savanna), *P. doguera* (E savanna), *Taurotragus derbianus* (W savanna), *Tragelaphus oryx* (between upper courses of Niger and Senegal Rivers), *T. spekei* (Lake Chad and W Senegal) and *Vulpes pallida* (floodplains of N). *Canis aureus* and *Hyaena hyaena* visit floodplains in the Sahel zone, while in the Soudanian zone they are replaced by *Canis adustus* and *Crocuta crocuta. Erythrocebus patas* occurs on the floodplains in the northern savanna and southern Sahel zones.

Arboreal species in swamp forests of the two rain forest blocks include *Anomalurus beecrofti, A. derbianus, A. peli, Cercocebus torquatus, Cercopithecus mona* (including mangroves), *C. nictitans, Colobus polykomos, Dendrohyrax arboreus, Epixerus ebii, Funisciurus pyrrhopus, Galago demidovii, Heliosciurus rufobrachium, Idiurus macrotis, Nandinia binotata, Paraxerus poensis* and *Protoxerus stangeri.* Those confined to the eastern block are *Cercopithecus cephus, C. l'hoesti* (E Niger Delta only) while those confined to the western rain forest block are *Anomalurus pusillus, Cercopithecus petaurista, Colobus badius* (extends into Senegal), *C. verus, Heliosciurus gambianus* and *Poiana richardsoni. Cercopithecus aethiops* and *Galago senegalensis* are found throughout the savanna zones.

Small mammals found in wetlands throughout the region, although scarce in the Sahel zone, include *Aonyx capensis, Atilax paludinosus, Cricetomys gambianus, Genetta tigrina, Herpestes ichneumon, H. sanguineus, Lutra maculicollis, Thryonomys swinderianus* and *Viverra civetta.*

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Crossarchus obscurus, *Felis aurata* and *Malacomys longipes* live in the rain forest blocks while *Dasymys incomtus*, *Ichneumia albicauda*, *Leptailurus serval* and *Mungos mungo* occur in the savanna zones. *Potamogale velox* was believed to occur only in the extreme southeast of the region, on the Cross River, but has recently been reported from rivers in Guinea Bissau. Some of these species are uncommon in wetlands, but nevertheless merit mention because they do visit them and are known to eat frogs and freshwater crabs, e.g. *Crossarchus obscurus* and *Ichneumia albicauda*, while *Mungos mungo* often eats *Dasymys incomtus* and *Thryonomys swinderianus* which it takes in marginal wetlands. Several bats have been observed in and over high swamp forest, including *Glauconycteris superba*, *Hypsignathus monstrosus* and *Taphozous mauritianus*, while *Eidolon helvum*, *Epomophorus gambianus* and *Epomops franqueti* live in, or visit, wetlands of the savanna zones.

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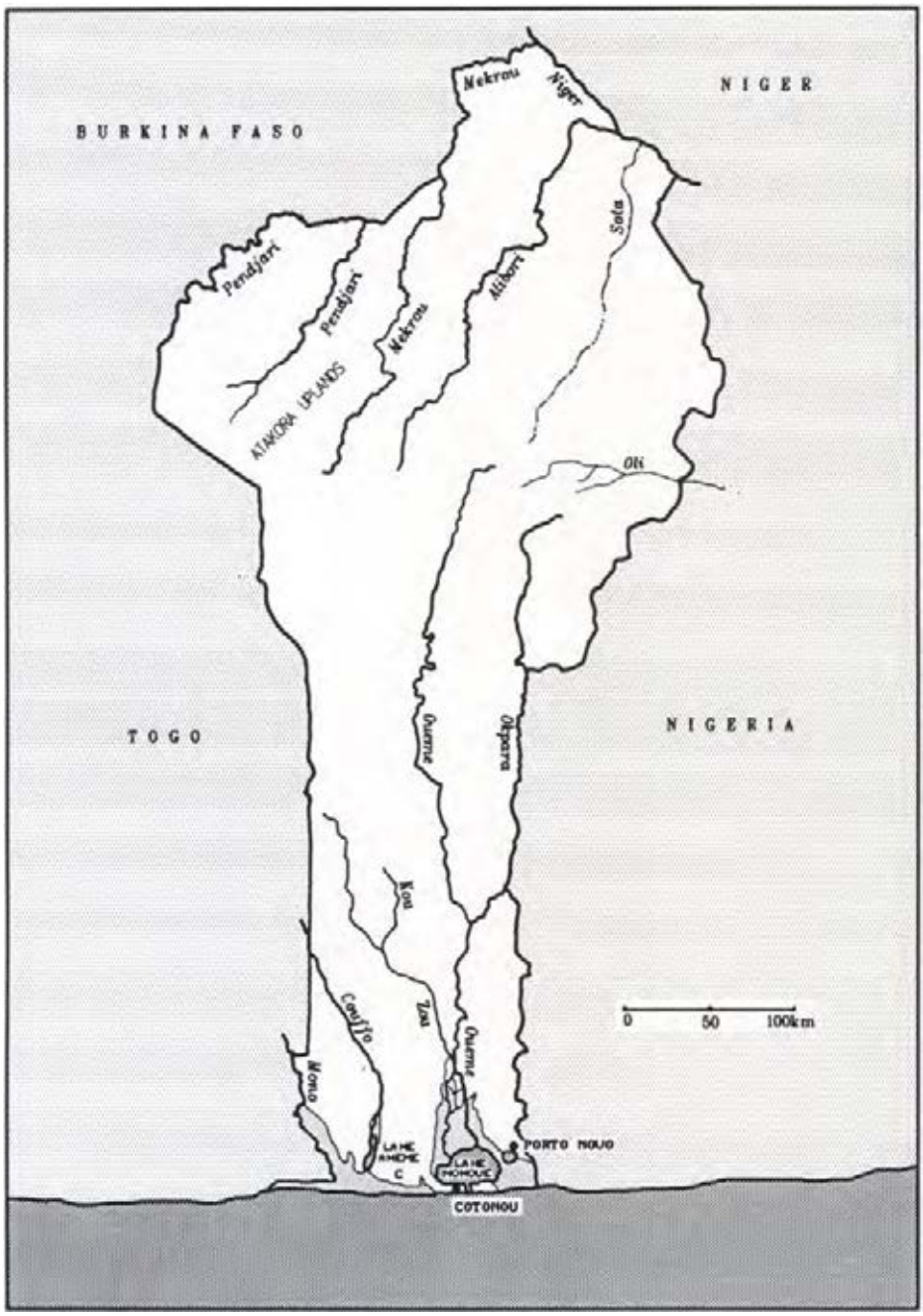

Map of Benin

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3.1 BENIN

Introduction

Benin, formerly known as Dahomey, has an area of 112 620 km^2, a population of 3 905 000, and thus, a mean population density of 34.7 persons/km^2. The country has a coastline of 100 km, along the Gulf of Guinea, and is bounded by Togo in the west, Burkina Faso and Niger in the north, and Nigeria in the east. It extends 675 km from north to south, between latitudes 12°23'N (on the Niger River) and 6°16'N (on the coast at the Togo/Benin border), and 330 km from east to west between longitudes 3°52'E (on the Benin/Nigeria border) and 0°48'E (on the Togo/Benin border). It is shaped like a cudgel, with the handle, about 125 km wide, leading due north from the coast, and widening to the head, 330 km wide, above a latitude of 9°N.

The littoral region is characterised by an almost continuous sand-bar, built up under the influence of the west to east longshore drift, which is estimated to carry some 1.5 million m^3 of sand/yr along the coast from the Volta delta to the Niger delta (Klingebiel, 1981). Some coconuts are planted on the bar, particularly in the west, and immediately to landward there is a lagoonal system, connected to Lake Ahémé some distance inland, but not to Lake Nokoué. Both these lakes are moderately deep and were created when their river valleys were flooded during the last marine transgression. The lagoons, some now artifically maintained as canals, are oriented E-W behind the coastal sand-bar and connect with a similar lagoonal system in Togo to the west. Another system, beginning at Lake Nokoué, connects with Lagos Lagoon in Nigeria to the east. In Benin the westerly lagoons have outlets to the sea at Boca del Rio, west of Grand Popo (6°17'N/1°50'E), and Lake Nokoué has an opening at Cotonou (6°21'N/2°26'E), where an artificial deepwater harbour was opened in 1965.

Both Lakes Ahémé and Nokoué are situated in the lower reaches of shallow valleys at the back of the sandy coastal plain. The plain rises gently towards the north, to the low southern plateau country at an altitude of 200-300 m. However, the coastal slope is broken by the Lama Depression, a swampy clay plain between Abomey (7°11'N/1°59'E) and Cotonou, which is intensively cultivated, and the valleys of the Couffo, Zou and Ouémé Rivers which penetrate far into the plateau region; the floor of the Ouémé Valley is for example, less than 40 m asl 150 km from the coast.

The plateau extends north, covering most of the country, with isolated hills rising to heights of between 350 and 625 m, but it is interrupted by the escarpment of the Chaîne de l'Atakora which enters the country on the parallel 10°N, and crosses the northwestern extremity obliquely from SW-NE. This range, which is an extension of the Chaîne du Togo, reaches a maximum altitude of 641 m at a point 10°19'N/1°33'E. From these mountains, the land surfaces slope down to an altitude of 150 m along the course of the Pendjari (Oti) River, which forms the border with Burkina Faso for some distance in the northwest before it flows into Togo. In the northeast, the Niger River forms the border with Niger, at altitudes which decline from 175 to 161 m in passing downstream.

The Pendjari River drains the Chaîne de l'Atakora in the northwest. It rises on the southeastern flank of the range and initially flows northeastwards before looping around the end of the mountains to flow back southwestwards in parallel. The northeastern part

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of the interior plateau is drained by three principal streams, the Mékrou, Alibori and Sota Rivers, which all flow northeastwards to join the Niger River. Drainage of virtually the entire country south of the parallel 10°N, is to the Ouémé River. This stream rises just below the 500 m contour at a point 9°52'N/1°33'E near the town of Kopargo, but receives several ephemeral tributaries which rise farther north than this. It flows almost due south down the centre of the country, receiving in its lower reaches its two major affluents. These are the So River, which drains the central western borderlands and the Okpara River, which drains the central eastern areas and forms the border with Nigeria for several hundred kilometres. The Ouémé receives its last affluent, the Zou River which drains much of the central southern plateau, 75 km from the sea. Immediately below the confluence it breaks into a distributary system which traverses a delta 60 km long with a base 31 km wide on Lake Nokoué. The waters of the Ouémé reach the sea via this lake and the lagoonal system at Cotonou. A small part of Benin, in the southwest, is drained by the Mono and Couffo Rivers, the latter discharging into the lagoonal system via Lake Ahémé. Water from both these rivers reaches the sea 12 km east of Grand Popo, at Boca del Rio (6°17'N/1°58'E).

Climate

Along the coast, rainfall increases from west to east. Mean annual rainfall at Grand Popo is close to 800 mm, but this has increased by more than 50% at Cotonou. Precipitation at the coast is bi-modal, with 2 wet seasons. The principal rains are from March to July, with a brief dry period in August, followed by renewed rains from September to November. The main dry season lasts 3 months, from December to February inclusive. Mean annual precipitation at Cotonou is 1307 mm, with a mean monthly maximum of 380 mm in June and mean monthly minima of 27 mm in August and 16 mm in December. It rains on about 100 days each year at Cotonou. In passing inland the dry period in August is lost, but the major dry season increases in length. Thus at Savé (8°02'N/2°29'E), 190 km from the coast, it still rains on 100 days each year, but the single dry season lasts from November to February inclusive. The mean annual precipitation is 1090 mm, with a mean monthly maximum of 171 mm in September, and mean monthly minima of 8 mm in both December and January. At Kandi (11°08'N/2°56'E), rain falls on less than 80 days each year and mean annual precipitation is close to 900 mm, while the dry season persists for 7 months, from October to April, but the Atakora Massif is wetter, with annual falls of 1100-1300 mm, and very high precipitation in July to September.

In the south, temperatures are relatively constant throughout the year with daily maxima and minima close to 34°C and 22°C. By contrast, in the north, the hot desiccating dust laden Harmattan wind blows during the dry season, when daytime temperatures can exceed 43°C and night-time readings can be as low as 19°C.

Vegetation

In general the southern half of the country supports a Guineo-Soudanian transition type of vegetation, since although there are 8 wet months, total rainfall is not high and humidity is very low during the major dry season. The northern half of the country supports Soudanian savanna vegetation, with galleries of forest along the rivers. Most of the original forest has been cleared for agriculture, except along the rivers, where the forest tends to be swampy.

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Wetlands

The sea beaches are sandy, but there are small mangrove stands in the lagoons and in Lake Nokoué. A swampy strip, inundated during the rainy seasons and measuring up to 5 km in width, surrounds the lagoons and extends along the entire coast immediately to landward of the low coastal dunes. Zones of periodic inundation extend inland from this strip, up minor streams for distances of up to 23 km, while swamps occur around the several small lakes on the coastal plain, and extensive swamps occur in the delta of the Ouémé River, on the Couffo River at the head of Lake Ahémé, and on the lower course of the Mono River.

On the interior plateau, in the central eastern district, extensive permanent swamps occur in the headwaters of tributaries of the Okpara River, some 50 km east of Parakou (9°21'N/2°37'E). In the northeast, floodplains and permanent swamps occur all the way along the Niger River where it forms the boundary between Benin and Niger. In the northwest, floodplains and permanent swamps occur on the Pendjari River and many of its affluents, both to the east and west of the Atakora Mountains.

There are numerous small agricultural impoundments in the interior and northern parts, and a major dam is under construction on the Mono River, at Nangheto in Togo. This will no doubt influence the flood regime below the dam, and hence the Mono Swamps in Benin.

List of Wetlands Described

1. Wetlands of the Coastal Plain
   (a) The Coastal Lagoons
   (b) The Mono River Swamps
   (c) Lake Ahémé & the Couffo River
   (d) Lakes Nokoué & Porto Novo & the Ouémé Delta
   (e) Minor Lakes & other Wetlands
2. Wetlands on the Niger River
3. Wetlands on the Pendjari River System

1. Wetlands of the Coastal Plain

(A) THE COASTAL LAGOONS

Location: 6°16'-6°26'N/1°48'-2°47'E
Area: c. 29 000 ha (2500 ha open water, 26 500 ha seasonal wetland)
Altitude: sea level
Nearest Towns: Cotonou and Porto Novo (in system)

General: Swampy land subject to seasonal inundation occupies a strip 96 km long and up to 7 km wide (mean width 3.6 km) behind the barrier dunes along the entire coastal strip, with a total area of some 29 000 ha. These swamps are developed along a semi-continuous line of narrow lagoons, which are weakly tidal. The swamps, although not the lagoons, provide a continuous wetland, connecting the swamps at the mouth of

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the Mono River on the Togo border with those that surround Lake Nokoué and Lake Porto Novo on the Nigerian border. The floodplain swamps of several minor coastal streams, e.g. the Toha, Todoubo and Dati, which discharge into the lagoons, extend these coastal swamps up to 20 km into the coastal plain. The lagoons are best developed in the west, where they are in contact with the sea through the Boca del Rio, but they peter out in a series of small lakes just before Cotonou is reached. Some of these little lakes may become continuous in June-July, at the height of the rainy season, and the large central lagoon may gain contact with the open western lagoon near the village of Djègbadji (6°19'N/2°05'E), carrying the discharge of the minor coastal streams to the sea.

Flora & Fauna: The lower swamps are tidal, and especially towards the Boca del Rio, they support scattered mangroves and extensive swards of *Paspalum distichum* with various sedges on their fringes. Groves of *Hibiscus tiliaceus* and *Pandanus candelabrum* occur on some shores. *Sporobolus virginicus* is common in the fringes on the seaward side. *Avicennia* and *Concocarpus* occur around some of the isolated lagoons. Reeds and bulrushes occur on affluent streams, and fringe some of the upper lagoons. The fish fauna is characteristically estuarine in the western areas, but both marine and freshwater species occur in the eastern lagoons and in the affluent streams. Several marine fishes and prawns enter the lagoons to breed, after which their juveniles utilise the lagoons as nurseries. There is a rich coastal avifauna.

Human Impact & Utilisation: The southern third of the country is far more densely populated than the north, and the three major cities of Grand Popo, Cotonou and Porto Novo have been constructed in the coastal strip. A main international road and railway run along the landward side of the swamps, the ramparts built for these structures in places effectively limiting the landward extension of the inundated lands. Both the road and railway cross the swamp belt west of Cotonou, and the city interrupts the swamp lands on the southern shore of Lake Nokoué. Locally the lakes, lagoons and swamps are fished, and the adjoining lands which are free from inundation, are intensively cultivated, but apart from drainage and clearances for buildings around villages, the swamps of the coastal strip have not been extensively altered since traditionally the wetlands are considered unsuitable for agriculture. Hunting takes place in the swamps and many water fowl are taken each year.

Conservation Status: It was proposed in 1985 that a reserve be set up to protect some mangrove stands, but the wetlands of the coastal strip are presently unprotected.

(B) THE MONO RIVER SWAMPS

Location: 6°17'-6°33'N/1°42'-1°52'E
Area: c. 46 400 ha (26 800 ha in Benin)
Altitude: 0-20 m asl
Nearest Towns: Grand Popo (2 km S); Lokossa (10 km N)

General: The lower course of the Mono River meanders over a floodplain and forms the border between Togo and Benin. Here, for 36 km above Grand Popo, the banks of the river are swamp-clad on both sides, the zone of inundation reaching 10.2 km in width near Comè (6°24'N/1°52'E) in Benin. The swamp zone includes much open forest or woodland, which is inundated seasonally, and permanent reed and tree swamps. Flooding is deepest in June-July, during and after the heaviest rains, and much of the area is

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dry in December, though strips of permanent swamp occur along the river and in depressions on the floodplain. Immediately above Grand Popo, the Mono River flows under a road bridge and swings due east along the coast behind a long sandspit, discharging to the Gulf of Guinea at Boca del Rio.

Human Impact & Utilisation: The swamps and floodplain are fished and a railway traverses the swamps along most of the eastern boundary, where agriculture has begun to encroach upon the swamp land. Although the great expanse of swamp land is little disturbed, wood is cut for fuel locally. The dam being constructed at Nagheto in Togo will undoubtedly reduce flooding of the Mono swamps and will reduce the wetland area.

Conservation Status: Unprotected.

(C) LAKE AHEME AND THE COUFFO RIVER

Location: 6°30'N/1°59'E
Area: 12 600 ha (8640 open water + 3960 lakehead swamps)
Altitude: c. 3-5 m asl
Nearest Towns: Lokossa (30 km W); Cotonou (48 km ESE)

General: Lake Ahémè and its lakehead swamps, which may be inundated at high water, are 35 km long with a maximum width of 5.5 km and a mean width of 3.6 km. The lake is 24 km long and its southern extremity extends into the inundated zone of the coastal strip, and is in contact with the sea through the western coastal lagoon into which it discharges.

Flora & Fauna: The riparian and lakeside swamps are dominated by *Phragmites* and *Typha* with some *Cyperus papyrus*. Typical floodplain grasses occur to landward of the permanent reed swamps around the lake head, with *Echinochloa* and *Vetiveria* spp. Aquatic macrophytes occur in extensive beds around the lakeshores including such genera as *Ceratophyllum*, *Nymphaea*, *Pistia*, *Potamogeton*, *Trapa* and *Utricularia*. The lake fauna comprises a mixture of species, some with marine affinities and others with riverine and lacustrine affinities.

Human Impact & Utilisation: The lakeshore is densely populated and the lake is fished intensively. Cultivation extends right to the lakeshore, and abuts the lakehead swamps. There is an increasing siltation problem due to heavy erosion occasioned by intensive local agriculture.

Conservation Status: Unprotected.

(D) LAKES NOKOUE & PORTO NOVO & THE OUEME DELTA

Location: 6°23'-7°04'N/2°07'-2°37'E
Area: c. 103 600 ha (17 600 open water)
Altitude: 0-12 m asl
Nearest Towns: Cotonou (on lake); Porto Novo (on lake)

General: Both Lakes Nokoué (6°25'N/2°25'E) and Porto Novo (6°28'N/2°35'E) are situated at the base of the Ouémé Delta, a protrusion of which separates them. Lake Nakoué opens to the sea by a channel some 5 km long passing along the eastern side of Cotonou, which city is situated on the coastal sand-bar between the lake and the sea. The mouth of the channel can become obstructed by sand in the dry season, then interfering

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with tidal fluxes between the lake and the sea. The lake is 19.2 km long with its long axis oriented E-W, has a mean width of 7.3 km, and an open water area of 16 000 ha at high water. It is connected by a 7 km long canal to Lake Porto Novo farther east, which is 5.4 km long and 3 km wide, and provides a further 1600 ha of open water surface. This latter water body is itself connected eastwards to the Lagos Lagoon system in Nigeria by a navigable channel, locally over 1 km wide.

The Ouémé Delta extends northwards from the lakes for 70 km, decreasing in width from 31 km to 9 km. It comprises over 86 000 ha of permanent swamp land, fringed locally by zones of seasonal inundation. It is traversed by two meandering distributaries with many anastomoses and numerous oxbow lakes and sections of abandoned channel, especially on the western side. Some of the oxbow lakes are 5 km long and nearly 1 km wide. The western distributary discharges into Lake Nokoué and the eastern one into Lake Porto Novo.

There are numerous tracks through the swamps, many villages and encampments, the latter more numerous on the eastern side, and several substantial patches of dry land.

Hydrology & Water Quality: Water enters Lake Nokoué from the Ouémé River, from the sea by tidal influx, and from direct precipitation, and leaves it by tidal efflux, throughflow to the Lagos Lagoon system, and evaporation. However, the level of the lake and its water chemistry varies with the seasons and the periodic closure of the mouth of the Cotonou Canal. High water is coincident with the rainy season over the central catchments of the Ouémé River, between August and November, when the lake level may rise by 1 m, increasing its total volume by 80 million m^3, from 250 to 330 million m^3. High tide is not in phase in the two lakes, which sometimes leads to dramatic tidal scouring and currents of more than 2 m/sec in the connecting Totché Canal. At times of low lake water and spring tides, saline sea water pours into the lake and makes its presence felt as far as 40 km up the Ouémé River.

The lake water is not stratified because of tidal fluxes and currents due to riverine inflow and outflow. Surface temperatures do not vary greatly throughout the year, but vary from around 26°C in the mornings to 32°C in the late afternoons. pH varies from 7.4 to 7.6 over the course of the year, being lowest during the rains, and transparency decreases from west to east. Secchi depths reach maxima close to 1.2 m in the west, and minima of a few centimetres in the east during the rains. Salinities depend very much upon whether the Cotonou Canal is open or closed. If closed during the rainy season the whole lake can become almost fresh. When closed, mean salinities of 0.8-8.5‰ have been recorded in different parts of the lake, while the range for the same locations when the mouth is open is 5-19.5‰. Once closed, the mouth tends to remain closed until opened artificially. The mouth closed in April 1978 and remained closed for several years, but by 1985 it was open again.

Flora & Fauna: In the southeast of the lake, where salinities are highest but flood levels lowest, the tidally inundated banks are covered by dense swards of *Acrostichum aureum* and *Typha* sp., the latter having been cited as *domingensis*, *australis*, *latifolia* and *latifolia* var. *capensis* by different authors. The first of these is probably correct. Waterways and lakes in the delta, right down to the lake, are fringed by *Cyperus papyrus* and *Phragmites karka* where inundation is permanent and tidal fluctuation is small, although seasonal changes are substantial. Behind the reed swamps, typical floodplain

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grasses occur around the lake and on the margins of the delta, e.g. *Echinochloa pyramidalis*, *Paspalum distichum* and *Vetiveria negritana*. During the rains, free-floating species drift into the lake and form large carpets, and sometimes these include large rafts of *Cyperus papyrus*. An old mangrove swamp, consisting mainly of *Avicennia africana* and some *Acrostichum aureum* is situated at the mouth of the Contonou Canal.

The benthic fauna of the two lakes is dominated by molluscs and crustaceans. Among the former *Arca senilis*, *Corbula trigona*, *Crassostrea gasar*, *Pahymelania* spp., and *Tympanotus* sp. are common, while among the latter *Callinectes latimanus*, *Cardiosoma armatum*, *Clibernhardius africanus*, *Goniopsys cruentata*, *Macrobrachium* sp., and *Penaeus duorarum* are most numerous. The fish fauna changes with the salinity, but the most numerous species appear to be little affected, and include *Ethmalosa fimbriata*, *Hemichromis fasciatus*, *Tilapia melanopleura* and *T. zillii*. The sensitive fishes retreat far into the delta during periods of high salinity in the lake, and prawns and large sea fish disappear from the lake if the mouth is closed for any length of time. Among reptiles snakes, turtles, terrapins, monitor lizards, crocodiles and agamids are found in the delta and lake fringes. The avifauna is rich with a typical spectrum of West African coastal wetland species. All the typical wetland mammals occur here including manatees.

Human Impact & Utilisation: Over 250 000 persons live in the vicinity of Cotonou and the density of the population around the lakes is great. The lakes are therefore fished intensely, with annual catches of 800-2000 tonnes, and the large populations of *Arca*, *Callinectes* and *Crassostrea* are also exploited. Many small fishing villages are set on piles on the lakeshore and it is estimated that no less than 25 000 persons are engaged in the fishing industry. Fish culture is carried out in the lakes and delta, involving 22 species, but the annual catch from the delta is not easy to determine. Liquid industrial wastes presently enter the two lakes untreated, and pollution is an evet increasing threat.

Conservation Status: Unprotected.

(E) MINOR LAKES & OTHER WETLANDS

General: Several small lakes occur on the coastal plain. The most important being Lake Tobaoji (6°44'N/1°42'E) of 600 ha and Lake Toho (6°37'N/1°48'E) of 2590 ha in the west, and Lake Sélé (7°09'N/2°27'E) of 300 ha and Lake Aziri (7°15'N/2°27'E) of 300 ha in the east. All are fringed by reeds but they are not described in the literature in any detail.

Some strips of inundated forest occur along the Ouémé River and its tributaries, and of these some occur in the Forestry Reserves of Ketou Forest, Dogo Forest and the Forest of Ouémé and Boukou, where the river traverses one boundary of each of the forests. All these reserves are situated on longitude 2°30'E, between 7°20' and 8°00'N.

2. Wetlands on the Niger River

Location: 11°40'-12°23'N/2°50'-3°37'E
Area: 44 000 ha floodplain
Altitude: 161-175 m asl
Nearest Towns: Malanville (on floodplain); Porto Novo (575 km S)

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General: The River Niger forms the Benin/Niger border for a distance of 120.6 km in the far northeast in the Soudanian vegetational zone. Here it has a broad and often braided course with the main channels reaching 1.5 km in width, and many islands, some of which in the vicinity of Malanville (11°50'N/3°23'E) measure 4x1.5 km. Over this 120 km stretch the river overflows its banks each year. The floodplain is widest in the south, around Malanville, where the flood extends 12 km away from the river on the Benin bank, but in the north it is reduced to about 3 km in width. There are numerous lagoons and ponds on the floodplain, some semi-permanent, others ephemeral. The floodplain is covered by typical floodplain grasses, with patches of levée forest and gallery forest along the river and on some of the islands. The lagoons carry typical aquatic vegetation.

Over this 120 km section the Niger receives four major tributaries, from north to south, the Mékrou, Kompa Gorau, Alibori and Sota Rivers. The Mékrou forms the northern boundary of the National Park du 'W' du Benin for 129 km. The entire Kompa Gorau system lies within this park, and the Alibori forms the southern park boundary for 78 km, but the park does not extend to the Niger. All the park rivers carry galleries of forest, some of which are flooded, but floodplains are either very narrow or non-existent, except immediately above the confluences with the Niger. The park itself contains vast areas of *Isoberlinia* woodland, but in this there are some isolated marshes, occupying waterlogged depressions.

Flora & Fauna: The vegetation of the wetlands is as described in the regional introduction, with floodplain grasses such as *Echinochloa pyramidalis* and *Oryza barthii*, and swampy gallery forests containing *Cola laurifolia*, *Khaya senegalensis*, *Kigelia aethiopum*, *Mitragyna stipulosa* and *Parkia* sp. Most of the large mammals found in the savanna country visit the floodplains at some time, but all the usual aquatic types, e.g. *Aonyx*, *Atilax*, *Crocodylus*, *Hippopotamus*, *Lutra*, *Pelomedusa*, *Pelusios*, *Trichechus* and *Varanus* are present. There is an important elephant population in the National Park but *Giraffa camelopardalis* and *Taurotragus derbianus* are absent from the park.

Hydrology: The flood is bi-modal, reaching a peak in August-September, from rains over the Atakora Massif and the northeast of Benin in July and August, and a subsequent peak which usually arrives in December-January from rains over the upstream catchments. The waters of the first flood are turbid and carry much suspended matter, while those of the second flood are clear, almost free of suspended matter, and stained black by humic residues. The floods vary in extent from year to year, and in high flood years parts of the floodplain may be inundated to depths of 2 m.

Human Impact & Utilisation: Population density in the region is low, but the floodplain is fished, using traditional methods, and cattle are moved in to graze it as the flood recedes. Parts of the fringes in the vicinities of settlements are cultivated each year, and there has been some small scale floating rice cultivation.

Conservation Status: No part of the Niger floodplain is protected, but considerable stretches of gallery forest, and many small dambo type marshes are protected in the National Park du 'W' du Benin.

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3. Wetlands on the Pendjari River System

Location: 10°55'-11°29'N/0°55'-1°57'E
Area: c. 85 000 ha (floodplain + permanent swamp)
Altitude: 125-200 m asl
Nearest Towns: Djougou (150 km S); Porto Novo (525 km SE)

General: The Pendjari River and its tributaries drain the Atakora Massif in NW Benin, which receives very heavy rainfall in June, July and August, leading to heavy flooding on almost all streams. Other tributaries of the Pendjari drain the Gobnangou Massif in Burkina Faso. Floodplain areas on the Pendjari include one of about 3000 ha (11°06'N/ 1°43'E) at the confluence of an un-named affluent. This is on the NE flowing section of the river, south of the Atakora Massif. Just before the river rounds the tip of the massif and begins to flow back towards the SW, there is another floodplain, some 20 km long with a mean width of 3 km, situated between the co-ordinates 11°16'-11°27'N/ 1°51'-1°57'E, and covering a further 6000 ha. Downstream, where the river meanders along the border with Burkina Faso for over 70 km, there is the so-called Mare aux Hippopotames (11°16'-11°32'N/ 1°16'-1°48'N), a floodplain of 28 000 ha with widths up to 5.5 km. A small floodplain occurs yet farther downstream on a bend of the river (11°16'N/1°06'E), and another where the river begins to meander again prior to entering Togo. Here its name changes to Oti River. This latter floodplain is the largest on the Pendjari River, but most of it is situated in Togo. The upper section in Benin is 30 km long and some 4-5 km wide, with a total area of 12 000 ha.

On the tributaries extensive floodplains occur on the Bori River (40 km long - 12 000 ha), the Yapili River (45 km long - 13 500 ha) and the Podiéga River (30 km long - 6000 ha) in Benin. In addition, numerous dambo areas and small valley head swamps occur in the Atakora Mountains.

Hydrology: The flood rises primarily as a response to rains in the Atakora Mountains, and generally peaks during September downstream. Maximum flood depths vary but may be as great as 4 m in some areas. Extensive lagoons, lakes, ponds and permanent reed swamps occur in the Mare aux Hippopotames.

Flora & Fauna: Typical floodplain grasses occur here, together with reed swamps, gallery and levée forest, as described in the regional introduction. Most of the West African savanna animals are found on these floodplains at some time of the year, and all the typical aquatic species are present. Among crocodiles, only *Crocodylus niloticus* has been identified. Turtles and terrapins, *Trionyx* and *Pelomedusa* are present, also *Varanus niloticus* and numerous snakes. The important plants and animals are listed by Sayer *et al.* (1979).

Human Impact & Utilisation: The area is sparsely populated and the wetlands outside the National Park and hunting zones are not heavily utilised. Fishing, cattle grazing and hunting occur on the floodplains, particularly along the Pendjari as it approaches the border with Togo.

Conservation Status: All the upper floodplains, including the Mare Aux Hippopotames, are included within the Pendjari National Park, as are the wetlands along the Podiéga River. The other wetlands downstream are unprotected.

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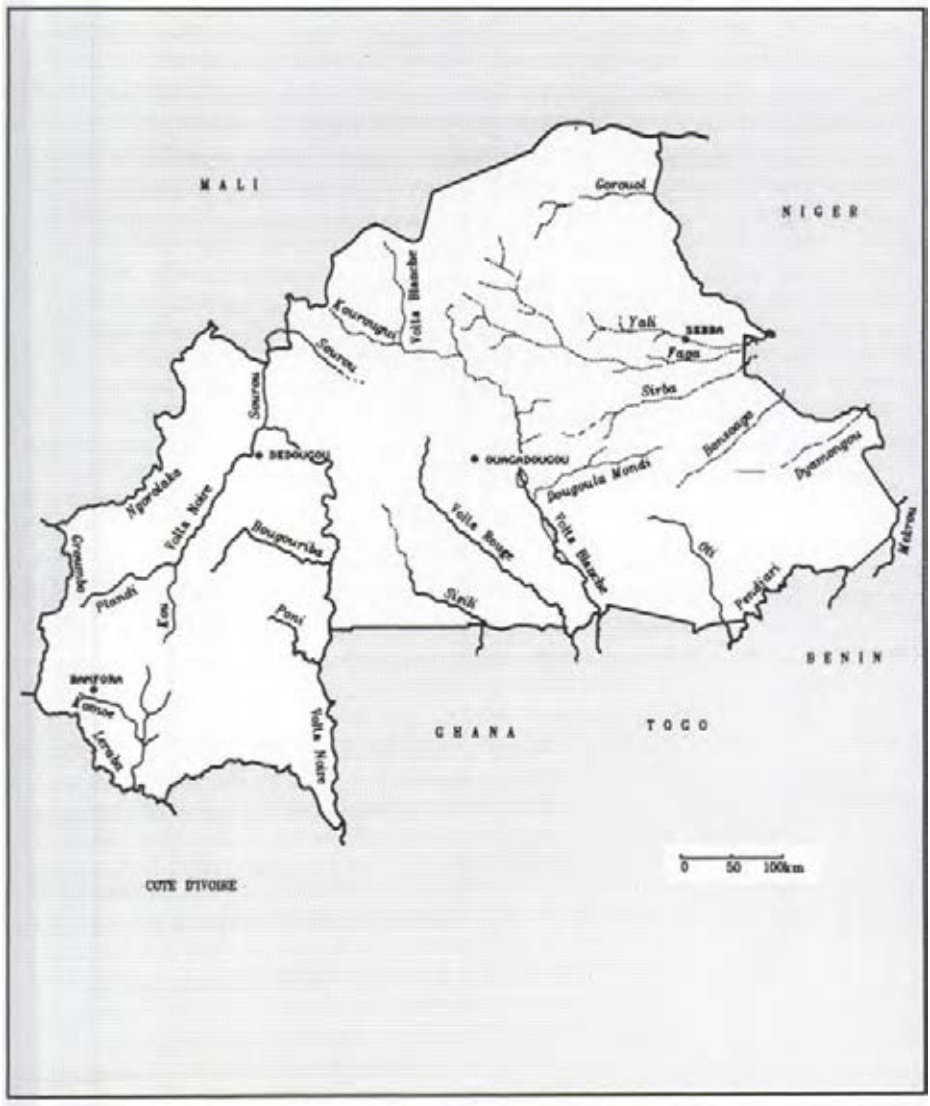

Map of Burkina Faso

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3.2 BURKINA FASO

Introduction

Burkina Faso has an area of 274 122 km^2, a population of 7 285 000, and a mean population density of 26.6 persons/km^2. The country is land-locked, being bounded by Benin, Togo, Ghana and Côte d'Ivoire in the south, Mali in the west and north, and Niger in the east. The country covers 5°41' of latitude from 9°24'-15°05'N and spans 7°51' of longitude from 2°22'E to 5°29'W.

Most of the country is occupied by a plateau, 200-500 m asl, with a general declination to the south. Lowlands, less than 200 m asl, penetrate Burkina Faso in the southwest as a narrow strip 225 km long in the valley of the Volta Noire River, and also in the central southern part of the country in the valleys of the Volta Rouge and Volta Blanche Rivers. The largest and lowest expanse of lowland however, is in the southeast along the valley of the Pendjari, while at the eastern extremity, another lowland tongue reaches into Burkina Faso along the valley of the Mékrou River. There are three highland blocks, which rise above 500 m. One, the Plateau of Tagouara, is in the southwest, where the highest point in Burkina Faso (749 m) is reached (10°46'N/5°25'W) close to the border with Mali. The other highland blocks are in the centre of the country to northwest and northeast of Ouagadougou (12°20'N/1°40'W).

Drainage is by a number of river systems. The Komoé River and its tributaries drain the southeastern slopes of the Tagouara Plateau, while the western slopes drain to the inland delta of the Niger River in Mali via affluents of the Bani River. The northwestern slopes of the Tagouara Plateau drain to the Volta Noire which also receives drainage from Mali in the north via the Sourou River. The central highland blocks drain west to the Volta Noire, or to the Volta Rouge which bisects them, or east to the Volta Blanche. A watershed lies to the east of this last river, oriented NNW-SSE. From this, short and comparatively steep streams flow west to the Volta Blanche, while long rivers, with a very gentle slope flow east to the Niger, but towards the southern end of this humpback, several streams flow southeast to the Pendjari.

Climate

Burkina Faso is a comparatively dry country, with mean annual rainfall decreasing from about 1100 mm in the south to 500 mm in the north, and the dry season increasing in length from 6-7 months in this direction. The wettest part is the Tagouara Plateau in the southwest where falls may exceed 1250 mm/yr. The city of Bobo-Dioulasso (11°11'N/4°18'W), at the interior end of the plateau, has a mean annual rainfall close to 1100 mm which falls over 88 days each year, and the dry season lasts 6 months from November-April. Farther north, in the centre, Ouagadougou (12°20'N/1°40'W) receives an average of 864 mm/yr over 70 rainy days, with 7 dry months, October-April. In the northeast, Dori (14°03'N/0°02'W) receives 520 mm/yr over 50 rainy days and has 7 dry months. The southeast receives significantly less rain than the southwest, although the rainy season is just as long. However, the average number of rainy days is less than 80 and mean annual falls are in the vicinity of 900 mm.

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The mean temperature of the coolest month at Bobo-Dioulasso is 24°C and that of the warmest month 30°C. Corresponding figures for the other centres mentioned are Ouagadougou, 26°C and 32°C; Dori, 24°C and 33°C. The warm rainy season lasts from June until September, with a cool dry season from early October until mid February. It is then hot and dry until June when the rains begin. Temperatures may fall as low as 10°C at night over almost any part of the country in the cool dry season, and frequently exceed 40°C during the day during the hot dry season.

Vegetation

Soudanian savanna predominates in the south, with extensive *Isoberlinia* woodlands, while the perennial rivers carry well developed gallery forests. The northern half of the country is however, less well wooded, and the vegetation grades into thorn-bush savanna in the Sahelian zone.

Wetlands

The principal wetlands of Burkina Faso are riverine floodplains, inundated seasonally. No floodplain is very large by comparison with those of neighbouring countries, but most rivers have them. Many intermittent streams have moist sandy beds during the dry season and often retain open water in pools. There are permanent lakes and ponds on some of the larger floodplains, a few small lakes away from the rivers, and a great many small impoundments. Generally the floodplain lakes are swamp fringed, and all watercourses carry galleries of forest or woodland. The open water surfaces are very important to wildlife.

List of Wetlands Described

1. Riverine Wetlands
   - (a) Floodplains of the Komoé River System
   - (b) Floodplains of the Niger River System
   - (c) Wetlands of the Volta River System
   - (d) Wetlands of the Pendjari Drainage Basin
2. Natural Lakes
3. Artificial Impoundments.

1. Riverine Wetlands

(A) FLOODPLAINS OF THE KOMOE RIVER SYSTEM

General The Komoé River has sources in Burkina Faso on the Banfora Plateau in the extreme southwest. Floodplains occur on four headwater tributaries west of the town of Banfora (10°38'N/4°46'W). These are the Komoé at Banfora, where a floodplain 1-1.5 km wide stretches 26 km along the river on either side of the town between 10°30' and 10°40'N and comprises 3350 ha of wetland. West of here a floodplain occurs on the Mou River (10°37'N/4°55'W), 14 km long and up to 1.5 km wide, with 1500 ha of

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floodplain. Farther west still there were small floodplains on the Léraba Orientale (10°36'N/5°05'W) and Léraba Occidentale (10°33'N/5°22'W) Rivers, both affluents of the Komoé, but these have recently been converted for rice cultivation in their entirety.

Human Impact & Utilisation: About 50% of the total wetland area on this river system in Burkina Faso has been utilised for growing rice. The remaining area is exploited locally, for the recession cultivation and the grazing of cattle. The rivers are fished.

Conservation Status: Unprotected.

(B) FLOODPLAINS OF THE NIGER RIVER SYSTEM

General: In the southwest of Burkina Faso a number of rivers drain westwards to the Bani River which enters the internal delta of the Niger. Some of these rivers carry floodplains in Burkina Faso. Floodplains occur on the Longo River and its affluent the Sélédogo, in an area (11°30'-11°37'N/4°50'-5°10'W). There is 55 km of floodplain, locally 5 km wide, covering 14 000 ha. Another floodplain occurs on the Groumbo River, for 30 km along the border with Mali (11°32'-11°40'N/5°15'W), with some 2800 ha of inundated land in Burkina Faso. The Groumbo joins the Longo, which then flows into the Ngorolaka River. This latter stream is an affluent of the Bani River. Above its confluence with the Longo, it also forms the border between Burkina Faso and Mali for an 80 km stretch running SW-NE (11°50'-12°13'N/4°35'-5°24'W). Over this distance it carries a floodplain reaching 3.5 km in width covering some 8000 ha in Burkina Faso.

In the east of Burkina Faso other rivers flow to the middle Niger, in Niger, and many of these, although intermittent streams, have floodplains. In the northeast the Gorouol River is intermittent, flowing due east at 14°23'N, but both it and its tributaries lie in humid beds with narrow floodplains in the rainy season, and a string of waterholes in the dry season. South of this there are extensive, but narrow floodplains along the Sirba River and its tributaries, particularly the Yali River. There is a barrage on the Yali below Sebba (13°27'N/0°31'E). A discontinuous floodplain, up to 1 km wide, occurs along the Sirba for over 230 km above its confluence with the Niger, providing something like 14 000 ha of seasonal wetland in Burkina Faso. All these rivers carry galleries of forest.

Yet farther south floodplains occur on the Boapendi, Bonsoaga, Dyamongou and Tapoa Rivers. All are intermittent rivers and all carry gallery woodlands. At the extreme eastern point of Burkina Faso, the Mékrou River flows east to the Niger and has a swampy and seasonally flooded headwater valley.

Human Impact & Utilisation: Rice is grown in these wetlands, but as yet not intensively. Fishing and cattle grazing are locally important, together with the small scale recession cultivation of assorted crops.

Conservation Status: Unprotected.

(C) WETLANDS OF THE VOLTA RIVER SYSTEM

General: The Volta Noire rises in the far west of Burkina Faso (11°12'N/5°17'W) close to the border with Mali near the town of Sintasso. The river is at first called the Plandi and it flows northeastwards, first developing a floodplain (11°19'-11°25'N/4°43'-4°48'W) near Koutséni. Here, up to 2400 ha can be flooded each year in a strip 12 km long. The river then meanders, still northeastwards, to a confluence with the Kou (or Baoulé) River,

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after which it is known as the Volta Noire. It continues northeastwards with a floodplain which begins just above this confluence, past Dédougou (12°29'N/3°28'W), for 187 km to a confluence with the Sourou River (12°29'N/3°28'W) which flows due south from Mali. The floodplain reaches widths of 10 km, e.g. at Bossora (11°43'N/4°06'W), and covers more than 50 000 ha (11°26'-12°45'N/3°28'-4°25'W). In its upper section, just after the confluence of the Plandi and Kou Rivers, there is a permanently swampy region with numerous ponds and a lake known as the Mare aux Hippopotames. The lake and ponds are separate from the river but in continuity with it during floods. Floodplains also occur on streams flowing southeastwards from the highlands along the Mali/Burkina Faso border to join the west bank of the Volta Noire in this sector. The tributaries concerned are the Kilé, Débére, Laye, Baflabé and Manmba Rivers and are to be found in the area 12°00'-13°00'N/4°00'-5°00'W.

There is a floodplain 28 km long on the upper Sourou River, reaching 4 km in width, with herb swamps and many permanent pools. This is situated from 13°00'-13°15'N on a longitude of 3°27'W. It comprises some 9600 ha of wetland and peters out 4 km above the confluence of the Sourou and Volta Noire Rivers. From the junction with the Sourou, the Volta Noire bends sharply round to flow southeastwards to the border with Ghana. In this last sector of 200 km the river meanders so that its course is 338 km long, but only locally, and then narrowly, does it overflow its banks.

The Volta Blanche rises (14°03'N/2°03'W) in the north of Burkina Faso, close to the border with Mali. It is an intermittent stream in its upper course and flows due south for 125 km through hilly country, and then, at a confluence with the Kourougui River, another intermittent stream, it flows east for a further 125 km. Here, hard under the hills at Kaya (13°05'N/1°06'W), it swings southeastwards for 200 km. Midway down this sector it receives the waters of the Massili River on its west bank. The banks of the Massili are liable to inundation from 12°44'N/1°45'W to its confluence with the Volta Blanche at 12°16'N/1°05'W. In this sector also, the Volta Blanche receives numerous tributaries from the hills to the east and becomes perennial in a permanently swampy area (11°58'N/0°54'W) at an altitude of 230 m asl.

The river continues to flow southeastwards until it crosses the border into Ghana, and swamps and floodplain areas become more prominent along its course and those of several affluents. A discontinuous floodplain occurs downstream for 45 km to the confluence of the Dougoula Mondi River, which drains the highlands to the east. This latter stream descends a valley to the Volta Blanche, into which a dozen small affluents flow, all having swampy floodplains on their banks, providing some 7000 ha of wetland. To the south and in parallel with the Dougoula Mondi, several small streams have floodplains above confluences with the Volta Blanche e.g. (11°43'-11°48'N/0°28'-0°38'W), (11°34'N/0°14'-0°20'W) and (11°28'N/0°28'W), and there is another floodplain on the Volta Blanche (11°29'-11°34'N/0°34'-0°46'W). East of this another floodplain (5700 ha) is situated in the hills on the Nouhao River (11°29'-11°43'N/0°02'-0°13'W) which joins the Volta Blanche on the southern border of Burkina Faso.

The Volta Rouge rises in central Burkina Faso (12°40'N/1°55'W) and flows southeastwards in parallel with the Volta Blanche. It carries no important wetlands until just above the border with Ghana, where floodplains totalling 7650 ha occur on four intermittent tributaries in the area (11°03'-11°17'N/0°41'-0°58'W)

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Human Impact & Utilisation: Some rice is grown on the floodplains of the Kou and Volta Noire Rivers. In general the floodplains are fished, grazed by domestic cattle and utilised for small scale recession agriculture. Apart from these traditional activities they are as yet little disturbed.

Conservation Status: The Volta Noire flows along the eastern boundary of the Deux Bales Classified Forest (approximately 11°30'-11°50'N/2°11'-3°10'W), and over a stretch of some 100 km, the gallery forest along its banks is protected. *Crocodylus niloticus*, *Loxodonta africana*, *Hippopotamus amphibius* and *Syncerus caffer* are found in the reserve. Farther downstream the river forms the eastern boundary of the Bontioli Partial Faunal Reserve, and here again small numbers of big game animals are encountered.

The Volta Rouge flows through the middle of the Pô National Park (approximately 11°10'-11°50'N/0°50'-1°50'W) which covers 149 400 ha and extends along the river for over 100 km, but apart from the river channel itself, little wetland is conserved here. There are narrow floodplains in places and the park itself is largely covered by alluvium deposited in more pluvial times. During the dry season the river contracts in its bed and is reduced to a trickle with many pools. *Cephalophus rufilatus*, *Kobus ellipsiprymnus*, *Loxodonta africana*, *Phacochoerus aethiopicus*, *Redunca redunca*, *Sylvicapra grimmia*, *Syncerus caffer* and *Tragelaphus scriptus* are protected here.

The course of the Volta Blanche is entirely unprotected.

(D) WETLANDS OF THE PENDJARI DRAINAGE BASIN

General: The Pendjari River rises in Benin and meanders southwestwards along the Benin/Burkina Faso border to the point where Benin, Togo and Burkina Faso meet. Several rivers tributary to the Pendjari flow southeastwards out of the hills of SE Burkina Faso to join the Pendjari and many of these carry wetlands. In the east there are three small floodplains, of 3000 ha (11°37'N/1°50'E), 1500 ha (11°38'N/1°58'E) and 750 ha (11°29'N/1°53'E) on the Kouriagou River and its affluents, above the confluence of this stream and the Pendjari. To the west there are 6000 ha of seasonally inundated land on the Arli River and its affluents (11°40'-11°50'N/1°30'-1°42'E) and a further 16 500 ha on the Doubodo River and its affluents. On this latter system the floodplains accompany 102 km of river channel (11°40'-12°00'N/1°01'-1°23'E). The Doubodo and Arli merge and discharge into a system of floodplains, lakes and permanent swamps which extend along the border on the Pendjari for 80 km (1°18'-1°50'E) in a second Mare aux Hippopotames. Much of this swamp is in Benin, but there are some 7000 ha in Burkina Faso.

To the west of the Mare aux Hippopotames, there is an extensive lake, swamp and floodplain system on the Singou River and its affluents. Coming downstream there is a floodplain along 70 km of the Singou and its headwater tributaries covering 12 000 ha (11°25'-11°46'N/0°39'-0°56'E). To the west, on the Kogotiari River, a tributary of the Singou, a permanent swamp system with a chain of central lakes, known as the Mare de Bopieni, is fringed by a narrow floodplain and occupies 13 500 ha. This wetland extends for 60 km along the Kogotiari and up some of its minor affluents. The Kogotiari joins the Singou in another lake/swamp system known as the Mare de Tinouri (11°17'-11°24'N/0°52'-1°03'E). Here there are about 3000 ha of wetland, and downstream a narrow floodplain accompanies the Singou for 24 km to its confluence with the Pendjari, providing another 2300 ha of wetland.

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Farther west there are small areas of floodplain and swamp on the Pendjari, which extend into Burkina Faso, and an extensive floodplain on the Oualé River. On this system the floodplain (11°03'-11°30'N/0°22'-0°45'E) extends for 65 km, attains widths of 5 km, and provides a wetland area of 16 500 ha. Farther north, on headwater tributaries of this river there are two other floodplains. One covers 2400 ha (11°52'N/0°27'E) on the Otabango River, and the other covers 5000 ha (11°50'N/0°07'E) on the Koul Péolgo River.

Human Impact & Utilisation: Traditional uses predominate. The wetlands are not as yet seriously disturbed, although large mammals have been intensively hunted in most areas.

Conservation Status: The faunal reserves of Arly, Singou, Pama and Kourtiagou are situated in the Burkina Faso part of the Pendjari catchment, but they protect little wetland. The Arly Reserve has frontage along the Pendjari River and protects some of the large gallery forests which are liable to flooding. The Singou Reserve has a northern boundary on the seasonally flooded banks of the Tonouarbougou River, while the SW boundary is on the Singou River which floods 1-2 km into the reserve. The Singou River also forms the boundary of the Pama Reserve to the west. Several seasonally flooded tributaries of the Singou flow through this reserve, but notably the Bigou River.

Hunting is permitted in many of the reserves, but poaching and the illicit extraction of timber is a problem in all of them.

2. Natural Lakes

General: There are four small natural lakes in Burkina Faso. Lake Tengréla (10°39'N/4°51'W) is situated in the southwest, just west of Banfora, at an altitude close to 290 m asl. It is 2 km long and 1.5 km wide.

Lakes Bam (13°22'N/1°30'W) and Dem (13°11'N/1°09'W) are both situated in northern Burkina Faso in the headwater catchments of the Volta Blanche River to which they drain. Lake Dem measures some 5 km x 2 km and has a capacity of 4 million m^3, while Lake Bam is nothing more than a widening of the channel of one of the affluents, some 12 km long and 0.5 km wide. However, it qualifies for description as a lake since the river which both feeds and drains it, is intermittent, and dries up completely for at least 6 months each year. While the river is dry, the lake persists, with a storage capacity of 31 million m^3.

The Mare d'Oursi is a small, reed fringed, shallow lake covering 160 320 ha (14°38'N/0°30'W). It is fed by an intermittent stream and may have an effluent stream after heavy rain; its surface shrinks between rains, but it is a permanent lake.

Lake Hina (13°38'N/0°43'E) has a surface area of 288 ha and is surrounded by permanent swamps. It is fed by a small stream and drains to a wooded tributary of the Babangou River and thence to the Niger.

Human Impact & Utilisation: Water from Lake Bam is used for small scale irrigation purposes, for domestic consumption and to water domestic cattle. The lake is also fished. Water from Lake Dem is used for domestic consumption. Water from the Mare d'Oursi is also used for domestic purposes and by wildlife. Tengréla lake is fished, but on a very small scale.

Conservation Status: Unprotected.

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3. Artificial Impoundments

General: There is a reservoir 90 km northeast of Djibo (14°09'N/1°38'W) in the far north of Burkina Faso, storing 2.2 million m^3 of water. To the south a barrage on an intermittent headwater tributary of the Volta Blanche near Ouahigouya (13°35'N/2°23'W) in north Burkina Faso stores another 2 million m^3 of water. These impoundments principally supply water for domestic use. To the east of this there are two barrages on ephemeral affluents of the Sirba River, itself an intermittent tributary of the middle Niger River. The Tougouri Barrage (approximately 13°19'N/0°32'W) stores 6 million m^3 of water and the Yalogo Barrage (approximately 13°25'N/0°55'E) stores 10 million m^3. Both these latter impoundments supply fish as well as water for agriculture and domestic use. In addition there are over 300 small farm and community dams.

Hydroelectric projects are planned on the Kompienga River in the east, and at Bagro on the Volta Blanche.

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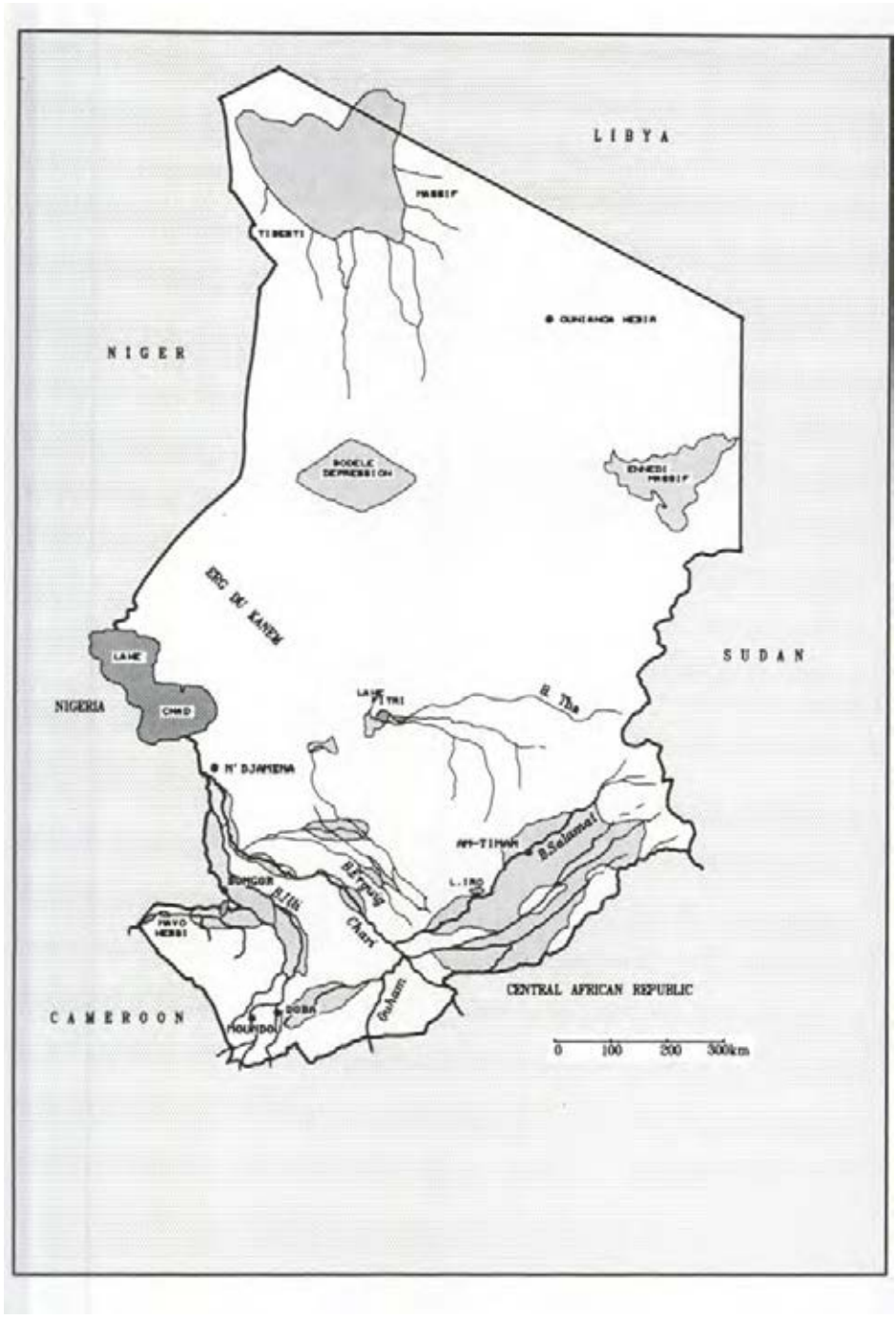

Map of Chad

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3.3 CHAD

Introduction

Chad is a landlocked country in the centre of North Africa being bounded by the The Central African Republic in the south, by Cameroon, Nigeria and Niger in the west, by Libya in the north, and by Sudan in the east. It is the largest and least densely populated country in region 3. It has an area of 1 284 000 km^2, a population of 4 970 000 (1983) and a mean population density of only 3.8 persons/km^2. It stretches some 1750 km from north to south between latitudes 23°30' and 7°33'N, and 1250 km from east to west between longitudes 13°33' and 25°00'E.

Over 90% of the country drains to Lake Chad on the central western border. Only two small areas drain to other countries. Part of the Mayo Kebbi district in the extreme southwest drains to the Benue River in Cameroon and thence to the Niger River, and the northern section of the Tibesti Massif drains to Libya and Niger. Chad forms the eastern side of the huge endorheic basin in which Lake Chad occupies one of the lowest, but not the lowest, points. Most of the country is a sandy plain, 300-500 m asl, sloping down to lake Chad at an altitude of 280 m asl, but the great diamond shaped depression of Bodélé comprising 35 000 km^2 of land, 155-180 m asl (16°05'-17°38'N/15°50'-18°50'E), lies to the north of Lake Chad. Lake Chad is prevented from draining northeastwards into this depression by the dune barrage of the Erg du Kanem.

Highlands rise to 1163 m asl in the Monts de Lam in Logone Orientale Province in the far south, and the entire eastern part of the country along the border with Sudan is a high plateau rising above 500 m asl. There are peaks of 1320 m asl (14°22'N/21°37'E) and 1450 m asl (17°41'N/22°15'E) in the Ouaddai and Ennedi Massifs respectively. Other high points are 1506 m asl (12°07'N/18°56'E) and 1613 m asl (11°55'N/18°12'E) in the Guera Massif in the central south, but the highest land is in the Tibesti Massif in the far north of the country, where several peaks exceed 3000 m asl. Here Emi Kousi (19°53'N/18°34'E), at the southern end of the range, is the highest point in both Chad and the Sahara, reaching 3415 m asl.

The Tibesti Massif is triangular in plan, with sides approaching 400 km in length. It comprises about 50 000 km^2 of land with an average height in excess of 2000 m asl. At least 60% of its total area is situated above the 1500 m contour. The basement is Precambrian, overlaid with Palaeozoic sandstones, all capped by Tertiary and Pleistocene outpourings of basalt. Residual volcanic activity is still evident in numerous fumaroles, solfatari, mud pools and hot springs. There are a dozen or so hot springs in the Soborom district of the central Tibesti, where waters issue from the ground with temperatures between 22 and 88°C. Other warm springs (37°C) are situated on the eastern flank of Emi Koussi at an altitude of 850 m asl.

The Tibesti Mountains, which receive very little rainfall indeed, drain in radial fashion by numerous intermittent watercourses which simply peter out in the surrounding desert. The waters draining from the massif do not spread away from the watercourses, and the water they carry is entirely lost by evaporation or infiltration to the soil, but the latter may be carried great distances by subterranean aquifers. Five major watercourses run northwards into Libya, the largest being the Bardagé Stream. A tributary of this stream

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flowed at a rate of 425 m^3/sec in 1954, but in the subsequent 9 years, was entirely dry for 4 years, had one short flow each year for 4 years (peaking at 5 m^3/sec), and in the ninth year had three flows peaking at 4, 9 and 32 m^3/sec.

The Tibesti Massif is roughly bisected along a N-S line by the great valleys of two fossil rivers or enneri. The Enneri Yébigé, which drains to the north and peters out in a fossil floodplain on the plateau of Sarir Tibesti, and the Enneri Tousoul which drains south. The sources of the two streams are separated by the 1800 m high watershed stretching between the peaks of Tarso Tiéroko in the west and Tarso Mohi in the east. The Enneri Tousoul joins the Enneri Ké and on some maps these are then shown as the Enneri Miski, which disappears in the Borkou plains.

The Ennedi Massif and the northern part of the Ouaddi Massif are also drained by a dendritic system of intermittent streams, and these too, peter out in central Chad. However, the Ouaddi south of the 14th parallel, receives over 400 mm rain/yr, and from here, and from the Guera Massif, streams discharge to the Ba Tha which empties into the seasonal wetlands around Lake Fitri, from where, in a wet year, water may travel via the Ba Tha de Leiri to the Bahr Erguig and thence to the Chari River and Lake Chad.

The Bahr el Ghazal is an intermittent watercourse running southwestwards across central Chad to the southeastern extremity of Lake Chad. The principal river system feeding this lake however is the Chari/Logone system. The Logone rises in Cameroon and flows NNE along the Chad/Cameroon border to the lake, receiving as its major affluent, the Chari River at N'Djamena (12°07'N/15°04'E). The Chari drains the northern part of the The Central African Republic and part of southwestern Sudan, being formed by the amalgamation of the Bahr Aouk, Bahr Keita, Bahr Salamat and Bahr Sara Rivers.

Climate

The hot dry dusty Harmattan wind blows across Chad from the east or northeast throughout the year. In November the inter-tropical convergence zone is situated at a latitude close to 4°N, but from this time until August it moves steadily northwards over Chad, with humid monsoonal air penetrating under the Harmattan and bringing rain. The monsoon front usually reaches 20°N and the Tibesti Mountains, but in some years may retreat southwards before it has reached this latitude.

It is warmest in the south of Chad in April. The mean minima and maxima at Moundou (8°35'N/16°01'E) are 14.9°C and 34.0°C in January; 22.3° and 37.3°C in April; and 21.2° and 29.6°C in August. Comparable figures for Fianga (9°57'N/15°09'E) are 14.1° and 34.4°C in January; 24.8° and 38.7°C in April; and 22° and 30°C in August. At Bol (13°27'N/14°40'E) on the eastern shore of Lake Chad they are 13.8° and 31.1°C in January; 24.1° and 38.6°C in April; and 24.2° and 34.1°C in August. By contrast, in the far north, August is the warmest month. The mean minima and maxima at Bardai (21°21'N/16°56'E) are 4.6° and 23.7°C for January; 14.4° and 34°C for April; and 19.4° and 36.7°C in August. Low temperatures of -10°C are not uncommon in the Tibesti, and readings of -5°C have been made on the Ennedi Massif. By contrast 50°C has also been recorded on the Ennedi. There is often a dust haze over the country in winter.

Precipitation decreases in passing north over the country. It exceeds 1100 mm along the southern border, being 1150 mm at Moundou and 1188 mm at Sarh (9°08'N/18°22'W).

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Both these places enjoy falls in excess of 300 mm in August, the wettest month, while the December-February period is rainless, and March and November are virtually rainless. A little farther north and east, Am Timan (10°59'N/20°18'E) still receives over 300 mm of rain in August, but has a mean annual total of only 902 mm. N'Djamena, on the Chari floodplain receives 582 mm/yr, with 240 mm in August and 6 rainless months, while Abéché (13°49'N/20°49'E) receives 433 mm/yr, with 200 mm in August and 7 rainless months. At Faya-Largeau (17°58'N/19°06'E) in the central north, mean annual precipitation is 43 mm, with 20 mm in August, but reliable rainfall is not experienced north of the 16th parallel of latitude.

Bardai (21°05'N/17°00'E) at 1020 m on the northern flank of the Tibesti Massif recorded a mean annual rainfall of 12 mm for the eleven years 1957-1968. However, during this period some years were completely rainless while in others over 60 mm were recorded. Precipitation is often due to storms, but these are not connected with the SW Monsoon which does not penetrate this far north, rather they occur following the development of Sahara-Soudanian depressions. Precipitation is greater at higher altitudes, e.g. at 2250 m at Trou-au-Natron (21°10'N/16°06'E), the mean annual receipt is 126 mm, and Emi Koussi probably receives even more than this, and snow is not an unusual phenomenon on the high peaks.

Vegetation

A mosaic of open forest and woody savanna covers the southern part of the country, extending 100 km north of Moundou and 50 km north of Sarh, while a pure wooded savanna belt reaches northeast of Am Timan. Here in the south, leguminous and combretaceous trees are dominant. North of this, shrubby savanna covers the rest of the southern third of the country, except for the great wetland areas. Thin *Acacia* savannas cover the Ouaddi Massif, but much of the Ennedi Massif is a barren desert. However, the deep gorges which traverse it carry intermittent rivers lined by gallery forest with fringes of *Acacia* woodland. Xerophytic scrubland fringes the central western dune area, while on the northern side of this there are Sahelian steppes which finally peter out in true desert in the north. Other wooded vegetation occurs in some of the gorges in the Tibesti.

Wetlands

Despite the facts that Chad includes part of the Sahara and that its northern two thirds are extremely arid, with little reliable rainfall, it has a greater area of seasonal wetland than any other country in the region. No less then 10 150 000 ha are subject to regular inundation, excluding land along the eastern shore of Lake Chad. There are several permanent lakes, in addition to Lake Chad, but no important artificial impoundments.

List of Wetlands Described

1. The Bahr Aouk & Bahr Salamat Floodplains
2. The Chari River Floodplain
3. The Logone Floodplain

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4. Wetlands of the Mayo Kebbi System
5. Natural Lakes
   (a) Lake Chad
   (b) Djikaré, Moilo & Rombou Lakes
   (c) The Ounianga Lakes
   (d) Rock Pools of the Ennedi Massif
   (e) Lake Fitri
   (f) Lake Iro
   (g) Lake Fianga
   (h) Lake Tikem
   (i) Lake N'Gara
   (j) The Léré Lakes
6. Wadis & Oases of the Tibesti Massif
   (a) The Mare de Zoui
   (b) The Oases of Borkou District
   (c) Other Oases

1. The Bahr Aouk & Bahr Salamat Floodplains

General: There are approximately 4 995 000 ha of seasonally inundated land in the southeastern corner of Chad, flooded each year by waters derived from southern Sudan and the northeastern parts of the The Central African Republic, as well as from local rainfall. Direct precipitation over the floodplains varies from 1150 mm in the south to 800 mm north of Am Timan.

The Bahr Aouk flows southwestwards along the southern border of Chad all the way from Sudan in the east to the confluence with the Chari in the centre. A floodplain stretches north from the north bank of this river to the northern side of the Bahr Azrak, 228 km distant, and this includes the courses of several rivers, notably the Bahr Keita and Bahr Salamat which flow in parallel with the Bahr Aouk to join the Chari. During the dry season important ponds are left in the channels of some of the intermittent streams, e.g. the Bahr Keita.

Hydrology: The flood begins to rise in all these streams in late August and peaks at the end of October. It declines rapidly in late November, and low water levels then persist from February to July. The Bahr Aouk does not carry a lot of water. Its mean year round discharge rate is 90 m^3/sec, with a peak flow of 1200 m^3/sec in October. The Bahr Keita carries more water at high flood, with flow rates approaching 1500 m^3/sec in October. Farther north the Bahr Salamat, which has formed from the Bahr Azoum and Bahr Azrak, carries even more water. However, the Bahr Keita, Bahr Azoum and Bahr Azrak are all intermittent, as are all the minor affluents of the system. Only the Bahr Azouk, Bahr Salamat and Chari are perennial streams. Annual variations in peak flow are very great, as are the areas flooded. In a wet year the floods may last for 3-4 months.

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Flora & Fauna: Typical floodplain grasses dominate the seasonally inundated land including species of *Andropogon*, *Cymbopogon* and *Hyparrhenia* on the fringes and *Echinochloa pyramidalis*, *E. stagnina* and *Oryza barthii* in deep water. *Acacia albida*, *A. scorpioides* and *A. sieberana* are common on levées and the floodplain margins.

Human Impact & Utilisation: The rivers and their associated floodplains are fished quite intensively. The total catch from the system amounts to some 15 000 tonnes/yr. During the 1960s, the catch on the Bahr Salamat/Lake Iro system yielded 6000 tonnes/yr, while that on the Bahr Keita yielded 4000 tonnes/yr and that on the Bahr Aouk, just over 3000 tonnes/yr.

It is estimated that the number of cattle in the southern Ouaddi exceeds 700 000, and that in addition there are over 400 000 sheep and goats. Many of these animals are brought onto the floodplains to graze in the wake of the flood, and recession agriculture is widespread.

Conservation Status: The Zakouma National Park and the Bahr Salamat Faunal Reserve which encloses it are situated in the seasonally inundated area, and in total protect more than 2 000 000 ha including Lake Iro. Animals ostensibly protected here include *Cephalophus* spp., *Cercapithecus aethiops*, *Crocodylus niloticus*, *Kobus ellipsiprymnus*, *Leptailurus serval*, *Panthera pardus*, *Phacochoerus aethiopicus*, *Sylvicapra grimmia*, *Syncerus caffer* and *Tragelaphus scriptus*. The avifauna includes species such as *Balearica povonina*, *Egretta* spp., *Leptoptilos crumeniferus* and *Pelecanus onocrotalus*. Fishing is permitted in the reserve, but poaching is a serious problem.

2. The Chari River Floodplain

General: The Chari River has several sources in the northern highlands of the The Central African Republic, and derives principally from the waters of the Gribingui, Bamingui and Bangoran Rivers. It flows northwards into Chad receiving the waters of the Bahr Aouk and Bahr Keita above Sarh (Fort Archambault) and those of a major tributary, the Bahr Sara (Ouham River) just downstream from this place. The Bahr Sara also has several sources in the north of the The Central African Republic and carries more water than the Chari at the confluence. Some 30 km below the confluence the Chari receives the Bahr Salamat on its east bank and then, a few kilometres farther downstream, the Batha de Lieri. This is an intermittent stream which drains the dry interior. Its course is parallel with that of the Chari for 200 km, just 5-10 km east of the Chari, but its direction of flow is opposite to that of the Chari. The Chari thereafter continues northwest towards Bousso (10°32'N/16°45'E), but some 80 km above this place it bifurcates, giving rise to an eastern branch known as the Bahr Erguig. Just below Bousso the main channel of the Chari receives the Ba Illi on the west bank. It then continues, with peak flows of 4000-5000 m^3/sec, to its confluence with the Logone at N'Djamena and thereafter discharges into Lake Chad with peak flows of up to 6000 m^3/sec.

Narrow floodplains occur on the Bahr Sara in Chad, but a major floodplain does not develop until just above the bifurcation which gives rise to the Bahr Erguig on the east bank. The floodplain is then 470 km long, reaching northwestwards along the Bahr Erguig and then across intervening lands to N'Djamena. It varies in width from 40 - 165 km and covers some 1 557 500 ha. Another floodplain on the Ba Illi covers about

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220 000 ha. It begins on one of the two intermittent headwater affluents of the Ba Illi, the Nam River, about 30 km above the point where the Nam and Dimlik Rivers meet to form the Ba Illi. From here it extends downstream for 130 km to the confluence of the Ba Illi and Chari, and has a maximum width of 35 km.

Yet another floodplain and permanent swamp complex occurs on the Batha de Lieri system which provides a further 1 137 500 ha of wetland. This includes floodplain and swamp land around Lake Fitri (12°16'-13°05'N/16°27'-17°59'E), and another floodplain immediately to the east of the Guera Massif (11°33'-12°08'N/17°21'-18°00'E).

Hydrology: Just above its confluence with the Chari, the Bahr Sara has peak flows in excess of 2300 m^3/sec, and flows in excess of 2000 m^3/sec may be maintained from late August until late November. However, dry season (January-June) flows are in the order of 150 m^3/sec. The peak flows in the Chari above the confluence are rather less than these and the annual volumes carried by the two streams are very different. Measured above the confluence, the Chari carries some 9.7 billion m^3/yr, while the Bahr Sara carries 16.8 billion m^3/yr. Thus below the confluence the Chari carries 26.5 billion m^3/yr. Much of this is dissipated over the floodplains where high water is generally 1-1.5 m deep, although in depressions it may reach 3 m. Direct precipitation makes a substantial contribution to the flood, soaking the surface soil so that river water is not quickly lost by infiltration. Thus at N'Djamena, above the confluence with the Logone, the Chari still carries 26.1 billion m^3/yr. Having received the contribution of the Logone, the mean annual flow of the Chari below N'Djamena is 38.7 billion m^3, the mean contribution of the Logone being 12.6 billion m^3/yr. At N'Djamena an absolute maximum rise in the river level, exceeding 7 m, was recorded in 1964, but the mean annual rise at this point is 5.3 m. Flow in the river below N'Djamena usually peaks in early November, with a mean maximum rate of 4450 m^3/sec, while a rate of more than 4000 m^3/sec is usually maintained throughout October and November. The flood subsides dramatically in late December and a mean minimum flow of 200 m^3/yr is attained at the beginning of May. In the south the flood is maximal between late August and mid-October, and water remains high until the end of November, but the flood is later at N'Djamena, where high water is attained in late September and persists until midDecember.

Flora & Fauna: The flora and fauna of the floodplains is as described in the regional introduction for Soudanian and Sahelian regions. The upper reaches of the river and its southern affluents flow through densely wooded Soudanian/Guineo-Congolan savanna with *Isoberlinia* and *Monotes* spp., and species such as *Berlinia grandiflora*, *Cola laurifolia*, *Cynometra vogelii*, *Diospyros elliotii* and *Parinari congensis* in swampy spots along the river. The typical spectrum of gallery forest animals is associated with these. In the northern reaches the galleries are replaced by lower levée woodlands with species such as *Acacia albida*, *A. nilotica*, *A. seyal*, *Balanites aegyptiaca* etc., again as described in the regional introduction.

Human Impact & Utilisation: Some 17 000 tonnes of fish used to be landed each year from the lower Chari, between N'Djamena and the delta in Lake Chad. However, this figure fell dramatically after the drought of 1972-74 and has not yet fully recovered. The fisheries above N'Djamena have been less drastically affected. The catch upstream of N'Djamena, as far as the confluence of the Chari and Bahr Erguig, produces about 7000 tonnes fish/yr, while that on the Ba Illi produces just over 2000 tonnes/yr. The catch

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between the confluence of the Chari and Ba Illi, as far upstream as Sarh, averages 4000 tonnes/yr. A large agro-industrial complex, producing and milling sugar cane, became operational at Banda in 1977.

Conservation Status: The Mandelia Faunal Reserve is situated on the floodplain between the Chari and Logone Rivers south of their confluence at N'Djamena, and is bounded by these two streams on the east and west. The park comprises 138 000 ha, and protected 660 elephants on its establishment in 1967. Other animals found in the park include *Gazella rufifrons*, *Kobus kob*, *Orycteropus afer*, *Phacochoerus aethiopicus* and *Tragelaphus scriptus*, and there is a rich avifauna along the rivers and around permanent waterholes.

The Manda National Park protects 114 000 ha on the west bank of the Chari, some way below the confluence of the Bahr Sara and Chari. The river bed is included in the park and forms the eastern boundary and there are numerous small swamps and pools in the park. Wetland species protected include *Hippopotamus amphibius*, *Kobus ellipsiprymnus*, *K. kob*, *Loxodonta africana* and *Syncerus caffer*. Again there is a rich avifauna associated with the wetland habitats.

3. The Logone Floodplain

General: The Logone has sources in Cameroon which rise as the Wind and Mbéré Rivers on the Massif de l'Adoumaoua, from where it flows northeastwards into Chad. Here it is joined by the Pende River which rises in The Central African Republic. The Logone then flows northwestwards for about 80 km, where it divides to form a secondary channel on the east bank. This is called the Marba, but sometimes also Ba Illi. At first it flows due north, away from the Logone which continues northwestwards, but after about 165 km it swings round and flows in parallel between the Logone and Chari Rivers, finally rejoining the Logone about 85 km above N'Djamena. A floodplain of 100 000 ha occurs on the Pende just below Doba (8°40'N/16°50'E), but the Logone does not overflow its banks until a point (9°03'N/16°33'E) just above the confluence with the Pende. Downstream from here the floodplain is continuous all the way to N'Djamena where the Logone and Chari Rivers meet. This floodplain is 400 km long. It begins at an altitude of 382 m asl and widens, some 80 km downstream, to occupy all the land between the Logone and Marba Rivers. Here, just above Bongor (10°18'N/15°20'E), it reaches a maximum width of 125 km, but then narrows abruptly to 25 km, before widening again to 40 km, a width it maintains to N'Djamena. The Logone/Marba floodplain comprises 2 100 000 ha of permanent swamp land and seasonally inundated land in Chad. The Logone forms the border with Cameroon for 275 km below N'Djamena, and its waters also inundate a substantial area in that country. In addition there may be a movement of water between the west bank of the Logone and Lake Fianga (10°02'N/14°20'E), and if conditions are right, water may pass from the Logone down the Mayo Kebbi system. Thus there is a connection between the Lake Chad and Niger Basins. At times of very high water, the Chari may overflow its west bank about 100 km below Bousso, and this flood may spread to meet that of the Marba, giving a common inundation zone between the Logone and Chari Rivers all the way to their confluence.

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Hydrology: Flow in the Logone at Moundou rises sharply to a peak in late August, when it regularly exceeds 2000 m^3/sec. In most years the flow rate then falls to about 1500 m^3/sec by mid-October, but then rises to another peak in early November, when the flow again exceeds 2000 m^3/sec. It falls sharply in December, to about 300 m^3/sec, thereafter declining slowly to a minimum flow of less than 100 m^3/sec in February. It then rises slowly to reach 500 m^3/sec by late June and remains at this level until the end of August when the cycle starts again. Flow rate in the Pende is much lower than in the Logone, but the peaks and troughs occur in unison.

Immediately above the bifurcation of the stream to form the Marba, the Logone carries a mean annual volume of 17.2 billion m^3 water. Here peak flow is bi-modal, reaching 3000 m^3/sec in mid-August and again in mid-October, with a drop to 2000 m^3/sec in mid-September. Having lost water to the Marba, flow in the Logone is reduced. At Bongor its flow approaches 2000 m^3/sec in September and remains just below this level until the end of October, whereafter it declines sharply. Farther north at Logone-Birni (11°50'N/15°00'E), above the confluence with the Chari, the mean annual volume carried is 12.6 billion m^3 and peak flows of 1000 m^3/sec are reached in November.

Flora & Fauna: The rivers carry dense Soudanian gallery forest in their upper reaches, but this thins out to the north, and levée forest or scrub prevails along the rivers in the floodplain zones. The floodplains themselves carry grasses. The fauna is as described in the regional introduction.

Human Impact & Utilisation: The rivers and associated floodplains are fished over their entire lengths, with annual catches approaching 19 000 tonnes. The catch is concentrated in the lower region, between the confluence with the Chari at N'Djamena and the point where the Marba rejoins the Logone. Some 10 000 tonnes/yr come from this short stretch.

Rice is grown on 54 000 ha of empoldered land at Bongor, and large areas of floodplain are devoted to flooded rice culture in the vicinity of Lai (9°22'N/16°14'E), amounting to some 112 000 ha.

Conservation Status: The Mandelia Faunal Reserve protects an area between the Logone and Chari Rivers near N'Djamena, as discussed in the preceding section, 2. The Chari River Floodplain. Otherwise unprotected.

4. Wetlands of the Mayo Kebbi System

General: Between 14° and 16°E the Chad/Cameroon border runs close to the parallel 10°N, and just to the south of this the Mayo Kebbi flows west in a broad swampy bed to join the right bank of the Benue River in Cameroon. The Mayo Kebbi rises in Chad, in the wetlands of the Logone Floodplain, and prior to crossing the border into Cameroon, connects a series of lakes. These are, in passing downstream from east to west, Lake Fianga, which is largely situated in Cameroon, Lake Tikem and Lake N'Gara; then having descended the 45 m drop of the falls at Gauthiot, it flows through the two Léré Lakes. The rivers and lakes have areas of permanent swamp land on their banks, and in places there is a narrow floodplain along the rivers. The lakes are dealt with individually in the next section.

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Hydrology: The Mayo Kebbi is fed principally by floodwaters from the lower Logone River as mentioned in the preceding section. The waters collect into the Kabia and Loka Rivers which merge above Lake Fianga. High water is from the beginning of August until late October.

Flora & Fauna: Galleries of Soudanian forest species occur along the rivers and there are typical aquatic floras in the lakes and on the floodplains, all as described in the regional introduction. Manatees survive in the system together with all the small aquatic animals. Large mammals are scarce but hunting still continues. Crocodiles are uncommon in the river.

Human Impact & Utilisation: The system is intensively fished and annual catches from the lakes and river in Chad are in the region of 10 000 tonnes. Rice is grown on the floodplains around all the lakes of the system.

Conservation Status: The Binder-*Léré* Faunal Reserve of 135 000 ha protects an area below Gauthiot Falls including Lakes Trénè and *Léré*. The reserve is set in *Anogeissus-Boswellia* savanna, and forest galleries, river beds and marshes are included, in addition to the two large lakes. Animals protected in the reserve include *Cercopithecus aethiops*, *Genetta tigrina*, *Hippopotamus amphibius*, *Tragelaphus scriptus*, *T. strepticeros* and *Viverra civetta*. There is a rich avifauna around the lakes. Poaching is severe and is locally attributed to people crossing the border from Cameroon and to military personnel.

5. Natural Lakes

(A) LAKE CHAD

Location: 12°29'-14°29'N/13°02'-15°21'E
Area: 2 500 000 ha at high water (c. 1 155 000 ha in Chad)
Altitude: 282 m asl (when lake surface covers 2 000 000 ha)
Nearest Towns: Bol (on E lakeshore); N'Djamena (100 km S)

General: Lake Chad lies just south of the Sahara and occupies a low point in one of the ancient drainage basins of Africa. The Bodélé Depression, 350 km northeast, is lower than the lake with surfaces 155-180 m asl, but drainage of the lake in this direction is precluded by the dunes of the Erg Kanem. However, according to Beadle (1981), during the peak flood years of 1962 and 1964, water travelled 50 km from lake Chad along the Bahr el Ghazal towards the Bodelé Depression.

The Lake Chad Basin has been in existence since the Cretaceous and has suffered little physical deformation, although the size and distribution of water surfaces in it have changed dramatically as a consequence of climatic changes, especially during the Pleistocene. The lake was, for example, 5 times its present size only 6000 years ago (Servant & Servant, 1970; 1973). Connections were established more than once between the basin and the surrounding basins of the Niger, Nile and Zaire Rivers during the Pleistocene, but today, only the Niger basin is connected, and that only tenuously through the Mayo Kebbi system.

The drainage basin occupies more than 2 500 000 km^2 and is bounded by the highlands of the The Central African Republic, the Massif de l'Adoumaoua and the Mandara Mountains in the south, by the Jos-Funtua Plateau in the southwest, by the Aïr Mountains

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in the northwest, the Tibesti Mountains in the north, and by the Ennedi and Ouaddi Massifs in the east.

Some 46% of the lake and its peripheral marshes are situated in Chad. Published accounts of the area of the lake vary between 1 379 200 ha (5325 square miles - Welcomme, 1972) and 2 500 000 ha (Beadle, 1981). According to Beadle the open water area has fluctuated between 1 000 000 ha and 2 500 000 ha this century. However, during the drought of 1972-1975 the area of open water fell below 250 000 ha and a similar state of affairs prevailed in 1908. During dry periods in the past, including the very recent past, when the lake has contracted greatly, parallel lines of wind blown dunes have developed along the eastern and northern shores. These are oriented NW-SE, and the fringes of these dune areas are flooded by the 'normal' lake producing lines of sandy islands along the eastern shore, often referred to as the 'archipelago zone'. The islands are particularly prominent in the southeastern sector. Farther into the lake, away from the eastern shore, in the northwestern part of the lake, lower dune ridges have been submerged, but they are so close to the surface that they are vegetated and form a series of reed covered areas, again oriented NW-SE. The 'normal' lake, such as persisted through the 1960s, is 235 km long, oriented NW-SE and some 100 km wide in the north. An arm, 100 km long and 50 km wide, extends due east from the southeastern corner. During the 1972-1975 drought the lake level fell from 282 m to 278 m, and the lake at first contracted to occupy three separate basins. By the beginning of November 1975 the northern basin was completely dry and little open water remained in the south basin. These events were accompanied by massive fish mortalities. At times during the Pleistocene, Lake Chad was vastly greater than it now is, and at one time extended to the Tibesti Mountains.

Hydrology & Water Quality: The lake is endorheic and both lake and lower basin are shallow, which is why the surface area of the lake is so variable. Of the total riverine inflow, 95% comes from the Logone/Chari system, the catchments of which, in the humid highlands of Cameroon, Chad and the The Central African Republic, represent about 25% of the total basin. The contribution of the El Beid River is minimal, possibly 2.5% of the total inflow, while the remainder is contributed by the Yobe, Yedseram and other intermittent streams. Precipitation over the lake probably averages 300 mm/yr, with variable and unreliable falls close to 250 mm/yr in the north, and more reliable, but still variable falls close to 460 mm/yr in the south. Potential evaporation over the lake is 2200-2300 mm/yr, and in excess of 2300 mm over the northern parts of the catchment.

The maximum depth of the lake water, with a surface at 281 m, is 7 m in the northern basin and 4.5 m in the southern basin. The lake water is well mixed and well oxygenated, being shallow and subject to moderate winds. The southern part of the lake has salinities well below 1‰. However, a ridge crosses the middle of the lake from east to west, known as the Grande Barrière, and although in the 'normal' lake this is inundated, it restricts circulation. Thus the northern part of the lake is significantly more saline than the southern half, with readings of 2‰, although it is still well mixed. The saline waters extend south to the Grande Barrière during the dry season but are pushed back to the north when the Chari is in flood. It is remarkable that, since an estimated 90% of the incoming water evaporates each year, the salinity of the lake is so low. Carmouze (1970; 1976) estimates that a substantial proportion of the incoming ions are removed by

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chemical or biological processes, amounting to 60% of the calcium, 54% of the magnesium, 36% of the potassium, 44% of the carbonate and 84% of the silicate. However, it seems likely that a lot of dissolved minerals are lost by the seepage of dense saline water into a subterranean system (Roche, 1970). Certainly it has been demonstrated that ground water is moving outward from the lake in the vicinity of Bol (Dieleman & de Ridder, 1964). The salinity of the water seeping out of the lake is about ten times greater than that entering the lake.

Flora & Fauna: The seasonally flooded fringes of the lake are covered by typical floodplain vegetation as described in the regional introduction. The permanent swamps along the southern lake margins are dominated by *Cyperus papyrus*, with *Phragmites (mauritianus?)* and *Vossia cuspidata*. Islands of papyrus break away from the peripheral swamp and float into the lake during windy weather, but by contrast, the northern shores and islands are covered by *Phragmites australis* and *Typha domingensis*. *Papyrus* becomes less common in passing northwards, while *Typha* becomes less common in passing southwards. A swamp belt, intersected by many channels, crosses the lake over the Grande Barrière. In the north, *Cyperus laevigatus*, a species common on the margins of saline pools, occurs on the lakeshore. In the south *Cyperus articulatus*, *Leersia hexandra* and *Pycreus mundii* occur on the fringes of the lake, with *Hyphaene thebaica* at the limits of inundation.

Ceratophyllum demersum, *Potamogeton schweinfurthii*, *Vallisneria spiralis* and some other submerged aquatics occur in the lake and are especially well developed between the islands along the eastern shore. A vast expanse of aquatic vegetation, with *Nymphaea* spp., and the submerged species already mentioned, covers a shallow coastal area in the southeast. More than 1000 species of algae have been identified in the lake. The dune island zone of the eastern side of the lake is the most productive part of the lake.

During the severe drought of 1972-75, the exposed parts of the southern basin developed a luxuriant vegetation, described by Fotius & Lemoalle (1976), but the dry areas of the northern basin did not. Among the most important species in this explosive colonisation were *Aeschynomene elaphroxylon*, *Cyperus papyrus* and *Vossia cuspidata*. The vegetation on the Grande Barrière became a serious impediment to the re-flooding of the northern basin when a 'normal' influx from the Chari occurred at the end of 1974 and again in 1975.

The invertebrate faunas of the north and south basins in a 'normal' lake are distinct from each other, and from that in the waters of the archipelago of sand islands along the eastern shore. Molluscs dominate the benthic fauna, contributing 75-90% of the benthic biomass in the southern basin. Molluscs are however, relatively scarce in the northern basin, although there are extensive fossil mollusc beds at the north end of the lake. The reasons for the differences in both flora and fauna between the northern and southern basins is not known, though numerous hypotheses have been advanced and an introduction to recent thought and research is given by Beadle (1981).

Lake Chad is in the Soudanian ichthyological province but it has been the meeting place of species from the Nile, Niger and Zaire Basins. 179 species of fishes have been identified in the Lake Chad Basin, of which 84 occur in the lake itself. 106 species are common to the Chad and Niger Basins, with 8 species confined to the two basins. There are 105 species common to the Chad Basin and the Mayo Kebbi, and of these 21 are not

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found farther downstream in the Benue/Niger system. 85 species are common to the Chad and Nile Basins, with 7 species confined to the two basins, while 47 species are common to the Chad and Zaire Basins, with 13 species confined to the two basins. Of these 47 species, 18 are found only in the upper reaches of the Chari and Logone Rivers and their headwater affluents, suggesting that they are recent immigrants from the Zaire Basin. The possibility clearly exists that exchanges could occur across the flat watersheds in the The Central African Republic during times of exceptionally heavy rain. The fish fauna of the basin is discussed by both Beadle (1981) and Lowe-McConnell (1975) who give further references.

Many species of fish leave the lake and swim up the affluent rivers when water levels begin to rise. They then leave the rivers and move onto the great floodplains to spawn, returning to the lake with the recession of the flood, e.g. *Alestes baremose*, *A. dentex*, *Distichodus rostratus*, *Eutropius niloticus*, *Heteropisus bebe*, *Labeo senegalensis*, *Mormyrus rume*, *Petrocephalus bane*, *Schilbe uranoscopus*, *Synodontis batensoda*, *S. membranaceus* and *S. schall*. Other fish are specialised for life on the peripheral floodplains, such as *Protopterus annectens*, while others are adapted to life in the peripheral swamps, e.g. *Brienomyrus niger*, *Clarias lazera* and *Polypterus* spp., but during the great drought of 1972-75 these latter species became abundant in the south basin. The balance of fish species and populations in the lake and lower affluents has changed following the Sahelian drought of the early 1970s, and this appears to have had moderately long term effects. These have been reflected in changing patterns of fish catches, and are discussed by Stauch (1977), Chouret (1978), Quensière (1976) and Benech *et al.* (1976). Rotting vegetation, after parts of the lake were re-flooded in 1975-76, led to local de-oxygenation and further fish losses.

Crocodylus niloticus is now very uncommon in the lake, but there are several species of semi-aquatic snakes on the banks. There is a rich avifauna. The lake is important to palearctic migrants, especially since the recent severe droughts in Senegal and Mali. Large numbers of ducks are now seen on the lake. Most large mammals have been hunted out and have been replaced by domestic cattle. Species which remain include *Tragelaphus spekei*, in the reed beds, and there is a reduced *Hippopotamus* population. Small aquatic mammals, such as *Aonyx capensis* and *Lutra maculicollis* are common.

Human Impact & Utilisation: Salification of the soil surrounding the lake is increasing, partly due to irrigation, but in part naturally as a consequence of the seepage of water away from the lake and its subsequent evaporation at the surface. This may preclude the large scale expansion of irrigation agriculture. At present this is largely confined to the vicinity of Bol where land is empoldered, and used to produce maize, legumes and a variety of minor crops. Salt is produced to the north of Baga-Sola, a short way northwest of Bol. The lake is fished extensively from villages in Chad and in the 1960s the mean annual catch exceeded 26 000 tonnes, but this declined dramatically during the drought of 1972-75, and has not fully recovered. The floodplains around the southern end of the lake are grazed intensively by large numbers of domestic cattle. There were over 300 000 cattle and more than 100 000 sheep and goats in the vicinity of the lake in Chad before the drought in 1972-75, but we have no figures for recent years.

Conservation Status: Unprotected.

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(B) DJIKARE, MOILO & ROMBOU LAKES

General: Several small permanent lakes occur immediately to the east of Lake Chad, in the Erg Kanem, where the water table reaches the surface in the troughs between dunes. In previous more pluvial times the area has been a part of Lake Chad and clays have been deposited in the inter-dune troughs where the lakes now occur. The three Djikaré Lakes are situated closest to Lake Chad. The largest, Lake Bodou, is 71 km NW of Bol and 11 km inland from the shore of 'normal' lake Chad. It has an area of 40 ha and a maximum depth of 2 m. Its waters are saline.

The two Moilo Lakes are 31 km NE of Bol, and each have areas of about 60 ha and depths close to 2 m. Lake Rombou is 70 km NE of Bol. It has an area of 15 ha and is 1 m deep. Direct precipitation over the lakes is less than 300 mm/yr in all cases and insolation averages 3000 hrs/yr while potential evaporation exceeds 2200 mm/yr. All of these lakes are fringed by lush green vegetation. In those lakes with a low bicarbonate content in the water, *Phragmites australis* is dominant, with isolated stands of *Cyperus papyrus* and *Typha domingensis*. The aquatic vegetation is dense and includes all the typical species, but *Phragmites* may totally occlude shallow lakes. Other lakes with higher bicarbonate concentrations are less densely vegetated. Again *Phragmites* is present, though usually less tall, and *Cyperus laevigatus* often forms an outer landward zone.

The faunas of these lakes are improperly known. Among the fishes, *Hemichromis bimaculatus*, *Parophiocephalus obscurus* and *Tilapia* sp. have been recorded in the least saline lakes. Crocodiles are probably absent, birds are common and *Hippopotamus amphibius* has been recorded in several of the lakes.

Human Impact & Utilisation: Some salt, natron, containing sodium carbonate, sodium bicarbonate and sodium chloride is extracted locally, and nomadic people utilise the water resources of the area. Otherwise the lakes are undisturbed.

Conservation Status: Unprotected.

(C) THE OUNIANGA LAKES

General: Southeast of the Tibesti Massif the edge of the mega-Chad Basin abuts the 200 km Ounianga Escarpment, oriented NW-SE. This is a sandstone structure and at its feet there are a number of permanent saline lakes at altitudes close to 402 m asl. These lakes owe their existence to the fact that water in a subterranean aquifer reaches the surface in depressions between sand ridges west of the escarpment. The lakes are situated in NE Chad (18°44'-18°05'N/20°31'-21°51'E) equidistant from the Tibesti Mountains and the Ennedi Massif.

The principal lakes are at Ounianga Kebir (19°05'N/20°31'E) where Lake Jua (345 m asl) has an area of 370 ha and a maximum depth of 25 m, and there are 3 smaller lakes close by, known as Lakes Uma, Mioji and Forodom. A second group of lakes 50 km east occupies the Ounianga Serir (18°55'N/21°51'E). Here ten lakes lie in rough parallel; these are Melekoui, Dierke, Ardiou, Teli, Abrome, Hogou, Diara, Tarem, Tibichei and Bokou. Lake Teli is the largest, covering 70 ha, with a maximum depth of 10 m and a high water surface at 360 m asl. The lakes are oriented NE-SW with their long axes parallel to the direction of the prevailing winds.

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Flora & Fauna: Most of these lakes are fringed by narrow stands of *Cyperus laevigatus*, *Phragmites australis* and *Typha capensis*. *Lemna* spp. are common in the freshwater springs and *Nymphaea* and *Potamogeton* spp. grow in most of the lakes, while in some *Ruppia maritima* is present. Phytoplankton is abundant but not well studied. The surrounding moist ground once held stands of *Hyphaene*, but these have been removed and replaced by *Phoenix dactylifera*. No less than 25 000 date palms grow in the oasis of Ounianga Kebir. The fauna of these lakes has not been adequately studied. The invertebrates are also not well studied, but the area abounds with mosquitoes. Among fishes, two species have been collected in the ponds, *Haplochromis bimaculatus* and *Oreochromis galilaeus*.

Human Impact & Utilisation: There is intensive date growing in the area. However, many of the ponds are undisturbed and almost totally occluded by plants. Cattle are taken to the lakes for water and grazing. Salt (natron) is extracted from Lake Jua.

Conservation Status: Unprotected.

(D) ROCK POOLS OF THE ENNEDI MASSIF

General: The western edge of the Ennedi Massif is deeply gullied and its gorges are forested, by contrast with its bare desert surface. Rain falls chiefly as a result of thunderstorms in July and August and is often very intense. At these times flow in the oueds is torrential and erosion of the surface sandstone occurs freely with the production of canyons 10 - 100 m deep. Being narrow these tend to conserve surface water after the flood has passed. For example, at Archei (16°54'N/21°46'E) there is a north facing gorge 1.5 km long opening out of the escarpment, with 6 large ponds (gueltas) joined by swampy strips. These are all fed by permanent springs at the head of the gorge. At Beskere (16°30'N/22°15'E) a 2 km long gorge opens to the west out of the escarpment. A number of springs at the head of the gorge fill a large guelta, several hectares in extent, and this overflows to a stream which then traverses a series of smaller ponds all the way down the canyon to a *Hyphaene thebaica* forest on the sands at the canyon mouth. Discharges from the springs at Archei have been measured as 600-700 m^3/day, while those at Beskere produce upward of 1000 m^3/day (Gillet 1957). There are many small pools with rocky bottoms along the other gorges of the lower, western part of the Ennedi Massif.

Flora & Fauna: The gorges contain dense riparian forest typical of areas farther south which receive at least 600 mm rain/yr. The pools are fringed by species of *Cyperus*, *Juncus*, *Phragmites*, *Scirpus* and *Typha*, and *Nymphaea* and *Potamogeton* spp. grow in them. The forest contains *Acacia nilotica*, *A. seyal*, *Adina microcephala*, *Balanites aegyptiaca*, *Boscia angustifolia*, *Ficus ingens*, *F. populifolia*, *F. sycomorus* and *Vitex doniana*. The algal flora appears to be transitional between that of Lake Chad and that of the Sahara (Compère, 1970). The invertebrate fauna is improperly known but it certainly includes mosquitoes and *Caridina africana*. Among the fishes, *Barbus apleurogramma* (also in Lakes Victoria & Tanganyika), *B. macrops*, *Coptodon zillii*, *Labeo tibestii* (endemic to the Ennedi-Tibesti region) and *Oreochromis galilaeus* have been recorded and a species of *Clarias* is common. *Xenopus mulleri* (a tropical species) is common in the gueltas, and there are other unidentified amphibians. *Crocodylus niloticus*

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survives here in substantial numbers. Many migrating birds come to the guellas, as do *Acinonyx jubatus*, *Hyaena hyaena*, *Panthera leo*, *P. pardus* and *Papio cynocephalus*.

Human Impact & Utilisation: Nomads utilise the water of the pools for domestic purposes, but the area is effectively uninhabited. There were permanent settlements here 6000 years BP.

Conservation Status: Extremely isolated and undisturbed. Several of these ponds are protected in the Fada Archei Faunal Reserve (16°35'-17°15'N/21°10'-21°32'E). Animals protected in the reserve include *Acinonyx jubatus*, *Addax nasomaculatus*, *Ammotragus lervia*, *Felis caracal*, *Gazella dorcas*, *Oryctetopus afer* and *Struthio camelus*.

(E) LAKE FITRI

General: Lake Fitri (12°41'-13°00'N/17°24'-17°38'E) measures 35 km in length, oriented NW-SE, and has a maximum width of 20 km. It is 290 m asl at low water and has an open water surface which fluctuates markedly. Because the lake receives its water from northern, semi-arid catchments, where annual variations in rainfall are great, and because its basin is remarkably shallow, annual changes in its area may be very great. It has possibly covered an area of 130 000 ha in some very wet years, e.g. 1870, and it dried almost completely in 1901 and 1973, but its 'normal' area is about 50 000 ha at low water when it has a 150 km perimeter. There are a number of permanent swamps around its 'normal' margin, and it is set on a seasonally inundated plain fed by the Batha, which drains the central part of the Ouaddi Massif and flows for 3-4 months of the year. It also receives water from several short streams which flow north from the Guera Massif. The lake is endorheic, but at times of high water it overflows onto the floodplain, and during an exceptionally high flood its waters may be carried south by the Batha de Leiri into the inundated lands of the Bahr Erguig, a part of the Chari system. Annual variations in water level are usually of the order of 1.5-2 m, peaking in October and falling to a minimum in May.

The lake water is fresh, with salinities below 0.8‰, well mixed and well oxygenated, but generally rather turbid with Secchi depths of 20-65 cm. The permanent swamps on the lake fringes are dominated by *Phragmites mauritianus* and there are large stands of *Echinochloa stagnina* and *Vossia cuspidata* on the edges. *Aeschynomene elaphroxylon* and *Mimosa pigra* are common in less deeply inundated places, while *Ceratophyllum demersum*, *Nymphaea* and *Potamogeton* spp. are abundant in the water. Many fish species are adapted to survive the dry season in the swamps, e.g. *Clarias anguillaris*, *C. lazera*, *Gymnarchus niloticus* and *Protopterus annectens*. The avifauna is as described in the regional introduction for floodplains and swamps. *Pelecanus onocrotalus* is sometimes present in large numbers. Crocodiles have been hunted to extinction, but *Loxodonta africana* is still present and may browse on the marginal vegetation.

Human Impact & Utilisation: The lake is fished intensively yielding a mean annual catch in excess of 3000 tonnes. The surrounding floodplains are heavily grazed by domestic cattle, and are utilised for the recession cultivation of crops locally, but the lake itself is almost undisturbed. Bilharzia is common in the local population.

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(F) LAKE RO

General: This small lake, 15 km long and up to 7 km wide, is situated (10°05'N/19°25'E) some 5 km north of the Bahr Salamat, with which it is more or less continuous at high water. It is 387 m asl at low water and then has an area approaching 10 000 ha. A floodplain is continuous between the lake and the river, but the northern lakeshore is not extensively flooded. The lake is fringed by dense herbaceous vegetation.

Human Impact & Utilisation: It is an important fishing centre, yielding 1000 tonnes/yr, while a further 1000 tonnes/yr is caught on the floodplain immediately to the southwest of the lake.

Conservation Status: The lake is included in the Bahr Salamat Faunal Reserve.

(G) LAKE FIANGA

Location: 9°46'-10°10'N/15°11'E
Area: 11 000 ha (7140 ha in Chad)
Altitude: 323 m asl (high water)
Nearest Towns: Bongor (15 km NE); N'Djamena (225 km N)

General: Lake Fianga spans the border with Cameroon and is situated in permanent swamps of the Mayo Kebbi Depression. A channel connects the northern end of the lake with the Logone River and another connects the southern end with an affluent of the Mayo Kebbi. Water flow in the northern channel is reversible and thus the lake effectively lies on a watershed between the Lake Chad and Niger Basins, as the Logone flows down to Lake Chad and the Kebbi flows to the Bénoué, a tributary of the Niger. The swamps, which lie to the east of the lake receive most of their flood water from the Logone and drain into Lake Fianga, the level of which varies by about 3 m in the course of a normal year. Fianga is a shallow lake, with a maximum depth of 4 m during low water (June-July), but the mean low water level varies by as much as 2 m from year to year.

Human Impact & Utilisation: The lake is fished quite intensively, and manatees, which are now extremely scarce in the Mayo Kebbi, have been hunted to virtual extinction.

Conservation Status: Unprotected.

(H) LAKE TIKEM

General: This lake is situated on the Mayo Kebbi (9°50'N/15°05'E). Its water surface fluctuates between 320-323 m asl during the course of a year, while its surface area ranges from 1500-6200 ha. The maximum recorded depth is 5 m at low water. Low water is from May to June inclusive and high water from September to October. The forests which occurred on the periphery of the floodplain have been very largely cleared, but the remnants include *Anacia albida*, *A. seyal* and some gallery forest species such as *Khaya senegalensis*.

Human Impact & Utilisation: Rice is grown in the seasonally inundated zone around the lake and the waters are fished intensively.

Conservation Status: Unprotected.

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(I) LAKE N'GARA

General: Lake N'Gara (9°55'N/14°44'E), part of the Mayo Kebbi system, has a water surface that fluctuates by about 4 m each year, from 319-323 m asl. Its area changes with these fluctuations from 4000 - 14 200 ha, and maximum depth does not exceed 4 m at low water. Rice is grown on the seasonally inundated plain and the lake is fished intensively. Some open forests occur around the lake, with several species subject to inundation including *Acacia albida*, *A. seyal* and *Khaya senegalensis*.

(J) THE LERE LAKES

General: These two lakes are about 234 m asl at low water and are situated on the Mayo Kebbi on the Chad/Cameroon border. The two basins are situated one east and one west of the town of Léré (9°41'N/14°17'E). The western basin, known as Lake Léré, measures 14.5 km in length and has a maximum width approaching 4 km. It has a maximum depth of 8 m and a mean depth of 4.5 m at low water, when it covers 4100 ha. The eastern basin holds Lake Tréné, which is 6 km long and 2 km wide. Both lakes are oriented E-W and both expand considerably at high water. Flooding in both lakes is bi-modal; local precipitation leads to a peak in August and a second flood comes down the Mayo Kebbi in October.

Both lakes are isolated from Lakes N'Gara, Tikem and Fianga, situated upstream on the Mayo Kebbi, by the Gauthiot Falls. The fish fauna of the Léré Lakes reflects this, showing great affinity with that of the Niger, while the faunas of the upstream lakes have their greatest affinity with that of the Chad Basin. Species which frequent muddy bottoms in the Léré Lakes include *Brienomyrus niger*, *Hyperopisus occidentalis*, *Mormyrus rume* and *Pollimyrus isidori*, while those that frequent rocky bottoms include *Labeo coubie*, *Mormyrops deliciosus* and *Petrocephalus simus*. *Crocodylus niloticus*, *Hippopotamus amphibius* and *Trichechus senegalensis* are present.

Human Impact & Utilisation: Rice is grown in the seasonal inundation zones on both lakes, and both are fished.

Conservation Status: Both lakes are included in the Binder-Léré Faunal Reserve.

6. Wadis & Oases of the Tibesti Massif

General: Although much of the Tibesti Massif receives less than 20 mm rain/yr some spectacular canyons leading out from it carry intermittent rivers (enneris). Most of these support vegetation, and pools of water persist for long periods in their upper gorges. A number of oases lie along the course of the Enneri Yébigé which drains north into the Libyan desert, and these are virtually unexplored. The longest enneri, the Enneri Tijilinga, extends almost 400 km south from the western end of the Tibesti before petering out in the sands north of the Bodélé Depression. Immediately east of this the Enneri Miski is the major southern effluent. It is fed by several streams from the western flanks of the Emi Koussi and by others from the eastern flanks of Tarso Kobour including the Enneris Korom and Aouei. Its waters also flow beneath the sands towards the Bodélé Depression. Several other watercourses drain the Emi Koussi in radial fashion, from southwest to southeast, and disappear in the Borkou, a sandy basin between the Tibesti

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and Ennedi Massifs. From them subterranean water finds its way to the Borkou Pools (discussed later). Above 2000 m the beds of most enneris contain strings of pools, often connected by flowing water, and most of these too, are unexplored. The water of the enneris is of low salinity. The gueltas are flushed by floods several times a year and never become very saline. Many of the pools are fringed by macrophytes, including *Cyperus laevigatus*, *Equisetum ramosissimum*, *Juncus fontanesii* and *Scirpus holoschoenus*, and most contain fish; *Barbus anema*, *B. apleurogramma*, *B. bateri*, *B. deserti*, *Barilius* sp., *Clarias gariepinus*, *Coptodon zillii*, *Labeo annectens*, *L. niloticus*, *L. tibesti* (endemic to Ennedi & Tibesti regions), *Oreochromis borkuanus* and *O. galilaeus* have been recorded from the Tibesti.

(A) THE MARE DE ZOUI

Location: 21°20'N/17°05'E
Area: a few hectares
Altitude: c. 600 m asl
Nearest Towns: Bardai (10 km S); Faya-Largeau (420 km SE)

General: This permanent lake, on the northern flanks of the Tibesti, is situated in the valley of the Enneri Bardagé, which in its upper reaches, is often referred to as the Enneri Zoumeri. The narrow lake is supplied by springs at the head of the gorge. After rain it overflows and a small stream cascades and trickles down the gorge through small marshy patches and pools.

Flora & Fauna: The lake is fringed by dense stands of *Phragmites* and *Typha*, possibly *P. australis* and *T. capensis*, and the open water supports *Potamogeton* spp. The phytoplankton appears rich but has not been properly described. On the fringes of the massif, farther down the enneri, where there is no surface flow and the water table may be 7-8 m deep, *Salvadora persica* and *Tamarix articulata* both grow. *Tamarix* is dominant, often forming a dense strip along the lowest part of the wadi. Higher up and farther into the massif, near the guelta, *Tamarix* is replaced by stands of *Acacia nilotica*. *Hyphaene theboica* grows sporadically at the mouth of the gorge. Neither amphibians nor fish have been recorded in the gorge, but this does not mean that they are absent.

Human Impact & Utilisation: Little use is made of the guelta and it is seldom visited, although an oasis farther out onto the plateau is used for horticulture, date production and watering domestic animals.

Conservation Status: Unprotected.

(B) THE OASES OF BORKOU DISTRICT

General: The plain of Borkou slopes gradually away from the feet of Emi Koussi, towards the south, in places descending by little scarps. Precipitation is negligible here and surface water is soon absorbed, despite which little ponds and springs arise at the feet of tiny scarps which are scattered over a wide region. These water sources all support small settlements, e.g. those at Medimi (19°04'N/18°28'E), Douki (18°50'N/18°56'E), Yarda (18°30'N/19°01'E), Tigui (18°38'N/18°47'E), Berchi-Guélé (18°16'N/19°43'E), Faya Largeau (17°59'N/19°07'E) and Galakka (18°05'N/18°25'E). All these places are within 400 km of Emi Koussi, and it is believed that water from the southern Tibesti

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travels underground to these sites where it emerges at springs. In addition to these oases there are numerous areas of humid sand which have a high water table throughout the year.

Flora & Fauna: Open ponds are fringed by reeds and *Typha domingensis*, with *Juncus maritimus*, *Phragmites australis* and *Scirpus laevigatus* on saline areas that develop around the ponds as a consequence of seasonal water fluctuations. Other hydrophytes associated with the ponds, and patches of marshy soils are *Epilobium mirei*, *Heleocharis tibestica*, *Helosciadium mauritianum*, *Kosteletzkia borkuana* and *Lotus borkuanus*. Only two fishes have been identified in the pools, *Epiplatys senegalensis* and *Oreochromis borkuanus* (endemic).

Human Impact & Utilisation: The oases are exploited intensively throughout the Borkou region. The springs are augmented by many artificial wells and bores, and there is a deal of small scale irrigation gardening. Cattle, goats and camels are watered at the centres, of which only about half have been cited. There are comparatively large plantations of *Phoenix dactylifera* in the areas of moist sands, but *Hyphaene theboica* and other native vegetation still survives.

Conservation Status: Unprotected.

(C) OTHER OASES

General: There are numerous other oases around the Tibesti on both the western and northern sides, e.g. at Zouar (20°26'N/16°31'E). Where these oases are accessible, and not infested by mosquitoes, their natural vegetation of *Acacia*, *Ficus*, *Hyphaene* and *Tamarix*, tends to have been replaced by *Phaenix dactylifera*. Communities have developed at several sites, sustained by date production and small scale horticulture, using traditional methods of irrigation. Generally goats and camels are kept at these places, and occasionally sheep. In addition, the pools of the oases are fished.

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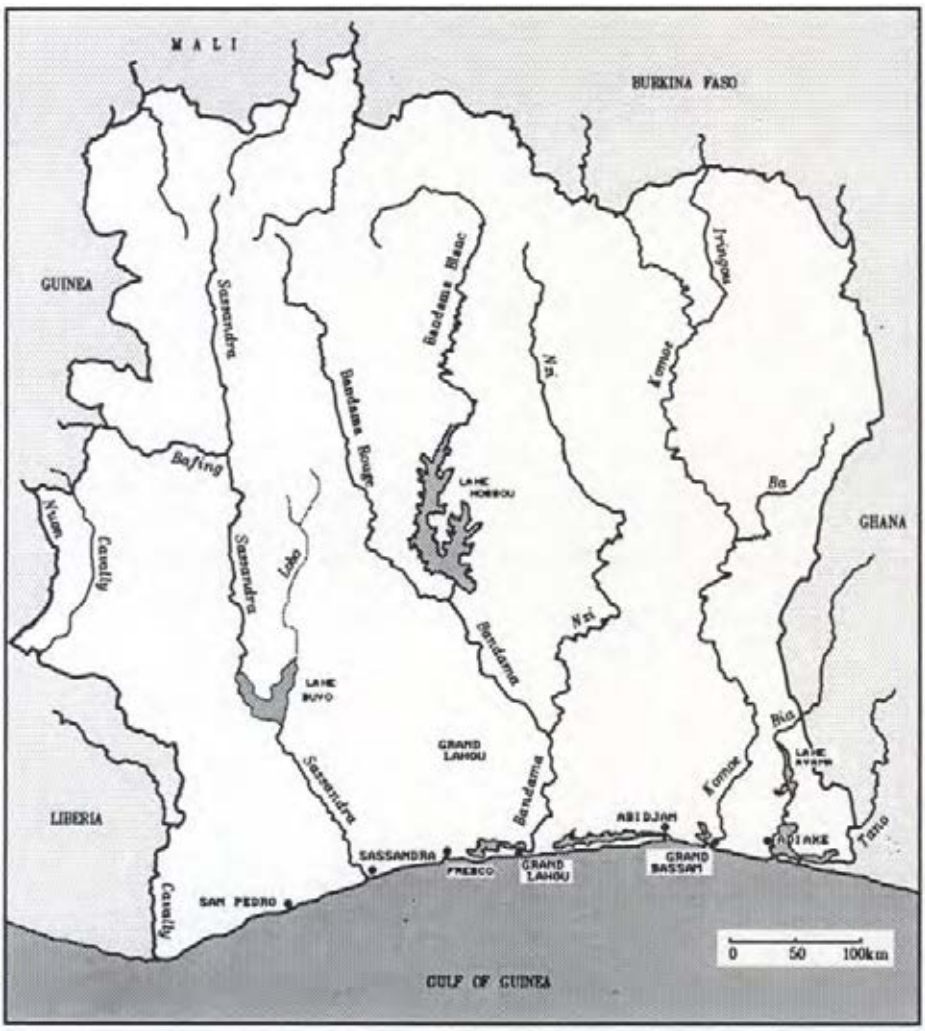

Map of Côte d'Ivoire

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3.4 COTE D'IVOIRE

Introduction

Côte d'Ivoire has an area of 322 465 km^2, and a coastline of 540 km along the Gulf of Guinea. Inland it has borders with Liberia in the southwest, Guinea in the northwest, Mali and Burkina Faso in the north, and Ghana in the east. It stretches approximately 690 km from N-S between latitudes 4°22' and 10°32'N, and 660 km from W-E between longitudes 2°28' and 8°36'W. The capital, Abidjan, is situated in the southeast of the country (5°19'N/4°01'W) on Ebrié Lagoon. In 1983 the population was 9 270 000, giving a mean population density of 28.7 persons/km^2.

From the Liberian border eastwards as far as Fresco (5°03'N/5°31'W), the coast is of comparatively high relief with rocky promontories and cliffs, as well as some sandy beaches. However, in the eastern sector the coast is flat and sandy, with a continuous littoral sand-bar built up by the prevailing longshore drift. In this sector the narrow coastal strip is occupied by a series of lagoons and marshes, which are maintained by the coastal sand-bar which attains 6-10 m in height between the lagoons and the sea. Inland, the coastal lowlands rise by a series of shallow stepped plateaux to undulating plains, which in turn continue to rise gently to an altitude of about 100 m. From the parallel 6°N the land again slopes upwards reaching a high plateau, 300-500 m asl, beginning close to the parallel 8°N. A mountain range forms the borders between the Côte d'Ivoire and Liberia and Guinea, with the highest peak, Mt. Nimba (1752 m), situated just inside Guinea where the three countries meet. The highest point in Côte d'Ivoire is Mt. Tonkoui (5°28'N/7°37'W) in the Man Highlands, 80 km due east of the Nimba Mountains. About 20% of Côte d'Ivoire, west of a line drawn between Man (7°31'N/7°37'W) and Ferkessédougou, is mountainous and quite deeply dissected, with 4 peaks exceeding 1000 m and many reaching 800 m asl.

Drainage of 90% of the country is to the Atlantic Ocean by a series of rivers flowing more or less due south. The most westerly of these is the Cavally, which for 400 km forms the border with Liberia, and which is interrupted by no less than a dozen cataracts in descending from the interior plateau to the coast. From here, in passing eastwards, the other rivers are the Dodo, Nero, San Pedro, Brimé and Sassandra (also riven by cataracts in its lower reaches) which all discharge directly to the sea. However, from Fresco, approximately midway along the coast, to the eastern border, the beach is formed by an almost continuous sand-bar, and the rivers from the central and eastern regions discharge behind the sand-bar into coastal lagoons. Many small lagoons have coalesced to form the three large lagoonal complexes. The eastern rivers are, sequentially, the Bolo and Nioumouzou, which enter Fresco Lagoon, the Baubo, Gô and Bandama, which flow into Tadio Lagoon, the Ira, Agnébi, Mé and Komoé, which flow into Ebrié Lagoon, and the Soumié, Bia and Tano, which discharge into Aby Lagoon. The last of these, the Tano, forms the border with Ghana for about 50 km inland from its mouth.

A watershed occurs on the highlands of the north, from which a small part of Côte d'Ivoire drains northwards to the Niger River, principally via the Baoulé and Bagoé Rivers, while in the northeast, some ephemeral streams flow eastwards into Ghana as affluents of the Black Volta.

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Climate

At the coast, in the west, there are only two seasons, one wet and one dry, but in passing eastwards a short dry season begins to become manifest in the middle of the wet season, so that there are then four seasons. For example, at Tabou (4°28'N/7°20'W) in the far west, mean annual rainfall is 3000 mm and the rains persist for 11 months; only February is dry. By contrast at Abidjan (5°19'N/4°01'W), where mean annual rainfall is 2047 mm, January, February and August are dry. Here the mean monthly rainfall maximum is 574 mm in June, while the mean monthly minima are 41 mm in August and 32 mm in January. However, in passing inland, the August dry season is lost, but the January dry season increases in duration. At Cagnoa (6°04'N/5°55'W) the wet season lasts 11 months, and January is dry. At Bouaké (7°42'N/4°01'W) the wet season lasts 9 months and November-January is dry, while at Ferkessédougou (9°30'N/5°10'W) the wet season is 7 months long and November-March is dry. Tabou has 170 rainy days/year, Abidjan has 160, Bouaké 110, and Ferkessédougou 100. The central coastal region, near Grand Lahou, is much drier than the eastern and western coastal extremities, with only 70 rainy days/yr, and a mean annual rainfall of less than 1500 mm.

Temperatures are remarkably constant throughout the year. The mean temperatures of the warmest and coldest months are very close, being 27 and 24°C for Bouaké and Tabou, 28 and 25°C for Abidjan, and 29 and 26°C for Ferkessédougou. The mean annual air temperature is 26.2°C at Abidjan, where March is the warmest month and August the coolest month. This centre receives a mean average of 1812 hours of sunshine/yr, with 200 hours in March and 80 hours in August. However, incidental solar radiation is greatest in April (mean 19.7 MJ/m^2/day) and lowest in August (mean 11.5 MJ/m^2/day), with a mean annual figure of 15.7 MJ/m^2/day.

Winds are predominantly from the southwest, with the greatest velocities in August and September and the lowest in October-December. The mean annual velocity is given as 5 km/h for Abidjan. Potential evapo-transpiration for Abidjan is 1356 mm/yr, with the greatest in March (mean 142 mm/month) and the least in August (mean 82 mm/month). Mean humidity is 85% at Abidjan. We have no data for the more westerly regions.

Wetlands

The entire country enjoys a humid climate with at least 7 rainy months, and most of the interior receives 1000-1500 mm rain/yr, while no part receives less than 1000 mm rain/yr. Since precipitation over the highlands varies greatly from season to season, the northern rivers are all prone to flood. For example, at Odienné (9°36'N/7°32'W) in the far northwest, the mean three monthly total for the December-February period is 29 mm, while by contrast, that for July-September is 952 mm. Thus the rivers, which have risen steadily during May and June, all tend to overtop their banks in August and September. Few of the northern rivers have broad flood plains because of the hilly nature of the terrain, but they may become raging torrents in places, and deep swift moving currents in others. The riparian vegetation reflects this, with many rheophytes in the river beds and on islands and banks which are dry for much of the year. Where the rivers traverse depressions there are swamp forests, and where they traverse flat places there are floodplains, but in the main these are too numerous and too small to detail individually.

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In a few localities the flats are long enough and broad enough for a river to meander, and here extensive floodplains do occur, e.g. along the Bago River (9°52'-10°13'N), the Upper Bandama River (8°30'-9°02'N) and along the northern border on the Komoé/ Leraba Rivers (9°37'-10°16'N). In addition there are major impoundments on the Sassandra, Bandama and Bia Rivers, and these have formed large lakes.

Small mangrove stands occur at the mouths of western rivers, but the principal wetlands are the large coastal lagoons and their associated swamps.

List of Wetlands Described

1. Major Lagoons
   (a) The Ebrié Lagoon Complex
   (b) The Tadio Lagoon Complex
   (c) The Aby Lagoon Complex
2. Minor Lagoons
   (a) Petit Digoué Lagoon
   (b) Digoué Lagoon
   (c) Katibo Lagoon
   (d) Fresco Lagoon
   (e) Hebé & Kodioboué Lagoons
3. Riverine Wetlands
   (a) Minor Western Rivers
   (b) The Cavally & Sassandra Rivers
   (c) The Bandama River
   (d) The Komoé River
   (e) The Gbanhala, Baoulé & Bagoé Rivers
4. Artificial Impoundments
   (a) Lake Kossou
   (b) Lake Buyo
   (c) Lake Ayamé
   (d) Minor Impoundments

1. Major Lagoons

(A) THE EBRIE LAGOON COMPLEX

Location: 5°16'N/3°33'-4°57'W
Area: 77 600 ha (56 600 ha open water + 21 000 ha swamps)
Altitude: sea level
Nearest Towns: Abidjan; Grand Bassam (on lagoon)

General: Ebrié is a long (150 km), narrow (1-9 km) lagoon complex which comprises Ebrié, Aghien, Potou and Ono Lagoons, with a number of small isolated subsidiary

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lagoons. The capital city, Abidjan, is situated on the banks of the complex, the long axis of which lies E-W, parallel to the coast, but the subsidiary basins of Aghien and Potou are orientated SE-NW.

Aghien Lagoon at the eastern end, is 14 km long and 2-3 km wide, and communicates with Potou Lagoon, some 16 km long and 1-3 km wide, through a narrow channel 4 km long. The Mé River enters this channel midway between the lagoons. Both these lagoons and the connecting channel are oriented NW-SE. Another broad channel, about 1 km wide, leads from the southern end of Potou Lagoon past the eastern end of the main Ebrié basin, which is oriented E-W parallel with the coast, to the sea at Grand Bassam (5°12'N/3°44'W). The Assinie Canal leads east from here for 65 km to communicate with Aby Lagoon. Ebrié Lagoon extends westwards from the junction with the channel below Potou Lagoon, for over 150 km. It is 1-9 km wide and contains several large, and numerous small, islands. The main basin of Ebrié Lagoon connects with the ocean by the Vridi Canal, opened as a dredged and navigable passageway in 1950. The opening at Grand Bassam is subject to heavy silting during the dry season.

The small subsidiary lagoons around the periphery of Ebrié Lagoon account for about 2% of the open water surface of the complex, and the numerous long narrow arms, which lead off from the main basin, account for a further 8%. Aghien Lagoon, which is upstream of the Mé River, and is comparatively isolated, accounts for a further 3-4%. The Ira and Agnébi Rivers enter the main Ebrié Basin, the former in a highly indented estuary at the western end, the latter in the middle section. The Mé enters in the east between Aghien and Potou Lagoons, and the Komoé enters the extreme eastern end of the basin near the origin of the Assinie Canal, and only a few kilometres above the natural mouth of the system at Grand Bassam. Another small lagoon, Ono Lagoon (5°22'N/3°33'W), measuring 4km x 1 km, is situated on the Amia River, a tributary of the Komoé, some 10 km above the confluence of these streams and about 30 km upstream of Ebrié Lagoon.

In general, the substrates of the basin, which was initially flooded by the last great marine transgression, are composed of sandy clays of Miocene-Pliocene origin in the north, and silico-argilaceous soils from the early Holocene in the south, while the littoral sand-bar comprises marine sands of Recent origin. The lagoons are fringed by marshes and permanent swamps, and there are about 20 000 ha of seasonally inundated lands behind these, the largest single block of which is at the western end of the complex between the head of the lagoon and the estuary of the Bandama River. Other patches of land subject to seasonal inundation lie 10 km to the north of the lagoon complex in a depression between the Ira and Bandama Rivers. Useful references are Charles & Durand (1982) and Durand & Skubich (1982).

Hydrology & Water Quality: The surface area of the drainage basin is 93 600 km^2, of which 65% is in the drier upland zone, receiving 1100-1500 mm rain/yr. There is considerable variation in freshwater run-off from year to year, but it averages 9.85 billion m^3/year. Of this the Komoé contributes 7.1, the Mé 1.5, and the Agnébi 0.9 billion m^3/year. The Komoé, which receives much of its water from the upland zone, is in flood in September and October, whereas the other rivers peak in June and July. Direct precipitation accounts for 1.1 billion m^3/year. Tidal exchanges

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through the Vridi Canal account for the movement of 38 billion m^3 of water per year. The residence time of river water entering the lagoon varies from place to place with a mean of 104 days. However, in open regions it is only about 12 days, while in secluded bays it may be as long as 912 days. Man made canals link Ebrié Lagoon with the two neighbouring lagoons.

Great variations in the physico-chemical parameters of the water occur from place to place in the lagoon, and also from season to season. Mean surface temperatures range from 25-31°C throughout the lagoon, with extreme values of 22.5-35°C. The water is generally very turbid, especially in the open areas near the city of Abidjan, where dissolved inorganic nitrogen averages 12 µg/l, dissolved organic nitrogen 350 µg/l and particulate nitrogen 700 µg/l. Dissolved phosphate levels average 40 µg/l and particulate phosphorus 42 µg/l in the same area. These levels are much lower in both the more rural open waters and in the numerous closed bays. The pH values vary between extremes of 10.0, recorded in the evening in eutrophic zones during low water periods, and 6.5, recorded in the morning in the proximity of river mouths. Disturbance of the water by wind and currents keeps the shallow waters well mixed, but this is not the case in the deepest regions. An unusual period of calm in 1980 resulted in the formation of a deep, anoxic, reducing layer which gradually spread towards the surface, and eventually resulted in a mass mortality of fish. Horizontal mixing is brought about by the twice daily tidal rhythms and by wind seiches which develop over the lagoon. A certain amount of layering occurs at the mouth of the estuary (Vridi Canal) where the sea water forms a wedge beneath the outflowing, less dense, freshwater.

Phosphate is limiting in the closed areas and nitrogen in the open areas. In closed regions autotrophic productivity is almost exclusively maintained by internal cycling of nutrients, augmented a little by minerals from river and sea water. Overall, Ebrié Lagoon imports nutrients as minerals and organic detritus, and exports undegraded plant material to the sea. Mean annual losses of nitrogen are estimated at 3500 tonnes.

Flora & Fauna: Mangroves occur in the mouths of the system, and upstream in the west as far as Potou Lagoon. The calm bays and banks of the main lagoon are dominated by herbaceous vegetation. Generally one finds an outer zone of free-floating hydrophytes, a middle zone of rooted hydrophytes, both floating leaved and submerged species, and an inner zone of emergent macrophytes comprising reeds, sedges and grasses. These zones merge with each other and their boundaries are not always clear. Extensive areas of swamp land occur at intervals around the lagoon, covered by tall herbs, and often by trees, the latter especially at the western end. These vegetational zones are regressing rapidly because of local urbanisation, land clearance, agricultural development and the cutting of mangrove timber for firewood, and this despite the paramount importance of the vegetation to the ecology of the lagoonal ecosystems.

In the lagoon zooplankton biomass is relatively low compared with that of other planktonic forms. However, the calanoid, *Arcatia clausi*, plays an important role in Ebrié Lagoon. It is practically the only species in the western part, and is dominant in the central and eastern parts. In shallow waters, down to about 3 m, polychaetes, crustaceans (isopods, amphipods, decopods), molluscs, oligochaetes and nemerteans are found. The lamellibranch 'ship worms', *Bianka bagidaeusis* and *Teredo petiti*, are abundant in Ebrié Lagoon where they parasitise any woody material in the lagoon. The former is found in

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salinities of 16-35‰ and the latter in ones of 3-10‰. Important crustaceans include the prawn *Penaeus duorarum notialis*. This species reproduces at sea, but the larvae migrate into the lagoon to complete their development. Another prawn *Macrobachium* sp. reproduces in the rivers and frequents the more brackish parts of the lagoons, while the crabs *Callinectes amnicola* and *Callinectes pallidus* (which grow to 14 cm across the carapace and weigh 150 g) are common.

The fish fauna is typical of the West African coast, as described in the regional introduction. More than 100 species have been recorded, the most abundant being *Chrysichthys nigrodigitatus, C. walkeri, Elops lacerta* (mostly juveniles), *Ethmalosa fimbriata, Liza falcipinnis, Pomadasys jubelini, Sardinella maderensis, Tilapia guineensis, T. heudelo, T. jentinki* and *Tylochromis jentinki*. Animal life is abundant in the swamps, but several species are now rare or endangered, in particular *Choeropsis liberiensis, Crocodilus cataphractus, C. niloticus, Osteolaemus tetraspis* and *Trichechus senegalensis*. Roth & Waitkuwait (1985) discuss the status of the latter species.

Human Impact & Utilisation: What follows also applies, at least in major part, to the other large lagoonal complexes of Aby and Tadio. Significant changes have occurred in and around the three major lagoonal systems during the past decade, due primarily to dramatic increases in population. For example, the population of Abidjan was 550 000 in 1970, but had increased to 2 000 000 before 1984. It is apparent that in recent years a number of factors, operating in concert, have altered the ecological status of the coastal lagoons. These include increases in salinity, brought about by the construction of permanent canals between the lagoons and the sea; changes in the hydrological regimes of the rivers, brought about by the construction of dams; and overfishing and pollution, both brought about by a burgeoning population on the lagoon shores.

Fishing: This is the major industry of the coastal lagoons. In 1981 the total annual fish production from the three lagoons approximated 10 000 tonnes, although in previous years catches of 15 000-20 000 tonnes were recorded. Although in the past the lagoons were fished both individually and collectively, traditional methods were used which did not destabilise the stocks. Today, in Ebrié Lagoon in particular, much fishing is carried out by foreign licencees using highly efficient collecting techniques. From 1964-75 the use of seine nets and ring nets increased by 360%, and during this time the length of the nets increased by a factor of 4-5 times, and for a while some reached 2000 m in length, and the mesh size was decreased from 40 mm to 14 mm. Hence the quantity of fish taken and the proportion of juveniles increased dramatically. However, some measures to prevent abuse have recently been taken (see conservation status). In Ebrié Lagoon fishing is carried out using many different kinds of tackle: gill nets, cast nets, multi-hooked lines for individual fishing, beach seine nets and ring nets for collective fishing. It is estimated that 700-800 seine net operations catch the same quantity of fish as 3000 individual fishermen.

Eight species comprise more than 85% of the catch; *Ethmalosa fimbriata* (61.3%), *Tilapia guineensis* and *T. heudelotii* (6.1%), *Elops lacerta* (5.5%), *Chrysichthys nigrodigitatus* and *C. walkeri* (5.0%), *Tylochromis jentinki* (4.3%) and *Sardinella maderensis* (4.2%). There is also a thriving prawn and shrimp fishing industry.

Agriculture: In and around the lagoonal areas large industrial plantations and smaller family concerns produce coffee, cacao, palm oil, coconuts, rubber, bananas and pine-

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apples. Further north are found cotton and sugar-cane plantations. Pesticides are reputedly used in only moderate amounts, yet some residues (e.g. DDT, lindane) are found in lagoon sediments, and there is evidence of increased siltation.

Manufacturing Industry: This is concentrated at Abidjan. The largest enterprises utilise agricultural products and give rise to much organic pollution. 25% of the organic pollution in Ebrié Lagoon comes from this source. Sediments in the urban area contain measurable levels of PCB, DDT, lindane and heavy metals.

Sewage: The effluent from 500 000 Abidjanian inhabitants is collected by a reticulation system and released into Ebrié Lagoon after incomplete primary treatment. It is estimated that the organic waste from at least 20% of the remaining 1.5 million people also enters the lagoon. This organic waste (about 20 000 tonnes/yr) consumes one third of the available oxygen in the lagoon locally. Eutrophication occurs with the increase in minerals and organic matter. Bathing in the area is considered dangerous, with more than 2000 faecal coliform bacteria per 100 ml water.

Conservation Status: The left bank of the lower Bandama River and the most westerly bank of Ebrié Lagoon are included in the Azagny National Park which is situated between the Bandama River and Ebrié Lagoon, covering 20 000 ha with an additional small buffer zone. Some 7000 ha of permanent freshwater swamp is included in the park, together with a further 10 000 ha of primary rain and seasonally inundated forest, some 550 ha of seasonally inundated grassland and about 250 ha of tidal forest. Here many locally endangered species survive, including *Cephalophus dorsalis, C. sylvicultor, Choeropsis liberiensis, Colobus polykomos, C. verus, Felis aurata, Hyemoschus aquaticus, Loxodonta africana cyclotis, Neotragus pygmaeus, Pan troglodytes* and *Syncerus caffer nanus* with *Trichechus senegalensis* and all three African crocodiles in the waterways.

Following the collapse of the lagoonal fishing industry in 1981 (in Aby Lagoon only 500 tonnes of *Ethmalosa* compared with 5000 tonnes in 1979), a number of new regulations were implemented. Seine nets are now prohibited in Tadio Lagoon, and their use is limited in Ebrié and Aby Lagoons. In addition the number of fishing licences is restricted, the lengths of the nets controlled, and the mesh size may be no less than 30 mm. The periods of the year during which fishing is permitted are also controlled.

(B) THE TADIO LAGOON COMPLEX

Location: 5°09'N/4°59'-5°25'W
Area: 23 500 ha (19 000 ha open water + 4500 swamps)
Altitude: sea level
Nearest Town: Grand Lahou (on lagoon)

General: This lagoon complex includes the Tagba, Makey, Tadio and Niouniouzou Lagoons, and the estuaries of the Ô and Bonou Rivers. It has a permanent natural opening to the sea near the town of Grand Lahou. The principal basin is elongated with an axis oriented E-W, and is 50 km long, parallel to the coast. It has a mean depth of 3 m, and communicates with Ebrié Lagoon via a man-made canal through the intervening swamps. The lagoons are fringed by marshes and there are seasonally inundated zones behind these, the latter best developed at the eastern end between the head of the lagoon

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and the estuary of the Bandama River. A further 2400 ha of swamp land is situated some 25 km up the Bandama River.

Hydrology & Water Quality: The catchments comprise a total of 104 000 km^2, 93% of which is in the drier zone. Run-off from the land is estimated at a mean volume of 10 billion m^3/year, 95% of which is contributed by the Bandama River, although there is considerable fluctuation from year to year. Direct precipitation and tidal exchange have not been estimated for this lagoon, but it is thought that residence time of riverine water is about 20 days. Water quality is much the same as that in Ebrié Lagoon.

Flora & Fauna: As for Ebrié Lagoon.

Human Impact & Utilisation: As for Ebrié Lagoon.

Conservation Status: Unprotected.

(C) THE ABY LAGOON COMPLEX

Location: 5°05'-5°23'N/2°05'-3°20'W
Area: c. 60 000 ha (41 500 ha open water + 18 500 swamp)
Altitude: sea level
Nearest Towns: Adiaké (on lagoon); Abidjan (84 km W)

General: This complex includes the Aby, Tendo and Ehy Lagoons and the Bia and Tano Estuaries. Part of Tendo Lagoon, and the whole of a large subsidiary lagoon, Univaye Lagoon, which constitute the southernmost parts of the system, are situated in Ghana. The complex comprises a main basin in the west oriented N-S perpendicular to the coast. This is 28 km long with a mean width of 8 km. The system opens to the sea at its southwestern extremity, at Assinie, where the Assinie Canal enters from Ebrié Lagoon. From the southeastern tip of the main basin, a broad arm, 3-5 km wide, known as Tendo Lagoon, leads eastwards for 36 km to terminate as Ehy Lagoon. The Tano River enters Tendo Lagoon on its seaward side. The mean water depth of the system is 3.8 m, with a maximum depths of 23 m in the centres of the basins. The lagoons and estuaries are fringed by marshy zones, and some 18 500 ha of seasonally inundated land occurs on the periphery, the bulk in two large blocks, one at the western end towards Grand Bassam, the other at the eastern end along the Tano Estuary and around the head of Ehy Lagoon.

Hydrology & Water Quality: The drainage basin of the lagoon is 26 500 km^2, situated entirely within the wetter zone. Some 30 km^2 of the catchment is situated in Ghana. Two rivers discharge into the lagoon. The Bia supplies a mean annual volume of 1.9 billion m^3 water and the Tano 4.2 billion m^3, while direct precipitation amounts to an additional annual receipt of 0.9 billion m^3. Maximum river levels occur in June and July, with secondary rises in September and October, but there is great variability from year to year. The average residence time of water in the complex has been given as 146 days, but volumetric details of the tidal flux are not known. Water quality is similar to that given for Ebrié Lagoon.

Flora & Fauna: As for Ebrié Lagoon.

Human Impact & Utilisation: As for Ebrié Lagoon.

Conservation Status: Ehotilés National Park comprises a group of five islands situated in Aby Lagoon, which is otherwise unprotected.

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2. Minor Lagoons

(A) PETIT DIGOUE LAGOON

Location: 4°42'N/6°46'W
Area: 150 ha open water
Altitude: sea level
Nearest Towns: Menolé (6 km W); Sassandra (80 km E)

General: This is an open inlet rather than a lagoon, but it is often referred to as a lagoon. It is 3 km long and some 500 m wide. It is protected from high wave energy by low headlands and by the fact that it is branched behind the mouth. It supports some tidal forest, and receives water from the Krénovo/Néma River, and another coastal stream. Patches of swamp forest occur on all three streams.

(B) DIGOUE LAGOON

Location: 4°44'N/6°40'W
Area: c. 480 ha open water
Altitude: sea level
Nearest Towns: San Pedro (5 km E); Abidjan (310 km E)

General: This is a closed lagoon situated a few kilometres west of San Pedro. It is just over 5 km long, over 2 km wide in the centre, and is oriented roughly E-W parallel with the rocky/sandy coast. It receives water from three local streams. The Baba is the largest of these and rises some 6 km inland at an altitude of 50 m. A watercourse, the Dreganobo Stream, connects the lagoon to the San Pedro River and water flow in this stream is reversible. The southern extremity of the lagoon is very close to the sea beach at Digoué, and at times of high water the sand-bar may be breached. There are permanently marshy zones around the lagoon, and a zone which is inundated periodically. Other small permanent swamps occur in the headwaters of the Baba River.

(C) KATIBO LAGOON

Location: 5°03'N/5°47'W
Area: c. 640 ha
Altitude: sea level
Nearest Towns: Fresco (24 km E); Abidjan (200 km E)

General: Katibo Lagoon is a flooded valley system, set in steep coastal hills. The lagoon has two arms, each 4 km long, and each much branched. The arms diverge inland, one oriented NE, the other NW. The valley sides rise steeply from the water along both arms, reaching an elevation of 51 m above the water just 100 m from the shore of the NW arm. Several minor streams enter the arms and their branches, but the lagoon is closed at the seaward end by a sand-bar, which is usually breached during the rainy season. There are no important swamps on the steep shores which are forested down to the water's edge. There are 7 very minor lagoons in the district, 1 west and 6 east of Katibo Lagoon. These are little lakes at the ends of ephemeral streams which become dammed behind the coastal sand-bar.

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(D) FRESCO LAGOON

Location: 5°06'N/5°35'W
Area: 1700 ha open water
Altitude: sea level
Nearest Towns: Fresco (on lagoon); Abidjan (180 km E)

General: The Bolo and Nioumouzou Rivers discharge into the lagoon, which has a wide mouth open to the ocean. The lagoon shores are marshy in places, particularly along the estuaries, and there are areas subject to seasonal inundation immediately behind the marshes. There are small mangrove stands inside the lagoon mouth, and some swamp forest occurs at the river mouths.

(E) HEBE & KODIOBOUE LAGOONS

Location: 5°12'N/3°30'W (Hebé); 5°14'N/3°35'W (Kodioboué)
Area: c. 1400 ha (total, both lagoons)
Altitude: sea level
Nearest Towns: Grand Bassam (20 km W); Abidjan (50 km W)

General: These are separate closed lagoons, situated some few kilometres behind the beach barrier dunes, almost equidistant from Ebrié and Aby Lagoons. They are surrounded by marshlands, behind which there are small zones subject to seasonal inundation. Some *Avicennia africana* is present.

3. Riverine Wetlands

General: As discussed earlier, the great seasonality of the rainfall causes the inundation of narrow strips along the banks of most interior rivers, but there are no major floodplains in Côte d'Ivoire. However, although they are too numerous to deal with individually, many small wetland areas, patches of swamp forest, strips of periodically inundated gallery forest, patches of grassy floodplain, riparian reed swamps and dambos occur throughout the higher plateau region, north of the parallel 8°N. Wetlands are comparatively scarce south of this parallel, because the rivers flow more steeply down to the coast from this point. Along the western part of the coast small mangrove stands occur at river mouths, many of which are protected from wave action in some way. Many such small wetland areas are protected in National Parks or other reserves. A brief account of some interior wetlands is given here by river system.

(A) MINOR WESTERN RIVERS

General: Tidal swamps, grading into freshwater swamps occur in the estuaries of the Houo River (4°30'N/7°12'W), the Niégwabo River (4°31'N/7°07'W) and the Dodo River (4°32'N/7°03'W). Swamps extend 7 km upstream on the Dodo, and also occur in a 7 km depression to the east, away from the river.

The Nero (or Mono) River drains the highlands of SW Côte d'Ivoire between Mts. Kopé (4°59'N/7°26'W) and Niénokoué (5°25'N/7°10'W), and reaches the sea in a sheltered situation behind a promontory in western Côte d'Ivoire (4°39'N/6°55'W). It supports close to 7000 ha of swamp land around its small estuary which grades from tidal

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(mangrove) forest into freshwater tidal and seasonal swamp forest, with another 1000 ha patch of freshwater swamp forest to the east in a depression. The swamps extend inland for 12 km and reach a maximum width of 18 km across the river 4 km upstream. These forests are unprotected, but presently subject to little disturbance.

(B) THE CAVALLY & SASSANDRA RIVERS

General: Between them these two rivers drain almost the entire western part of Côte d'Ivoire; they flow directly to the sea and their lower courses are beset with waterfalls and rapids. The Taï National Park, and adjoining game and forest reserves, which in total cover 500 000 ha, are situated between the lower reaches of these streams in an area that contains numerous swamps. The National Park is reputed to contain many endemic plant species, the survival of which, at least in Côte d'Ivoire, probably depends upon the maintenance of these reserves. In addition there are several endangered animals including *Cephalopus jentinki, C. zebrae, Choeropsis liberiensis* and *Loxodonta africana cyclotis*. Upstream the Sassandra drains other wetland areas in the Mont Peko and Mont Sangbé National Parks. The lower course of the Sassandra was dammed in 1979, at Buyo, a matter dealt with later. The Cavally reaches the sea on the Liberian border at Cape Palmas, its mouth deflected a little eastwards. The Sassandra reaches the sea in a broad island studded estuary at the town of Sassandra. This is tidal for at least 22 km inland and widens to 3.2 km across the island inside the mouth. Mangroves are quite well developed at the Sassandra mouth.

(C) THE BANDAMA RIVER

General: The two branches of this river, the Bandama Rouge and Bandama Blanc Rivers, drain the central part of Côte d'Ivoire and discharge into Tagba Lagoon. The river has been dammed at Kossou producing an artificial lake in the Guinean-Soudanian transitional savanna zone. North of this lake the river banks are protected, at least ostensibly, in the Reserve de Haut Bandama, covering 10 100 ha. Farther downstream small areas of riverbank are protected in the Lamto Scientific Reserve, Azagny National Park and several Forest Reserves.

(D) THE KOMOE RIVER

General: This river drains the eastern part of Côte d'Ivoire and discharges into the eastern end of the Ebrié Lagoon complex. Formerly it had a natural outlet to the sea but this was closed by road construction in 1980. Almost the entire length of the Komoé is accompanied by riverine and gallery forest, much subject to seasonal inundation. Seasonally inundated areas occur along the river and its tributaries between 8°-9°30'N, in patches and strips which vary from 500-2000 m wide. Rice is grown on the floodplain locally, e.g. around 8°17'N/4°00'W, near the confluence with the Segbono River. About 18 000 ha of the upper valley is protected within the Komoé National Park, which itself has an area of 1 150 000 ha and is considered one of the most important conservation areas of the West African Soudanian zone. This protected stretch of the Komoé contains an important population of *Hippopotamus amphibius* in an area where the wide, seasonally inundated alluvial grasslands sustain a great variety of wildlife. There are also

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a number of permanent and seasonally flooded pans (mares) which provide an important habitat for migratory and other birds, as well as for all three African crocodile species.

The lower course of the Komoé is partly protected in the Mabi-Yaya-Sougan-Tamin Forest Reserve complex, which comprises an area of about 250 000 ha of rain forest. Roth *et al.* (1984) give some account of the large mammal populations in Côte d'Ivoire.

(E) THE GBANHALA, BAOULE & BAGOE RIVERS

General: These three rivers rise in, and drain, the northwest part of the country. They all flow northwards and are affluents of the Niger. The Gbanhala forms the border with Guinea for some distance. All these rivers, and their many affluents, have narrow floodplains, north of 9°20'N, and a deal of rice is grown along them.

4. Artificial Impoundments

(A) LAKE KOSSOU

General: The barrage on the Bandama Blanc River at Kossou was completed in 1972. The lake which developed behind the dam (7°03'-8°06'N/5°20'-5°49'W) appears from the latest maps to be 155 km long with a mean width exceeding 5 km, thus providing an open water surface of at least 77 000 ha at capacity, but lower figures, c. 40 000 ha, have been cited in some publications. The hydroelectric plant has a potential production of 535 million kWh. The lake is situated in the Guineo-Soudanian transitional savanna zone. It supports a population of *Hippopotamus amphibius*, is an important habitat for many aquatic and semi-aquatic species and has a progressively diversifying avifauna. A fishery has been developed on the lake in a joint UNDP/FAO project. The lakeshores are unprotected.

(B) LAKE BUYO

General: The Buyo Dam on the Sassandra River became operational in 1980 and produces 850 million kWh of electrical power. The lake (6°17'- 7°04'N/6°53'-7°34'W) is 130 km long, and attains a maximum width of 16 km. It is shaped like a letter U and occupies the valleys of the Sassandra and one of its ephemeral tributaries. It appears to provide an open water surface of approximately 65 000 ha at capacity, although lower figures (c. 35 000 ha) have been quoted.

(C) LAKE AYAME

General: This impoundment on the Bia River (5°42'-5°57'N/3°07'-3°18'W) provides an open water surface of some 30 000 ha in the Guinean Forest zone, behind the dam known as Ayamé I. Some few kilometres downstream there is another dam, Ayamé II, and both are used to generate hydroelectric power. The southern side of the western arm of the lake is protected in the N'Zo Faunal Reserve.

(D) MINOR IMPOUNDMENTS

General: There are several, the largest being at Man, Taabo and Ferkessédougou.

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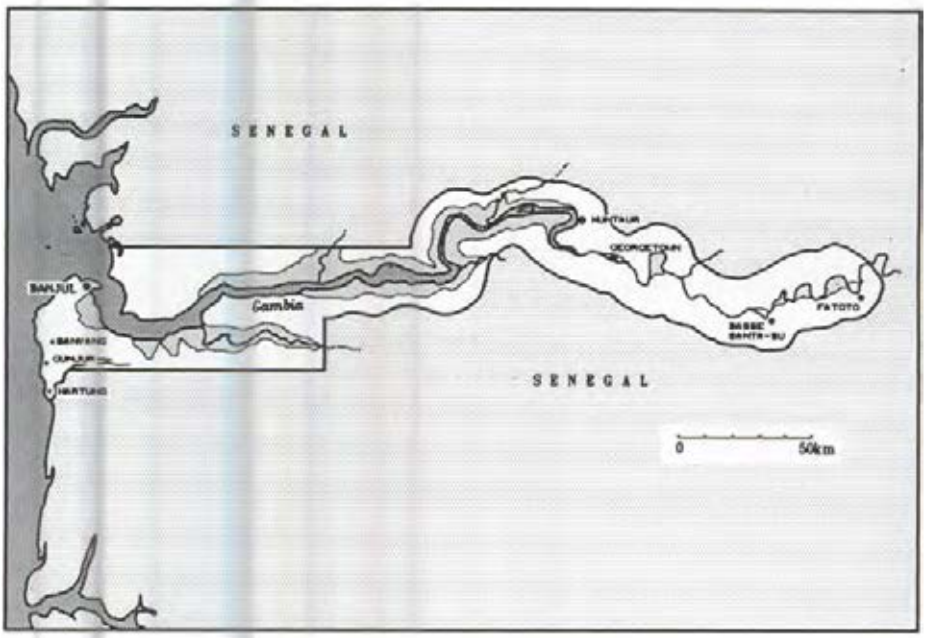

Map of Gambia

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3.5 GAMBIA

Introduction

Gambia is situated on the Atlantic coast of West Africa and, apart from its coastline, is entirely enclosed by Senegal. It occupies 10 690 km^2, and with a population of 695 886 (1983), has a mean population density of 65 persons/km^2. The country is long and narrow with a maximum width of only 45 km (N-S) and a length of 315 km (E-W), the latter being the distance it extends inland from the Atlantic Ocean. The country stretches from 13°04' to 13°44'N and from 13°53' to 16°50'W. Physiographically it is dominated by the estuary of the Gambia River which, seasonally, is weakly tidal almost as far as the eastern boundary. The river mouth is 4 km wide between Banjul (13°28'N/16°39'W) on the south bank and Barra on the north bank, but the estuary widens a few kilometres inland to a maximum of 14 km. Thereafter the channel narrows progressively in passing upstream, but is still 1 km wide more than 200 km from the mouth. The Gambian coastline, measured along inlets to the point at which their widths decline below 1 km, is thus disproportionately long, exceeding 550 km.

Both north and south of the Gambia River, the Atlantic coast is sandy and backed by parallel lines of dunes which carry littoral woodland and scrub. Several short coastal streams reach the sea on the Gambian coast, and the mouths of these are deflected along shore to form lagoons with sandy margins. The coast is one of submergence and the Gambia River valley is a drowned valley, set on a low sandstone plateau of Tertiary age. No part of the country exceeds 100 m asl. In the lower section, the muddy river banks slope gently into the water, but in the middle course the channel is braided, with many vegetated islands, and the outer banks are low cliffs, rising locally to 15 m in height. The river is navigable by ocean going ships, of up to 3000 tonnes, as far as Kuntaur, 250 km upstream, while smaller vessels can reach Georgetown (13°31'N/14°50'W), 283 km upstream. Above this place river boats carry cargo and passengers far beyond the Gambian border, but huge clearances for agriculture along the banks of the river in Senegal have led to serious increases in siltation which necessitate dredging operations to keep the channel open far downstream. Away from the river, in the west, the land surface comprises sandy hills separated by flat sandy plains, while in the east, higher land, mostly lateritic, prevails between tributaries of the river.

Climate

The intertropical convergence moves across Gambia from the south, arriving in late May and moving northwestwards to cover most of the country by June. There is a short season of intense rainfall sometime between June and October, but the onset, duration and intensity of the rains is very variable. Total annual rainfall varies by as much as 500 mm (975-1475 mm) at Keneba, 80 km inland on the Bintang Bolon, a major south bank tributary of the Gambia River. The dry season is long and severe, lasting at least from November to April inclusive, during much of which time a desiccating Harmattan wind blows from the east or northeast. Precipitation is greatest at the coast and decreases inland, as is usual in the region, but virtually the entire country receives mean annual falls in excess of 1000 mm. At both Yundum (13°23'N/16°42'W) and Banjul near the

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coast, mean annual precipitation is close to 1300 mm, while at Basse Santa Su (13°23'N/14°15'W) towards the eastern extremity, it is 1075 mm. The range of the mean monthly temperature over most of the country is 25°C (coolest month) to 30°C (warmest month), with the coastal region cooler than the interior and subject to longshore winds. Temperatures in the interior often exceed 40°C in March and April, with absolute minima of about 12°C having been recorded at several stations.

Wetlands

At the coast, swamps and marshes occur in the swales of the dunes, and there are several lagoons and some small lakes associated with minor coastal streams. Some small rivers, e.g. the Allahein (San Pedro) River, are fringed by tidal (mangrove) swamps in their lower courses and by freshwater swamps and marshes in their upper courses. On the Gambia River, permanent tidal swamps extend in a semi-continuous belt along the lower estuary and reach nearly 200 km upstream. There are approximately 45 000 ha of mangrove swamp in Gambia. Over the middle course of the river, the floodplain is inundated only during the wet season. The depth of flooding decreases downstream, but at the eastern border it may exceed 12 m. At the height of the flood, river water backs up behind the flood tide, and tidal fluctuations are transmitted much farther upstream than in the dry season.

List of Wetlands Described

1. Coastal Wetlands
2. Swamps & Marshes of the Gambia River

1. Coastal Wetlands

General: The left bank of the Allahein (San Pedro) River forms the southern border with Senegal for several kilometres above the river mouth. The river meanders southwestwards to the sea with mangroves extending upriver from the mouth in a continuous belt 1-2.2 km wide. On the landward sides of the mangroves there are bare saline mudflats in flanking strips 50-300 m wide, and these are fringed, at the tidal limits, by successive belts of saltmarsh herbs, halophytic grasses, and stunted trees. Among the latter, *Avicennia africana, Conocarpus erectus* and *Mitragyna inermis* are present. Some rice is grown on the river floodplain, to landward of the salinas in the vicinity of Kartung (13°05'N/16°45'W), but this is more common in less saline areas upstream.

Swamps extend back up the Allahein River and its affluents, almost to their sources. The mangrove forest gives way to palm and freshwater swamp forest, which may be tidal during the rains, and this in turn to herbaceous swamp land. Some 15-20 km inland, the flow of the river becomes diffuse, and the waters pass through numerous small watercourses connecting a series of little lakes and lagoons. This whole system is encompassed by tall herb swamp with patches of forest along some watercourses. However, at the upstream end of this section the river is again a single discrete stream, and from here to its source swamps used to be almost continuous. More recently however, many have been converted for rice cultivation, which in places extends in a strip 1 km wide across

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the river. In 1981 a small natural swamp, 50 m wide and 4 km long, marked the final stretch below the source.

There is an open lagoon, with about 100 ha of tidal water surface, which extends into the dune swales south of Kartung, north and west of the Allahein River mouth. Farther northwards along the coast a swamp system occurs in the dune swales between Gunjur (13°11'N/16°46'W) and Sanyang (13°16'N/16°46'W). Along this stretch of coast the dunes are covered by littoral woodland and scrub, while grass swamp and swamp forest occupies a strip 100 m wide and 10 km long between the seaward dune and the next dune inshore. At the northern end of this swamp the little Kakima River crosses the dunes, and here the swamps are 800 m wide and extend back into some more landward dune swales. Still farther north there are two small lagoons, both with sandy shores, before the Tanji River is reached. This stream has been deflected northwards along the coast by a strong northerly flowing longshore current, so that the river reaches the sea at the end of a 2 km lagoon at Cape Bald. The lagoon shores are sandy, but there is a small mangrove swamp at the head of the lagoon, covering 100 ha, and tidal influence extends upstream for about 5 km. Flow in the Tanji is intermittent, but the lagoon mouth is open semi-permanently. Between this point and the Gambia River, there is another lagoon at the mouth of Kotu Stream. This is usually closed, the sand-bar at the river mouth being breached during the rains each year. This lagoon has sandy shores and supports no mangroves.

The coast to the north of the Gambia River is sandy and exposed to strong wave action, but at the northern border, a number of small rivers (or bolons as they are known locally) merge to form the Karenti Bolon. The most important affluents here are the Niji and Massarinko Bolons. A mangrove forest extends 1.7 km across the mouth of Karenti Bolon and several kilometres upstream. On this river, in Gambia, there are about 1000 ha of mangrove forest, with the swamps extending upstream into Senegal.

Flora & Fauna: The marshes in the dune swales support tall grasses and sedges, with patches of riverine swamp woodland along watercourses. The mangrove vegetation is as described in the regional introduction. *Cercopithecus aethiops* and *C. mona* occur in all types of swamp woodland, including mangroves, while *Colobus badius* is common in riverine forest. The small mammals typically associated with herb swamps are common, e.g. *Atilax paludinosus*, *Dasymys incomtus*, *Lutra maculicollis* and *Thryonomys swinderianus*, while *Cephalophus* spp. are the commonest larger mammals. *Trichechus senegalensis* occurs in the rivers, and the herb swamps and lagoon margins support a rich avifauna, typical of the West African coast.

Human Impact & Utilisation: Hunting occurs in the swamps. *Hippopotamus amphibius* no longer occurs along the coast, except perhaps in the Karenti system, and *Crocodylus niloticus* has probably vanished from most sites. The streams are fished, and locally, rice is grown on the swamp fringes; this practice being most extensive on the middle course of the Allahein River.

Conservation Status: So far unprotected, but a National Park, to be known as the Gambia Saloum National Park, is proposed on the northern coast to include the Karenti Bolon system. It is planned that this will be contiguous with the Sini Saloum National Park in Senegal. The mangroves in this area, if protected, could be important to the survival of both crocodiles and manatees in Gambia.

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2. Swamps & Marshes of the Gambia River

General: Peak volumetric discharges from the Gambia River are in the region of 2000 m^3/sec during the flood, and 90% of the total annual discharge occurs during the 4 months from July to October. Flood waters rise by 12 m in the east, on the border with Senegal, and a great deal of land is flooded seasonally along the river, perhaps 20% of the national land surface in some years. However, the height of the flood declines towards the sea. Much of the lower estuarine floodplain is flooded every day by tidal water, and these areas are covered by mangrove vegetation. Behind this zone, on land which is flooded only very infrequently during the dry season, there are unvegetated and highly saline mudflats. These are crusted by salts during the dry season, at which time the water table has usually dropped 1 m or so below the surface. The lowness of the water table at this time of the year ensures that the waters of even very high tides do not flood the surfaces of these flats. However, by contrast, during the rains, when the water table reaches the surface, all normal high tides cause extensive surface flooding, and the depth of this is increased by the backing up of the freshwater flood coming downstream.

The lower, wide part of the Gambia Estuary is largely cloaked by mangrove forests, although there are substantial discontinuities in the mangrove belt, especially on the north side, where in places the shore is of high relief. Bare saline mudflats occur to landward of the mangroves, and at places within them, becoming progressively more extensive in passing up-estuary. The mangroves are best developed at the mouths of small affluents, while upstream on any watercourse, the tallest forest, comprising *Rhizophora* spp., occurs as a riparian strip, backed by a low open woodland of *Avicennia africana*. Far upstream, where saline influence wanes, the *Rhizophora* forests may grade into palm-pandan swamps, or into herb swamps or riverine swamp forest. Towards the estuary mouth the mangrove stands extend back from the river for 8 km or more, e.g. near Banjul, on Oyster Creek. Here, a single block of tidal forest covers 4800 ha. On this same side of the river, in passing upstream, major mangtove stands occur on Mandina Bolon, and then on Jaleh Cassa, Bulok, Pima and Payama Bolons, where the forest belt is 3 km wide and covers some 7600 ha. The principal southbank tributary is the Bintang Bolon, and swamp forests extend up this stream for 86 km and along all of its lower affluents. The mangrove belt is at first 1.5-2 km wide across this river, but this diminishes to 1 km at the 40 km mark. There may be 10 000 ha of swamp forest on this tributary system.

On the north bank of the Gambia River an extensive mangrove block occurs in the Salikene (13°29'N/15°58'W) district, comprising a total of 8000 ha. Tall mangroves occur at the mouths of the Jurunkku, Tambana and Mini Minium Bolons in a continuous forest block which continues upstream for 30 km. Here the mangrove belt is 1-2.5 km wide along a stretch of almost deltaic river bank where many streams reach the estuary in parallel. However, the mangrove belt is backed by a broad salina 2-3 km wide, and locally 6 km wide. This is tidal only during the rainy season. Farther upstream near Japeni (13°26'N/15°26'W), the river is flanked by mangrove forests 2 km wide on both banks, with salinas 1.5 km wide behind them.

The river narrows quite sharply to the east of Mansa Konko (13°20'N/15°30'W) at the limit of the drowned part of the valley, and meanders north, east and south, in a great loop. It becomes full of islands, with patches of permanent swamp forest at convex bends,

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and although still tidal, saline influence is minimal and the open mudflats give way to vegetated areas dominated by *Paspalum distichum* (= *P. vaginatum*). *Phragmites* is found in permanent swamps and rice cultivation is important in this region. The river is 300-500 m wide where it passes Georgetown (13°31'N/14°50'W) on MacCarthy Island.

In the far east of Gambia, the floodplain is characterised by a seasonally flooded area, on which grasses predominate, but with many permanent swamps supporting some trees, palms and pandans, as well as *Phragmites* and *Typha*. In the Diabugu District, for example, the swamps of Prufu (13°19'N/14°12'W), Faraba (13°22'N/14°08'W), Fajang (13°24'N/14°00'W), Jonkoto-Kubesi (13°27'N/13°59'W) and Kusum (13°26'N/13°55'W) occur along the river, each covering several hundred hectares. Many of these permanent swamps contain lakes or ponds, the largest of which are some 500 m long and perhaps 100-200 m wide. The area is deeply flooded during the wet season, at which time the ponds are in continuity with the river.

Flora & Fauna: The flora and fauna of the mangroves and the other floodplain wetlands are as described in the regional introduction, but the dry salinas in, and at the back of, the mangroves are a characteristic feature. They are prominent in all West African mangroves where mean annual precipitation is below 1500 mm and the dry season is severe. *Paspalum distichum*, *Sesuvium portulacastrum* and *Sporobolus virginicus* are to be found on the landward sides of these mudflats, among other species, with a fringe of trees including *Mitragyna inermis* at the extreme limit of flooding. As siltation raises the soil surface, so tidal flooding becomes less frequent, and the swamp tends to be colonised by non-mangrove vegetation. Where run-off from the adjacent high land is great, and salinity is not high, a herb swamp may develop between watercourses, generally dominated by *Phragmites* and *Typha*. Accounts of the mangroves and the mangrove soils adjacent to the Bintang Bolon at Keneba are given by Giglioli & Thornton (1965), Thornton & Giglioli (1965) and Giglioli & King (1966). In the east the floodplains are covered by typical floodplain grasses, including *Andropogon gayanus*, *Echinochloa pyramidalis*, *Panicum anabaptismum*, *Paspalum orbiculare* and *Vetiveria nigritana*, while permanent swamps, which are acid and peaty, contain *Oryza brachyantha*, the asclepiad *Adelostemma senegalense*, the legume *Bryaspis luplina*, *Genlisea africana* (Lentibulariaceae) and *Berchemia discolor* (Rhamnaceae). *Mimosa pigra* often forms thorny clumps in the centres of marshy areas. The typical spectrum of riverine trees is present.

Human Impact & Utilisation: The river is the principal communication route in Gambia and there has always been a deal of river traffic. The river and its affluents are fished throughout the country and there is an estuarine and offshore prawn fishery. Hunting occurs in the riverine wetlands and many species are taken, including wildfowl. *Crocodylus niloticus* and *Hippopotamus amphibius* have been hunted almost to the point of extinction and are both endangered in Gambia. *Trichechus senegalensis* also occurs in the river, but has been hunted and is now uncommon. Mangrove and other swamps along the river have been cleared for rice cultivation, but this has been a more common practice in the less saline regions upstream. Traditionally the lower estuary has been regarded as too saline for cultivation, while the middle part of the river, with its extensive freshwater floodplains, has been the principal site for agriculture. Intensified agriculture

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and the destruction of natural riverine wetlands, both in Gambia and upstream in Senegal, has brought with it the problem of increased erosion and silitation, which has necessitated dredging operations in order to keep the river channel open throughout most of its upper course.

Conservation Status: At present the only protected area on the Gambia River is the Gambia River (Baboon Island) National Park, north of Kuntaur. Here a group of 5 islands is protected. *Trichechus senegalensis* has been sighted here, together with *Hippopotamus amphibius*, and various small aquatic mammals such as *Aonyx capensis* and *Atlax paludinosus*. *Kobus ellipsiprymnus*, *Tragelaphus scriptus* and *T. spekei* are other wetland species known to occur in the park. Some mangrove swamp and lagoons may be protected in the proposed Kiangs National Park on the south bank of the Gambia River, approximately 13°25'N/15°55'W.

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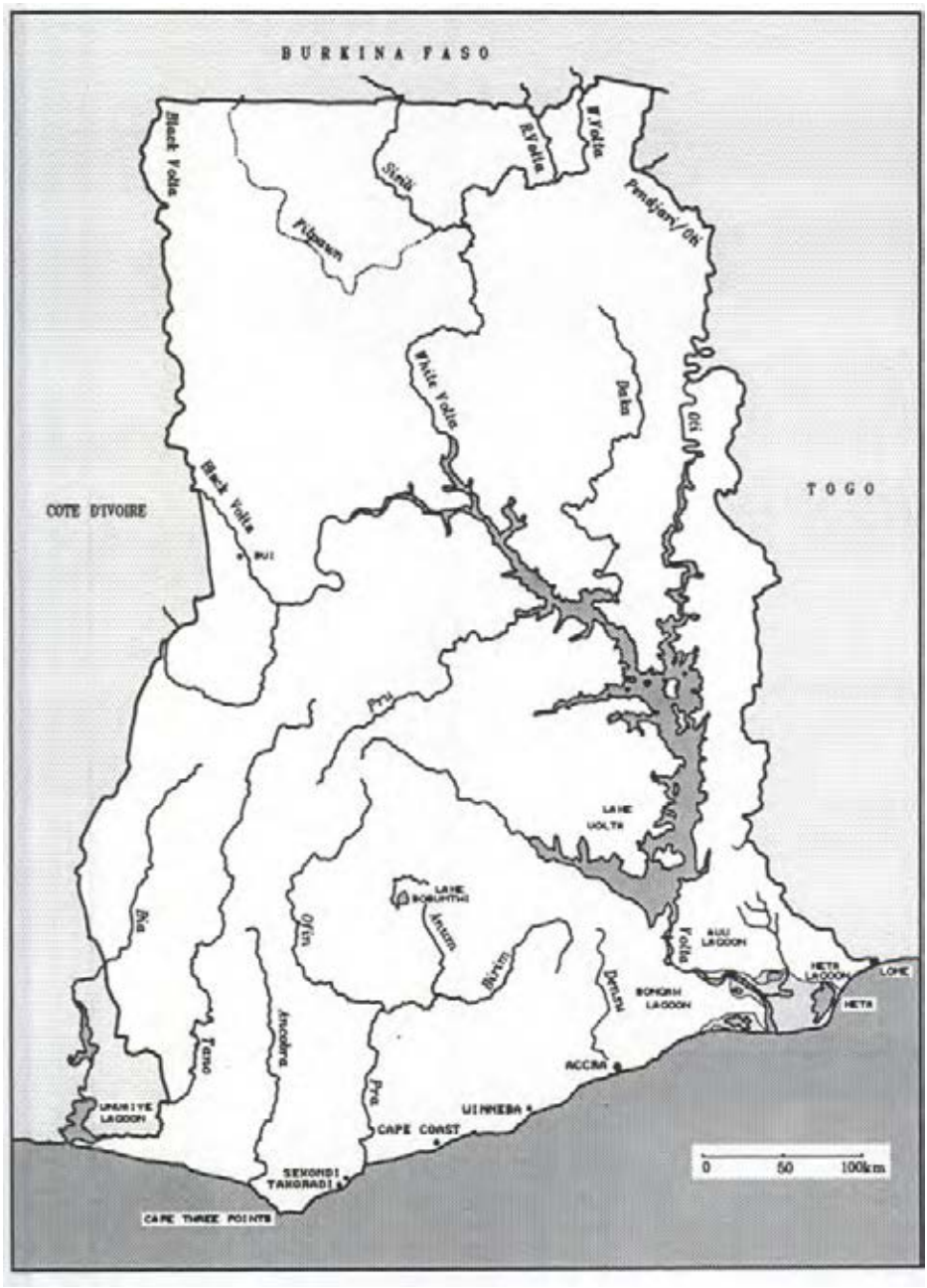

Map of Ghana

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3.6 GHANA

Introduction

Ghana covers 238 305 km^2, and with a population of 12 827 000 has a mean population density of 53.8 persons/km^2. The sandy coast extends for 580 km along the Gulf of Guinea, backed by a broad coastal plain. This is 170 km deep in the west, narrowing to 25 km near Accra (5°33'N/0°13'W), but broadening again in the east above the lagoons and delta of the Volta River, to 70 km. A triangular mountainous wedge intrudes into the country from the west, with its southern boundary backing the coastal plain along the parallel 6°N, with numerous peaks between 600-760 m asl. Mountains of the Chaîne du Togo form the lower eastern boundary, while much of the eastern interior region is occupied by the valley of the Volta, entirely below the 200 m contour and now partly flooded by the largest artificial lake in Africa. The highest points in Ghana are all in the Chaine du Togo, with a maximum of 876 m asl at Mt. Djebobo (8°20'N/0°37'E). Higher plateau land, 200-400 m asl, lies along the northern border, but is broken at the northwestern and northeastern corners by the valleys of two rivers, both tributaries of the Volta. In the northeast, the Oti River flows in from Togo, with which country it forms the border for 100 km, while in the northwest the Black Volta enters from Burkina Faso and forms the border with that country, and then with Côte d'Ivoire for a total distance of 250 km.

Drainage is dominated by the Volta system. The Black and White Volta Rivers rise to the north in Burkina Faso and unite in Lake Volta. In the southwest, the Bia and Tano Rivers rise in the southern highland wedge and flow into Aby Lagoon in Côte d'Ivoire, while the Ankobra and Pra Rivers, and several minor streams flow directly to the sea.

Climate

Ghana is situated in the dry sector of the Guinea Coast centred on the meridian, and rainfall patterns over the country are quite complex. The highest rainfall is received over the coastal plain in the southwest, west of Cape Three Points (4°45'N/2°06'W). Here mean annual precipitation reaches 2125 mm, but decreases inland up the eastern border to 1625 mm at 5°30'N, at which level it remains as far as 6°30'N. Rainfall is 1625 mm at Cape Three Points from where it decreases progressively towards Accra (769 mm/yr) and then rises marginally to about 800 mm at Cape St. Paul (5°49'N/0°57'E) and then to 1000 mm at the eastern border. The mountain peaks of the southern central sector and the southeastern border receive falls of 1700-1750 mm/yr, but rainfall over the interior diminishes from about 1350 mm at the parallel 7°N to 1200 mm at 8°30'N, while the entire north of the country receives less than 1100 mm and the extreme northeast less than 1000 mm. The western coastal region has but one wet and one dry season, despite numerous reports to the contrary. At Axim (4°53'N/2°14'W) rain falls all the year and only August is dry. A bi-modal rainfall pattern sets in to the east of Cape Three Points, and at Takoradi (4°59'N/1°43'W) the major wet season lasts for 5 months from March to July, followed by a two month dry season in August-September, after which the rains return in October-November. A second dry season lasts from December-February inclusive. At Accra the rainy season lasts only 4 months, from March-June inclusive,

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while July-September is dry. The rains return briefly in October. Inland the short dry season disappears, and at Kumasi (6°41'N/1°35'W) in the southern highlands it rains all year except for January and February. In the mid-north, at Tamale (9°25'N/0°50'W), the dry season lasts for 5 months from November-March inclusive.

Hot dusty Harmattan winds blow intermittently in the north during the long dry season. They may persist for several weeks, then cease for a period before blowing again. Occasionally they reach as far south as Accra. The mean temperature of the coolest month is 24°C at Accra and that of the warmest month is 27°C, with an identical regime at Takoradi. At Kumasi equivalent figures are 24 and 26°C, while at Tamale they are 26 and 30°C. Potential evaporation increases along the coast from west to east, and from the coast towards the north. It is estimated as 1630 mm/yr at Axim and 2058 mm/yr at Accra, and over 2200 mm/yr throughout the north. Sunshine receipts range from 1600 hrs/yr at Axim to 2400 hours/yr at Accra.

Wetlands

Small mangrove stands occur at river mouths along the coast and on some of the lagoons, being best developed on the western coast, between Côte d'Ivoire and Cape Three Points. Swamp forest and permanent herb swamps occur on rivers and streams and around Lake Amansuri, in the wet, western coastal district. Tidal saltmarshes and grasslands occur on many small lagoons in the central and eastern sectors, and grassy floodplains, with some inundated gallery and levée forest occur on many streams on the coastal plain. Other areas of seasonally inundated grassland, away from permanent watercourses, occur in the vicinity of Accra.

Other floodplains occur in the dry northern zones on the Black Volta and Oti Rivers and their tributaries. The huge water surfaces of Lake Volta and the Kpong Dam dominate the interior, and other impoundments are planned, e.g. the Bui Dam on the Black Volta. Lake Bosumtwi, a crater lake in the southern highlands, is the largest natural lake in the country.

List of Wetlands Described

1. Coastal Wetlands
    (a) The Western Border
    (b) The Amansuri Wetlands
    (c) Ankwao River
    (d) Cape Three Points to Takoradi
    (e) Krobu River - Cape Coast District
    (f) Amisa River & Lagoon
    (g) Nakwa River & Lagoon
    (h) Sumina & Apabaka Lagoons
    (i) The Winneba Wetlands
    (j) Wetlands of the Accra District
    (k) The Volta Delta

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2. Floodplains of the North
   (a) The North East
   (b) The North West
3. Lake Bosumtwi
4. Artificial Impoundments
   (a) Lake Volta
   (b) Lake Bui (projected)
   (c) Other Impoundments

1. Coastal Wetlands

General: The wetlands are described from west to east along the coast. Most of the systems are small and only brief details are provided, since most conform to the pattern of typical open or closed lagoons at river mouths, described in the regional introduction. Biney (1982) gives a detailed account of the water chemistry and physical characteristics of 15 major lagoons on the Ghana Coast, while Mensah (1979) has reviewed work on the Ghana Lagoons to that date.

(A) THE WESTERN BORDER

General: In the extreme west, Unvaiye Lagoon (5°07'N/2°55'W) of 200 ha area, and which is entirely situated in Ghana, opens into Ehy Lagoon in Côte d'Ivoire, itself part of the Aby Lagoon complex. Close to it, and opening to the sea at 2°47'W, is the small Domini Lagoon, which with its peripheral zones of inundation covers some 400 ha. A few kilometres inland, the Ghana/Côte d'Ivoire border is delineated by the channel of the Tano River, which discharges into Ehy Lagoon, but above the lagoon permanent forested swamps cover 7500 ha in Ghana.

(B) THE AMANSURI WETLANDS

General: In moving east along the coast, a block of 8 000 ha of semi-permanent swamp land surrounds Lake Amansuri which lies 2.5 km inland behind a sandy/rocky coast which obstructs drainage seawards at 2°34'W. The lake measures 2.5km x1 km and is rectangular, with an open water surface of 2600 ha, while the surrounding wetland measures 24 km across and 11 km deep. Amansuri Lake receives water from several small streams, notably the Adenimumio, Evini, Bosoke, Eivla and Myejini, which have a combined catchment of close to 1010 km^2, mostly below the 50 m contour. The system is very flat, but is backed to landward by low hills about 10 km from the coast.

The lake has a mean depth of 2.8 m with a maximum depth of 5 m. The swamp lands are inundated to a depth of 1 m during the rainy season, but tend to dry completely by the end of the dry season. The lake level falls by 1-2 m in the dry season and the inflows cease so that the residual lake water becomes stagnant. The system drains via the Amansuri River to Amansuri Lagoon on the coast farther east at 2°23'W. The constricted mouth of this lagoon is mostly open, and the swamps and zone of temporary inundation which enclose the lagoon, extend inland for 12.5 km, attaining a maximum width of 8 km

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and an area approaching 9 000 ha. Secchi depths in the lake reach 1.1 m, and pH varies from 7.0 in the peripheral sedge zone to 5.9 in the open water. The concentrations of the principal ions are sodium 17 mg/l; potassium 2 mg/l; calcium 1.6 mg/l; sulphate 22 mg/l and chloride 20 mg/l.

The dominant macrophytes in the peripheral vegetation of the lake are *Fuirena umbellata* and *Rhynchospora wallichiana* in the fringing sedge zone, *Nymphaea lotus* and *N. maculata* in a zone of rooted, floating leaved plants, and in deeper water *Nymphoides indica* and *Cyrtosperma senegalense* with some *Raphia hookeri* and *R. vinifera* in water up to 3 m deep, with *Vossia cuspidata* between the stem bases. *Chrysichthys vellifer*, *Hemichromis fasciatus* and *Tilapia aurea* are the commonest fish. There are several villages in the area, with a total population approaching 5000. The lake is fished quite intensively from a fishing village built out into the lake on piles, coconuts are grown on the periphery of the swamps. *Raphia* palms are tapped for their sap, and hunting occurs in the swamps.

(C) ANKWAO RIVER

General: A 9000 ha floodplain which includes patches of permanent swamp land extends 15 km upstream from the mouth of the Ankwao River (2°15'W), reaching widths of up to 6 km.

(D) CAPE THREE POINTS TO TAKORADI

General: To the east of Cape Three Points, semi-permanent swamps occupy some 1200 ha on the Suni River (2°00'W) along the boundary of the Cape Three Points Forest Reserve. In continuing east, a zone of inundation occupying 950 ha occurs on an ephemeral stream which reaches the sea at longitude 1°54'W, and again there are small tidal floodplains on the little inlets at Mpatano (1°52'W) and Apowa (1°50'W). Immediately behind the mouth of the Hwini River (1°47'W) there is floodplain of 850 ha, and another small wetland exists immediately east of Takoradi (1°45'W).

(E) KROBU RIVER - CAPE COAST DISTRICT

General: A floodplain with some patches of permanent swamp, the lower parts of which experience some tidal influence, covers a total of 6000 ha behind the Krobu River mouth (1°37'W). It extends 7.5 km along the coast and 7.5 km inland. Farther east there are 8 isolated pockets which are subject to inundation during the rains. These include small areas of permanent swamp and total 4000 ha in extent. They are situated inland of Komenda (1°30'W), and a further 6 patches are situated inland of the town of Cape Coast (1°15'W). *Raphia* spp. occur in all these swamps. The small lagoon at Apa (1°10'W) has an open water area of a few hundred hectares.

(F) AMISA RIVER & LAGOON

General: There is a substantial lagoon at the mouth of the Amisa River (1°00'W). The lagoon is 3 km long and 1 km wide, while the peripheral floodplain covers 7500 ha and extends inland for 15 km, with widths of up to 8 km. The lagoon mouth is perennial.

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(G) NAKWA RIVER & LAGOON

General: Here (0°55'W) the lagoon has a maximum width of 1.7 km and is 5 km long, oriented E-W parallel with the coast, while a swampy floodplain extends up the Nakwa River for 30 km. There are patches of semi-permanent swamp a few kilometres distant from the river in depressions. The total on this system probably amounts to a little over 7200 ha, including the open water surface of the lagoon. *Raphia* spp. occur in this system.

(H) SUMINA & APABAKA LAGOONS

General: Still farther east are the little Sumina Lagoon (0°48'W), and Apabaka Lagoon (0°44'W), which with its peripheral tidal inundation zone occupies 1000 ha.

(I) THE WINNEBA WETLANDS

General: Areas of tidal and seasonal inundation occur around Muni Lagoon to the west of Winneba (0°37'W), while a floodplain and a lower tidal inundation zone occur on the Ayensu River which discharges to Ouiba Lagoon to the east of the town. The combined wetland extends along the coast behind the coastal dunes, for 12.5 km, and reaches 4 km inland. Other patches, totalling 2000 ha, subject to seasonal inundation occur inland on the Pon Pon, Ngana and Okruda Rivers, centred on a longitude of 0°26'W.

(J) WETLANDS OF THE ACCRA DISTRICT

General: West of Accra some seasonally inundated grasslands are found upstream on the Densu River and its tributaries extending 27.5 km inland from the sea, at a point 0°20'W, totalling some 6700 ha in extent. Tidal influence extends at least 10 km upstream and the lower pocket is partly tidal. Other areas of seasonally inundated grassland occur to the east of the city, amounting to another 3000 ha, situated between 20-38 km inland, at longitude 0°05'W. The vegetation of such coastal grasslands is dealt with in the regional introduction. Between the Accra wetlands and the Volta Delta there are 5 small lagoons, each with small peripheral inundation zones. Sakumona Lagoon (0°02'W) is the most westerly and Jange (0°10'E) and Moyo (0°12'E) the most easterly.

(K) THE VOLTA DELTA

General: Towards the eastern border with Togo, the delta of the Volta River extends for 82 km along the coast and associated wetlands extend upstream for 75 km. The wetlands fall into two blocks. The westward block comprises 25 500 ha, which includes Songaw Lagoon (0°30'E), some 16 km long from east to west and 7 km wide. The whole western block is 10 km deep along the river and tapers down to 4 km at the western end, over a distance of 36 km. The eastern block is much larger and includes Keta (0°50'E) and Avu Lagoons, and numerous small lakes and lakelets. It covers a total of 167 000 ha. Keta Lagoon has an open water surface of 27 000 ha and measures 27 km in length and 15 km in maximum width. Avu Lagoon is 11 km long with a maximum width of 5 km. The mouth of the Volta is 750 m wide, but immediately inside the mouth the river contains several islands and the channel

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expands to a width of 5 km. The total area of 182 000 ha, save for that of the lagoons, is flooded seasonally, but permanent swampland exists in a number of localities throughout the delta. These are concentrated on the east bank of the main channel and on the margins of some of the islands.

Songaw Lagoon has a mean depth of 1.75 m and a maximum depth of 4 m, while the corresponding figures for Keta Lagoon are 80 cm and 2 m. The mean pH values for these lagoons are 7.2 and 8.1 respectively, and mean salinity is 2.3 and 18.7 ‰. Mean Secchi depths are 85 cm and 35 cm. Water temperatures average 29.5°C in Songaw and 31.2°C in Keta Lagoon. Sodium and chloride are the principal ions in Songaw Lagoon, each having concentrations close to 35 meq/l, while potassium, calcium, magnesium and other anions are very low, all about 1 meq/l. In Keta Lagoon sodium and chloride both reach mean annual concentrations close to 280 meq/l, while the figures for potassium, calcium and magnesium are 9, 19 and 12 meq/l respectively, and those for bicarbonate and sulphate are 2 and 22 meq/l respectively. Songaw Lagoon is very rich in nitrates.

Flora & Fauna: As described in the regional introduction.

Human Impact & Utilisation: The construction of the dams on the Volta at Akosombo and Kpong has affected the ecology of Avu and Keta Lagoons, leading to lower water levels and increased salinities as seasonal floods in the delta have virtually ceased. The only discharges nowadays are those associated with the generation of electricity. Songaw Lagoon has however, been little affected. Some rice is grown on the coastal floodplains, and the estuaries and lagoons are fished intensively. Over 57 000 people were engaged in the fishing industry in 1960, and recent reports suggest that this figure has not altered significantly, due to the well developed fishery on Lake Volta. However, canoes have largely given way to motor boats as fishing vessels, and catches have increased. Sea fishing is now carried out almost exclusively by motor boats and large trawlers, but lagoon and lake fishing still involves traditional canoes. The mean national annual catch was close to 40 000 tonnes from inland waters and 184 000 tonnes from coastal waters in 1984 (FAO statistics). The bulk of the inland fish catch comes from Lake Volta. Prior to the construction of the dam at Akosombo, Keta Lagoon was the most principal source of non-marine fish and, although diminished in importance, it still supplies a substantial proportion of the inland catch. Oysters are farmed in the lower Volta below the Kpong Dam. Rice is grown on some of the coastal floodplains and the acreage converted to rice paddy is increasing.

Conservation Status: No coastal wetland is legally protected.

2. Floodplains of the North

(A) THE NORTH EAST

General: The Oti River, known as the Pendjari in Togo, enters Ghana in the far northeast and meanders south to the head of the eastern arm of Lake Volta. It has a seasonal floodplain 55 km long, averaging 7 km in width, at first, but at a point 10°35'N enters a stretch of permanent swamps with reeds and trees. This swamp extends downstream for 35 km, and also for 20 km up the Silébonga, a left bank tributary, and terminates at a point 10°23'N. Below this point floodplains are poorly developed, and extend away from

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the river for any distance only where tributaries enter. However, other floodplains occur on the western tributaries, e.g. the Gambara, Kountoné, Nagla, Wakpé, Bupiala and Kulaw Rivers. Altogether there are about 93 000 ha of wetland on the Oti and its tributaries.

The Red and White Volta Rivers both enter Ghana from Burkina Faso in the northeast of the country, coming to a confluence 160 m asl near the town of Gambaga (10°32'N/0°27'W). Above the confluence there is a floodplain on the White Volta (10°56'N/0°23'W), covering 3600 ha, and below the confluence, where the White Volta flows due west for a distance of 60 km, there is an intermittent floodplain to a longitude of 1°02'W, with a total area of close to 5500 ha. At this longitude the river turns abruptly south, and flows for a further 200 km to enter the head of the western arm of Lake Volta. En route there are intermittent floodplains, which include some oxbow lakes, for the first 60 km, and thereafter a continuous floodplain for the remaining 140 km. This latter floodplain has an average width of 4 km and also includes numerous little oxbow lakes. It has a total area of 60 000 ha. Other floodplains occur on several tributaries, notably the Nasia, Nyagpuni, Bumli, Kulabong and Paw Rivers. Here there are a further 55 500 ha of wetland, including some 15 000 ha of permanent herb swamp in on the Paw, Bumli and Nyagpuni Rivers.

Yet another 21 000 ha of permanent swamp land is situated along the Kalurakuni River and its tributary, the Mawli River, over a distance of 75 km above the western arm of Lake Volta, into which the Kalurakuni River discharges. Thus, at a conservative estimate, there are 238 600 ha of swamp and floodplain in northeastern Ghana on affluents of Lake Volta.

Hydrology: The floodplains on the tributaries of the Oti and Volta Rivers respond rapidly to rains over the local catchments which reach their peak from July-September, and the rivers thus flood from August-October. Water depths exceed 3.5 m on some of the eastern floodplains. The floods on the Volta River, which has its sources farther north, peak later and tend to extend flooding on the tributaries.

Flora & Fauna: As described in the regional introduction for herb swamps and floodplains of the Soudanian savanna region.

Human Impact & Utilisation: Cattle are grazed on the floodplains as the floods recede, and the rivers, lakes and floodplains are fished extensively. In recent years rice cultivation has begun in the area.

Conservation Status: Unprotected.

(B) THE NORTH WEST

General: The Black Volta River enters Ghana at its northwestern extremity and flows south along the Ghana/Burkina Faso border, and then along the Ghana/Côte d'Ivoire border for a total of 250 km. Over this stretch it receives tributaries principally from the higher lands to the west, while the streams entering the left bank, from Ghana, are not perennial. A discontinuous floodplain occurs along the Black Volta, and a narrow floodplain occurs on the Kohodio River which crosses the border from Côte d'Ivoire and now joins the Black Volta above Bui. From here the Black Volta flows east to enter the western extremity of Lake Volta, in this stretch receiving a major tributary, the Tain

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River shortly below Bui. The Tain rises in the southern highland wedge and flows due north to the Black Volta, and both it and its several affluents have narrow floodplains and headwater swamps. The total area of wetland on the Black Volta system has not been assessed accurately.

Hydrology: Floods peak in September-October.

Flora & Fauna: Essentially as described in the regional introduction for the Soudanian savanna zone; however large mammals are scarce. The intermittent affluents entering the Black Volta from Ghana carry gallery forest, some of which is flooded, and most of which is dominated by *Cola laurifolia*, *Diospyros mespiliformis* and *Syzygium guineense* in the wetter parts, and by *Borassus aethiopum*, *Cola laurifolia*, *Isoberlinia grandiflora* and *Kigelia africana* in drier parts. Two crocodiles, *Crocodylus cataphractus* and *C. niloticus* and two monitors, *Varanus exanthematicus* and *V. niloticus*, occur here. Among the large mammals recorded are *Cephalophus rufilatus*, *Hippopotamus amphibius*, *Kobus ellipsiprymnus*, *K. kob*, *Redunca arundinum*, *Sylvicapra grimmia*, *Syncerus caffer* and *Tragelaphus scriptus*. Locally, *Colobus polykomos* is common in the gallery forest trees.

Human Impact & Utilisation: Some rice is grown on the floodplain of the Kohodio River, and also farther north on the Black Volta. The river is fished, and some hunting occurs along the river.

Conservation Status: Unprotected, apart from the lower Kohodio River and the banks of the river which are protected in Bui National Park.

3. Lake Bosumtwi

Location: 6°30'N/1°24'W
Area: 3850 ha
Altitude: c. 130 m asl
Nearest Town: Accra (165 km SE)

General: Bosumtwi is a crater lake, almost circular in outline, with steep shores and a diameter of 7 km. A low hill rises to 145 m on its northern rim, and the land slopes up from its southern bank to a peak of 215 m asl some 10 km distant. There is a small fishery.

4. Artificial Impoundments

(A) LAKE VOLTA

Location: 6°16'-9°13'N/1°03'W-0°20'E
Area: 848 225 ha (open water surface - low water)
Altitude: 91 m asl (high water)
Nearest Town: Accra (90 km SSW)

General: The dam at Akosombo, just 100 km from the sea on the Volta River, was closed in 1964 to create the largest artificial water body in Africa. Lake Volta stretches 320 km from N-S, but the long axis of the lake measures 390 km. In the lower basin the lake has a mean width of more than 20 km, and the maximum depth of 75 m is found in the lower

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southern basin near the dam. The lake occupies a much branched river valley and has a shoreline of 4827 km (Welcomme, 1972). The annual draw-down arises only from evaporation and from the constant discharge necessary to generate hydroelectric power. The lake has seldom been full to capacity and large expanses of flat land are exposed around the lake margin. Three to four year's floods are required to fill the lake to capacity. The northern part of the lake is subject to a Soudanian climate with one wet and one dry season. The weather is rainy and windy from July-October and calm, warm and dry for the rest of the year. In the south, in the so-called forest zone (now very largely deforested), the climate is bi-modal as at Accra. A useful introductory account of the lake is given by Beadle (1981). In 1981 a second dam was completed at Kpong, 18 km downstream from the Akosombo Dam. Both dams are used to generate hydroelectric power.

Hydrology & Water Quality: The Volta Lake is fed principally by three rivers, the Oti and the Black and White Volta, and is drained by the Volta, the mean discharge rate of which, at the mouth, is 1176 m^3/sec. Direct precipitation makes a substantial contribution to the annual water receipt of the lake. The lake contains some 1640 billion m^3 of water at capacity (Petr pers. comm.), although far larger volumes have been cited in diverse publications. The water is well mixed and well oxygenated during the rainy and flood seasons, but it usually stratifies during the dry season when the bottom layer may become de-oxygenated.

Flora & Fauna: The peripheral aquatic vegetation is dominated by *Pistia stratiotes* and *Ceratophyllum demersum*, with some waterlilies in the shallow bays, backed by a reed-sedge flora. Floodplain grasses, including *Echinochloa pyramidalis* and *Oryza barthii* occur in areas subject to strong seasonal fluctuations in water level, and *Vossia cuspidata* occurs in the reed-sedge swamps around the margins. Gallery forest occurs along the northern rivers entering the lake, while some southern streams support high forest of the Guineo-Soudanian transition zone. Preliminary discussions of the fish fauna, together with numerous references to research papers, are given by Lowe-McConnell (1975) and Beadle (1981). Several papers by Petr (1968a,b,c; 1969; 1970a,b; 1971; 1972) relate to the faunal changes during the filling period. Mammals recorded in the rivers and riparian forests at the heads of the arms of the lake include *Cephalophus rufilotus*, *Cercopithecus aethiops*, *C. mona*, *C. nictitans*, *Colobus polykomos*, *Hippopotamus amphibius*, *Kobus ellipsiprymnus*, *Potamochoerus porcus*, *Sylvicapra grimmia* and *Tragelophus scriptus*, but all are now scarce, except in the National Park. Crocodiles and terrapins are also present, including, reputedly, *Osteolaemus tetraspis*.

Human Impact & Utilisation: The creation of the lake flooded a large area of seasonal wetland, and displaced the resident large mammal fauna, and has had an adverse effect upon fisheries in the delta. However, a new and more productive fishery has been established on the lake, with an estimated maximum sustainable yield of 39 000 tonnes/yr. Early catches, shortly after filling, were in the vicinity of 60 000 tonnes/yr, while the 1984 figure was 40 000 tonnes. Productivity in the young lake was higher than in the mature lake, as is usual with impoundments, thus accounting for some of the very high early catches. The mean annual catch now fluctuates about the estimated maximum sustainable yield. The lake has become an important site for

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aquatic birds, and there is an expanding reptilian fauna associated with it. The creation of the reservoir reduced the incidence of human sleeping sickness by destroying the breeding sites of tsetse flies along the river, but also by displacing the human population. A vector of bilharzia, *Bulinus truncatus*, has however become established in the lake and many fishermen are affected.

Conservation Status: The lake is unprotected, except for an area on the west central shore in the Digya National Park which borders two major arms of the lake and encompasses a third. The park extends from the south shore of the Sene Arm of the lake (7°32'N) to the north shore of the Obosum Arm of the lake (7°03'N) and includes the Djuwa Arm; the arms being named after the river valleys that have partially been flooded. The park extends east to the longitude 0°45'W.

(B) LAKE BUI (PROJECTED)

Location: projected, 8°19'-8°44'N/2°11'-2°26'W
Area: projected, c. 47 000 ha
Altitude: projected, c. 210 m asl
Nearest Towns: Sekondi-Takoradi (385 km S); Accra (380 km SE)

General: Although it has been marked on many maps and atlases since the 1960s, Lake Bui still does not exist. It is discussed here simply because excluding it might appear as a major omission. A 1985 report for the Volta River Authority by Acres International Ltd., of 5259 Dorchester Road, Niagara Falls, Ontario L2E 6W1, Canada, lists a dam at Bui among several alternative possible future developments. If built, the reservoir behind the dam at Bui on the Black Volta will provide an open water surface some 50.5 km long and up to 20 km wide. The lake so formed would be set in savanna country in the Bui National Park, and some gallery forests on the Black Volta and Kohodio Rivers would be destroyed.

Flora & Fauna: Not Applicable.

Conservation Status: If the dam is built the lake will be encompassed by the Bui National Park, established in 1983, and all its shores will be protected.

(C) OTHER IMPOUNDMENTS

General: Other impoundments exist at Voa, Tono, Weija, Dawhenge and Barekese.

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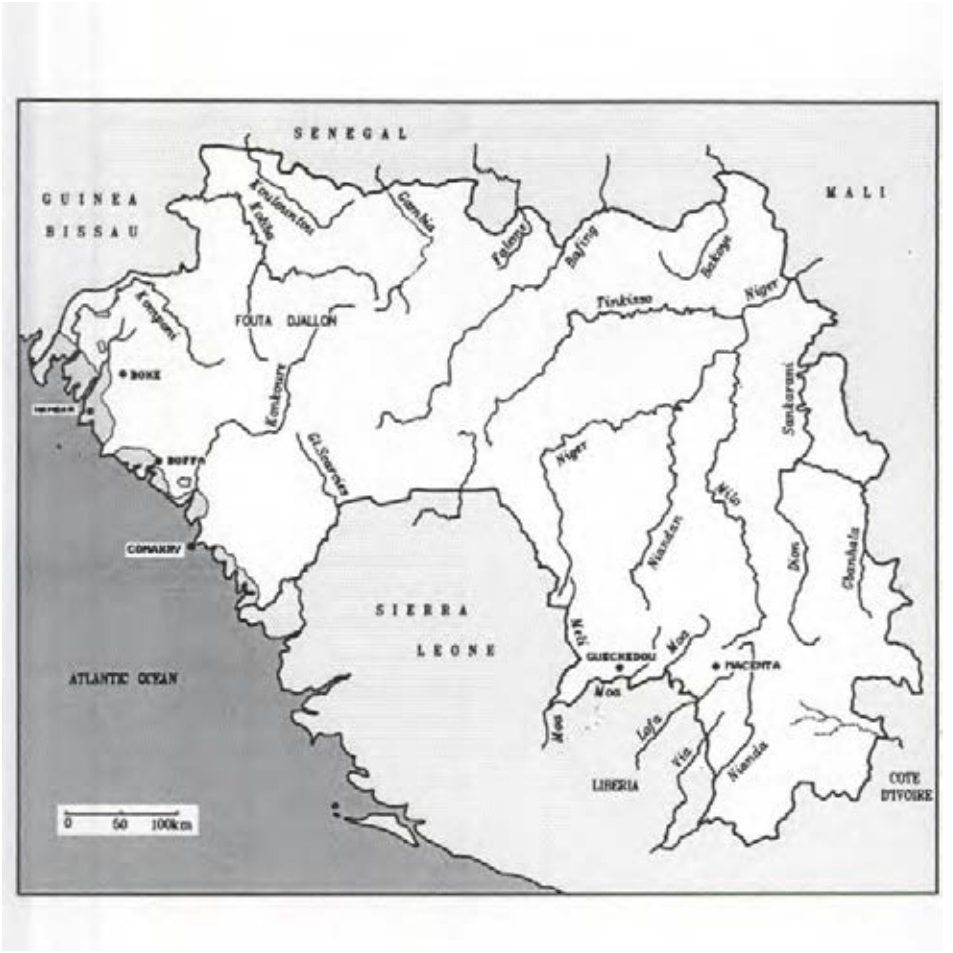

Map of Guinea

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3.7 GUINEA

Introduction

Guinea has an area of 245 855 km^2, a population of 5 412 000 (1983) and therefore, a mean population density of 22 persons/km^2. It is bounded by Guinea Bissau, Senegal and Mali in the north, by Côte d'Ivoire in the east, and by Liberia and Sierra Leone in the south. The country extends for some 600 km from north to south between latitudes 7°13' and 12°38'N, and about 775 km from east to west between longitudes 7°36' and 15°00'W.

The 280 km coastal sector is mainly deltaic, and 50 years ago, was mangrove clad along its entire length, except for a short section about Cape Verga (10°13'N/14°27'W) and in the vicinity of Conakry (9°31'N/13°43'W). However, in recent years much coastal forest has been cleared for agriculture so that there are now substantial gaps in the mangrove belt. The coastal plain is 60 km wide in the southern section, but narrows in moving northwards to 30 km in the central section, and is fully intercepted by hills which reach the sea at Conakry and again at Cape Verga. From this latter point the coastal plain broadens to a maximum width of 90 km at the northern border. Inland the foothills of the Fouta Djallon Mountains, which form the northwestern end of the so-called Guinean Dorsale, rise abruptly from the coastal plain. Indeed, immediately behind the Bay of Sangareya, to the north of the Conakry Peninsula, a hill rises from tidally inundated land to a height of 630 m asl, over a horizontal distance of 2 km and another, at the base of the Conakry Peninsula, has an elevation of 1000 m above the plain just 2 km distant.

The Guinean Dorsale runs southeastwards from the Fouta Djallon Mountains to the Nimba Mountains on the border with Côte d'Ivoire. It is here, at Mt. Nimba (7°38'N/8°24'W), that the highest point in Guinea is reached, at 1752 m asl. However, many peaks in the Fouta Djallon and Nimba Mountains exceed 1000 m, and the northwestern and southeastern areas are mountainous and deeply dissected.

The watershed of the Guinean Dorsale is roughly aligned NW-SE along the borders with Sierra Leone and Liberia, and from this region drainage is either southwestwards to the Atlantic Ocean or northeastwards to the upper Niger Basin. The Niger River rises in Guinea, in the Fouta Djallon Mountains, close to the Sierra Leone border (9°07'N/10°40'W) and just 17 km from the highest point in the Guinean Dorsale (1853 m asl in Sierra Leone). From its source the Niger flows northeastwards across the centre of a vast shallow basin. It is joined, towards the northeastern side of the basin, by the Bala and Milo Rivers on the right bank and by the Tinkisso River on the left bank. Both these latter streams meander excessively for several hundred kilometres above their confluences. The Tinkisso drains part of the Fouta Djallon, while the Milo drains the Nimba Mountains. The Niger is a broad stream, several kilometres wide, where it leaves Guinea and enters Mali.

Other rivers draining the dorsale and flowing north, at least initially, are the Koliba (Tominé), which swings towards the coast and enters Guinea Bissau as the Corubal River; several ephemeral headwater streams of the Gambia River, which flow into Senegal; the Senegal River; the Bafing River, a major tributary of the Senegal River, which initially flows through Mali; several ephemeral affluents of the Niger; and tha

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Gbanhala/Sankarani River which flows northwards along the Guinea/Côte d'Ivoire border and later along the Guinea/Mali border. In the east, some minor streams draining the Nimba Mountains flow into Côte d'Ivoire as tributaries of the Sassandra River. Many streams drain the dorsale southwestwards to the sea through other countries, the most important being the Saint Paul River which flows from southern Guinea into Sierra Leone. The most important of the purely Guinean streams are, as they reach the sea from north to south, the Kogon, Nunez, Fatala, Konkouré and Kolent Rivers, the latter forming the Guinea/Sierra Leone border for 156 km above its mouth.

Climate

Rainfall is greatest at the coast and decreases inland. The coast, running NW-SE, is opposed at right angles to the path of the prevailing, moisture laden, SW Trade Winds. At the coast, north of Cape Verga, mean annual precipitation is between 2500-3000 mm, increasing to more than 3000 mm south of Cape Verga. A very wet pocket, receiving more than 4000 mm/yr occurs around Conakry, extending for some 50 km along the coast and up to 50 km inland. However, from Conakry to the southern border coastal rainfall declines to 3500 mm/yr. In the interior, most of the Fouta Djallon and the Guinean Dorsale receive mean annual falls of 2500-3000 mm, while the Niger Basin in the northwest receives 1500-2000 mm/yr. These high rainfalls are somewhat deceptive in that rain is highly seasonal throughout the country, with a 5 month dry season at the coast and a 6-7 month dry season inland. Thus, at Conakry, where mean annual rainfall is 4370 mm, no less than 4318 mm, or 98.8%, falls in the 7 months May-November, and only 52 mm falls between December and April. Precipitation is extremely intense at the height of the rainy season. Averaged over the past 25 years, 2493 mm falls in August to September, but only 3 mm in December to January. This same pattern is followed in the other regions, e.g. at Labé (11°19'N/12°17'W) in the central Fouta Djallon. Here mean annual rainfall is 1699 mm, with 1581 mm falling in the 6 month wet season, i.e. 93% of the annual total. Again some months are virtually rainless. Conakry has 155 rainy days/yr, Labé 150, Kankan (10°23'N/9°18'W) has 105 and the Guinea/Côte d'Ivoire border about 115 rainy days/yr.

The mean temperature of the coolest month at Conakry is 25°C, while that of the warmest month is 27°C. Comparable figures for Labé, at an altitude of over 1000 m asl in the mountains, are 20 and 25°C. At Kankan, over 500 m asl in the Niger Basin in the northwest, they are 24 and 29°C.

Vegetation

The coastal plain is covered by broad-leaved lowland forest, both primary and secondary, while the Fouta Djallon and Nimba Mountains are covered by upland evergreen forests. The western borderlands are covered by deciduous forest and savanna, and the headwater basin of the Niger by Guineo-Soudanian transitional savanna, with broad bands of deciduous or semi-deciduous gallery forest along this river and its major tributaries.

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Wetlands

Almost all of the coast is deltaic and mangrove clad, broken only by the high land at Cape Verga and the township of Conakry which juts out into the sea on a 20 km long peninsula. Freshwater swamp forests occur behind the mangroves, and floodplains occur along most rivers due to the highly seasonal nature of the rainfall. However, many of the latter are narrow, except where the rivers debouche onto the coastal plain or cross the floor of the Upper Niger Basin. There are a few lakes in the mountains, and innumerable small swamps around the headwaters of streams.

List of Wetlands Described

1. Coastal Wetlands
2. Riverine Wetlands
3. Lakes
4. Artificial Impoundments

1. Coastal Wetlands

General: There were some 285 000 ha of mangrove forest on the coast in 1980, and some 56 000 ha of rice paddy in areas where mangroves had been cleared. The mangroves are rather better developed in the north and south than in the central region. Some 124 000 ha of tidal forest, with a canopy up to 40 m high, occurs on the estuaries of the Komponi and Nunez Rivers, locally reaching more than 30 km in width between the land and the sea. These forests are backed by periodically inundated freshwater swamp forests, the largest block of which extends in a depression towards the city of Boké (10°59'N/14°20'W). Because of the seasonality of rainfall, the floors of the freshwater swamp forests tend to be dry for half the year, but are flooded, and then often tidal, for the other half. A major rice paddy scheme, 38 km long and up to 6 km wide, has been established in the mangroves on the Kapatchez and Kitali Rivers, terminating at Cape Verga. On the south side of the Cape another mangrove forest covers 46 000 ha on both sides of the Pongo Estuary near Boffa (10°10'N/14°02'W), while to the south of this the mangroves have been totally cleared over a distance of 30 km to the estuary of the Konkouré River, and also up this estuary for a distance of 20 km. However, a 28 000 ha mangrove forest persists on the outer southern bank of the estuary and around the head of Sangareya Bay. A further 68 500 ha of mangrove forest persisted to the south of the Conakry Peninsula in 1980, but clearances of many thousands of hectares had been made there. Despite this, a continuous strip of mangrove forest runs for 60 km from the Kiéma River to the Sierra Leone border, with clearances in three major blocks of approximately 10 km x 2.5 km just behind the seaward mangroves.

Flora & Fauna: As described in the regional introduction for both mangrove and freshwater swamp forest. *Cercopithecus mona, Choeropsis liberiensis, Crocodylus niloticus, Hyemoschus aquaticus, Neotragus pygmaeus, Potamochoerus porcus*, and *Tragelaphus scriptus* have been recorded in the inner parts of tidal forests, the first species sometimes very common. Among the smaller mammals, squirrels and otters are common. Populations of crabs, including ghost and fiddler crabs, are prodigious.

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Human Impact & Utilisation: As indicated above, a large area, amounting to 16% of the mangrove, had been cleared by 1980 and utilised for rice culture. Traditionally the mangrove areas have provided a rich supply of fish and prawn protein, and the estuaries and mangrove creeks have always been fished. Today a large scale offshore and coastal fishery uses trawlers, and much of the annual catch is exported to the USSR. The mangroves are also exploited for constructional timber and for fuelwood.

Conservation Status: Unprotected.

2. Riverine Wetlands

General: The most extensive riverine wetlands are the floodplains of the Upper Niger and its tributaries the Milo, Sankarani and Tinkisso Rivers in the Upper Niger Basin. Here these rivers traverse flat savanna zones, but are cloaked by galleries of deciduous or semi-deciduous forest. The Tinkisso drains the Fouta Djallon and flows northeast and then east between longitudes 10°43'-9°10'W where it joins the Niger. Over this 200 km stretch, which lies between 11°07'-11°25'N, the river meanders tightly and continuously. At the height of the flood, following the June to September rains, the entire meander plain may be flooded briefly. Floodplains also occur on most of the tributaries, e.g. the Bouka, Nanie and Lélé Rivers, although they are not continuous. The total area subject to inundation in this system probably reaches 25 000 ha.

The Milo flows down from the highlands of SE Guinea from its source on a great N-S saddle between the Tibé Peaks (1504 and 1656 m). It begins to meander in its valley before it emerges onto the open basin at a latitude of 9°48'N. From here it winds its way northwards to a confluence with the Niger in the centre of the basin (11°03'N/9°13'W), and a floodplain is nearly continuous for 125 km along this stretch of the river, reaching a maximum width of 2 km. The total area subject to inundation, including that of the floodplains of minor affluents, reaches 16 000 ha in a wet year.

The Sankarani River is an extension of the Gbanhala River, which meanders along the border between Guinea and Côte d'Ivoire from 9°21'-10°00'N, where it has a floodplain 2-3 km wide on which, locally, upland rice is grown. On crossing the 10th parallel the Sankarani veers WNW, meanders, and receives three major affluents, the Kouraï, Yérémou and Dion Rivers. These latter streams drain the highlands of SE Guinea and contribute most of the flood water for the lower Sankarani. From the confluence of the Dion and Sankarani Rivers at 10°12'N, the Sankarani meanders due north, then northeast along the Guinea/Mali border for 62 km, before leaving Guinea and finally joining the Niger on its right bank far into Mali. The Sankarani has a discontinuous floodplain for 170 km in Guinea and has a bed almost 1 km wide where it forms the international border with Mali. On this system the total floodplain area is in the vicinity of 16 000 ha.

Substantial areas of flooded forest, with grassy floodplains behind, occur along the Niger across most its upper basin, while in addition, there are intermittent floodplains on its headwater affluents, the Mafou and Niandan Rivers. The bed of the Niger is broad and island studded for 150 km above the border with Mali, and a floodplain accompanies it over this entire distance. However, this is narrow, only 1-1.5 km wide, and it alternates from side to side of the river. Nevertheless, if the open water surface of the river is included, there is a wetland strip of 35 000 ha, with a mean width of 2 km right across the basin.

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Other wetlands occur on the Koliba or Tominé River in NW Guinea. This stream rises in the Fouta Djallon Mountains and flows onto a lowland plain north of Chaoual (11°45'N/14°08'W), where at an altitude less than 50 m asl, both it and its affluents overtop their banks flooding areas up to 2 km wide in meander bends. The river is quite deeply entrenched and most of the flooding takes place from affluents. It swings west and then flows SW along the Guinea/Guinea Bissau border, before finally entering the latter country at an altitude of 38 m asl where it is known as the Corubal River. Altogether there are (or were) some 120 km of intermittent floodplain on this system in Guinea, and the seasonally inundated area approached 21 000 ha. Not all of this flanked the river; some occupied depressions up to 10 km distant. There used to be a permanent wetland, including swamp forest and herb swamp, in the vicinity of Kitiara (12°10'N/14°41'W), but by 1980 at least 20 000 ha of rice culture had been established in the area. We do not know how much of the naturel wetland has been replaced. Some small floodplains, totalling 3500 ha, occur to the north, on the Koulountou River before it enters Senegal.

The coastal rivers, descending from the dorsale, where the south facing catchments may receive 2000 mm of rain in the two months of August and September, all flood strongly at this time. Since rice is now grown along many of these streams we do not know the area of wetland remaining. Both seasonally inundated and permanent wetlands occur along streams crossing the coastal plain.

There is an important rice growing district in the highlands near Guéckédou (8°33'N/10°09'W). This is associated with the headwater tributaries of the Moa River which reaches the sea in Sierra Leone. This part of southern Guinea is very wet, with, for example, a mean annual rainfall of 2869 mm at Macenta (8°33'N/9°28'W), and the hillsides and valleys here are densely forested. Inundated forests occur along the thalwegs. Details of floodplains of other rivers in Guinea have not been mapped and information is not available in the literature, but since seasonal precipitation is high, and more intense than in almost any other part of Africa, there can be little doubt that they exist. There are some non-riverine marshes in the highlands, e.g. one near Guéckédou (8°20'-8°22'N/10°35'-10°38'W) has an area approaching 5000 ha.

Flora & Fauna: The floras of swamp forest, seasonally inundated gallery forest, grassy floodplains, riverine ponds and lagoons are as described in the regional introduction. Most of the animals listed in the introduction for the various wetland types in the western sector of West Africa are found here.

Human Impact & Utilisation: Rice is grown on river floodplains. The largest developments are on the Koliba River before it enters Guinea Bissau in NW Guinea, and near Guéckédou, but some 5000 ha was under cultivation on the Tinkisso and Lélé Rivers, over a 36 km stretch between longitudes 9°40'-10°00'W, before 1970.

Conservation Status: Unprotected. Conservation issues receive very low priority here.

3. Lakes

General: There are numerous small lakes and ponds in the lowlands, but none is sufficiently large to merit specific mention except perhaps Lake Bento (10°25'N/13°45'W). However we have no information as to the hydrology or ecology of this lake.

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4. Artificial Impoundments

General: Hydroelectric power is generated at Pita (11°05'N/12°24'W) on the Konkouré River, at Kale (9°55'N/13°06'W) on the Badi, an affluent of the Konkouré, and at Tinkisso (11°15'N/10°57'W), on the Tinkisso River.

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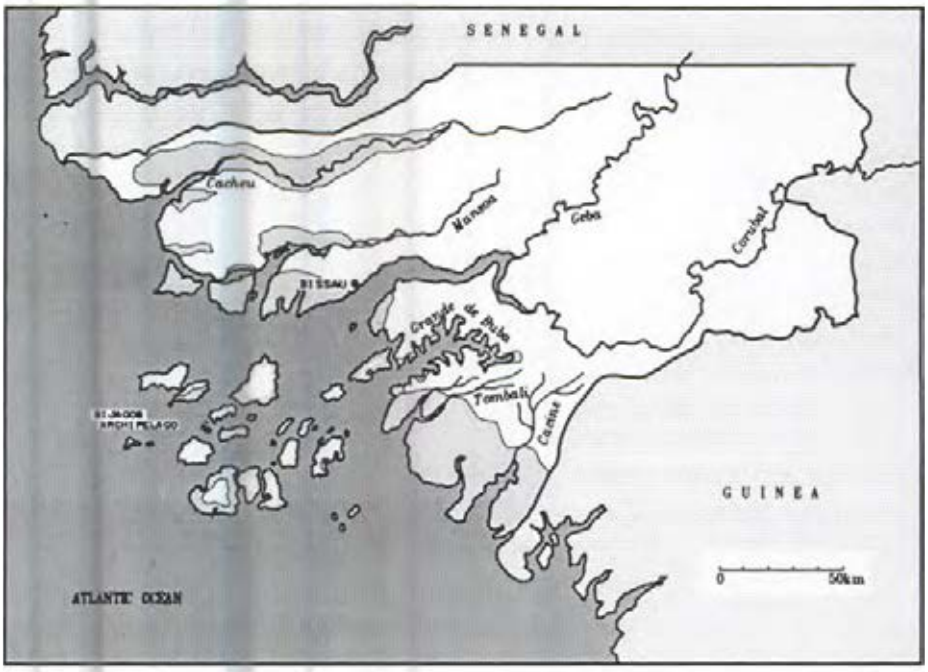

Map of Guinea Bissau

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3.8 GUINEA BISSAU

Introduction

Guinea Bissau is situated on the Atlantic coast of West Africa, bounded by Senegal and Guinea. It has an area of 36 125 km^2, a population of 826 000 (1983) and a mean population density of 22.8 persons/km^2. The country extends 200 km from north to south (10°55'-12°45'N) and 325 km from east to west (13°37'-16°43'W). The land surface is hilly but low lying. Virtually all the country is below the 100 m contour which is exceeded only along the borders. The highest points are Cape Roxo (12°21'N/13°37'W) on the northern border, and a 269 m 'peak' on the border in the southeastern extremity (11°45'N/13°43'W). The coastline is one of submergence, characterised by long, much branched, flooded valleys, along the shores of which deep layers of alluvium have been deposited. The coast is so highly indented that its length, including inlets to the point where their widths decline below 1 km, measures over 1000 km, while the offshore islands contribute a further 550 km.

Drainage is by a number of sluggish rivers which flow roughly southwestwards to the coast, between a series of parallel SW-NE watersheds. From north to south these are the Cacheu, Mansoa, Gêba, Grande de Buba, Tombali, Cumbija, Cacine and Inxanche Rivers, the latter, in its lower course, marking the southern border. The coast is entirely deltaic with many small muddy or sandy islands immediately offshore, and a major island group with some rocky shoals, the Bijagos Archipelago, just off the mouth of the Gêba River.

Climate

Most of the country receives 1500-2000 mm rain/yr, but the southwestern quadrant is more humid, with falls averaging more than 2000 mm. However, rainfall is highly seasonal and there is a 7 month dry period from November to May inclusive. This is most severe in the north where stations may record no rain at all for periods of 30-60 days. Precipitation is most intense in August, when any part of the country may receive a monthly total of 500 mm, or even more. In the north, 99% of the total annual rainfall may be received in the 5 months from June to October. The total rainfall for the 7 month dry season along the northern border may be less than 30 mm. Rain falls on 130 days a year at Bissau (11°52'N/15°35'W), the capital, situated in the central coastal district on the Gêba Estuary. The mean temperature of the coolest month at Bissau is 25°C and that of the warmest month 28°C. Temperatures are moderated by sea breezes.

Vegetation

The coastal lowlands are covered by dense forests, mostly swamp forests, while the interior is savanna covered, with gallery forests along streams.

Wetlands

The low coasts and estuarine shores are cloaked by mangroves, indeed there is little coastline that is not so vegetated. The exceptions are a 15 km strip along Varela Bay,

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south of Cape Roxo and immediately north of the Cacheu River mouth, which is sandy, and a 3 km strip south of Point Cabaciera (12°02'N/16°20'W), which is sandy/rocky. Other shores devoid of mangroves occur on the offshore islands, e.g. the north facing shores of Caravella, Carache and Bubaque Islands, and the west facing shores of Caravella, Uno and Orango Islands. The outermost islands, Unhocomo and Unhocomo-mozinho, are rocky.

Upstream of the mangroves, and behind them, are swamps dominated either by palms and pandans, or by freshwater swamp forest trees. Inland the country is characterised by low hills, 30-100 m asl. There is little flat land and no important wetland. However, almost all the narrow gallery forests are subject to periods of inundation during the rainy season.

List of Wetlands Described

1. Coastal Swamp Forests
2. Interior Wetlands

1. Coastal Swamp Forests

General: Tidal forests (mangroves) cloak much of the coast and extend far up many streams. They reach 100 km up the Cacheu River, whereafter they grade into palm swamps and freshwater swamp forest. This latter vegetation once extended for another 42 km upstream to the town of Farim (12°29'N/15°13'W), but much of it has been replaced by rice fields. Towards the river mouth the mangroves reach a maximum width of 15 km on the north bank. Once there were more than 110 000 ha of mangrove forest and 13 000 ha of freshwater swamp forest on this single river system, but 10-15% has been cleared in recent years. Tidal forests, backed by freshwater swamp forests, used to extend for 110 km up the Mansoa River, but here too most of the upper 65 km of brackish and freshwater forests have been cleared. Mangrove forests still reach 35 km up the Tombali River, but up the Cumbija River the upper 55 km have again been cleared. On this river mangroves now occupy only the lower 15 km. By contrast, the Gêba Estuary, the largest inlet in Guinea Bissau, never had extensive mangroves, being characterised by banks of high relief. Nevertheless, a major block of 9000 ha, which used to extend along the south bank upstream from the mouth for nearly 50 km, reaching widths of 3 km, has now been reduced to scattered stands. Above this, for many kilometres upstream, mangroves have always been scarce although small stands do occur in suitable sites. The estuaries of the Grande de Buba and Cacine Rivers are also lacking in extensive mangrove forests, except near their mouths. The offshore islands are partly fringed by mangroves, but this is a coast of submergence and the high islands of the Bijagos Archipelago, which represent old hilltops, rise quite steeply from the sea in places. However, all along the coast, numerous recent offshore mudbanks are largely, or even completely, covered by mangroves. There were approximately 250 000 ha of tidal forest in Guinea Bissau in 1975, but this had been reduced by 15-20% by 1986.

Flora & Fauna: The mangrove and Guinean/Soudanian freshwater swamp forest flora is as described in the regional introduction. The fauna is typical of tropical West African

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coastal swamps, again as detailed in the regional introduction. The coastal mudflats are important as a wintering ground for palearctic waders, and the Bijagos Islands support many sea birds.

Human Impact & Utilisation: Mangrove timber has long been cut for fuel, and mangrove poles are used for building. There are many villages in the mangroves, and fish, crabs and prawns from the mangroves have traditionally been an important source of protein for the people. Many thousands of hectares of swamp forest have been cleared for rice cultivation, particularly on the upstream ends of estuarine swamp forests. Annual production now exceeds 45 000 tonnes, and this is to be increased. Fishing is the second most important export industry in Guinea Bissau, most of the fish being trawled offshore and exported to the USSR. These fish and prawns however, spend their juvenile stages in the mangroves, and the vast annual catches, exceeding 100 000 tonnes of fish and 2000 tonnes of prawns, will inevitably alter the balance of the estuarine food chains. Overfishing is a fact rather than a threat.

Conservation Status: Unprotected.

2. Interior Wetlands

General: Floodplains occur on almost all rivers in Guinea Bissau above the limits of tidal influence. They extend, in semi-continuous fashion, up the Corubal for 230 km to the border with Guinea, and far up the Gêba River. In general they are forested, but narrow, about 0.5-2 km wide.

Human Impact & Utilisation: Many hectares of riverine floodplain have been cleared for rice paddy.

Conservation Status: Unprotected.

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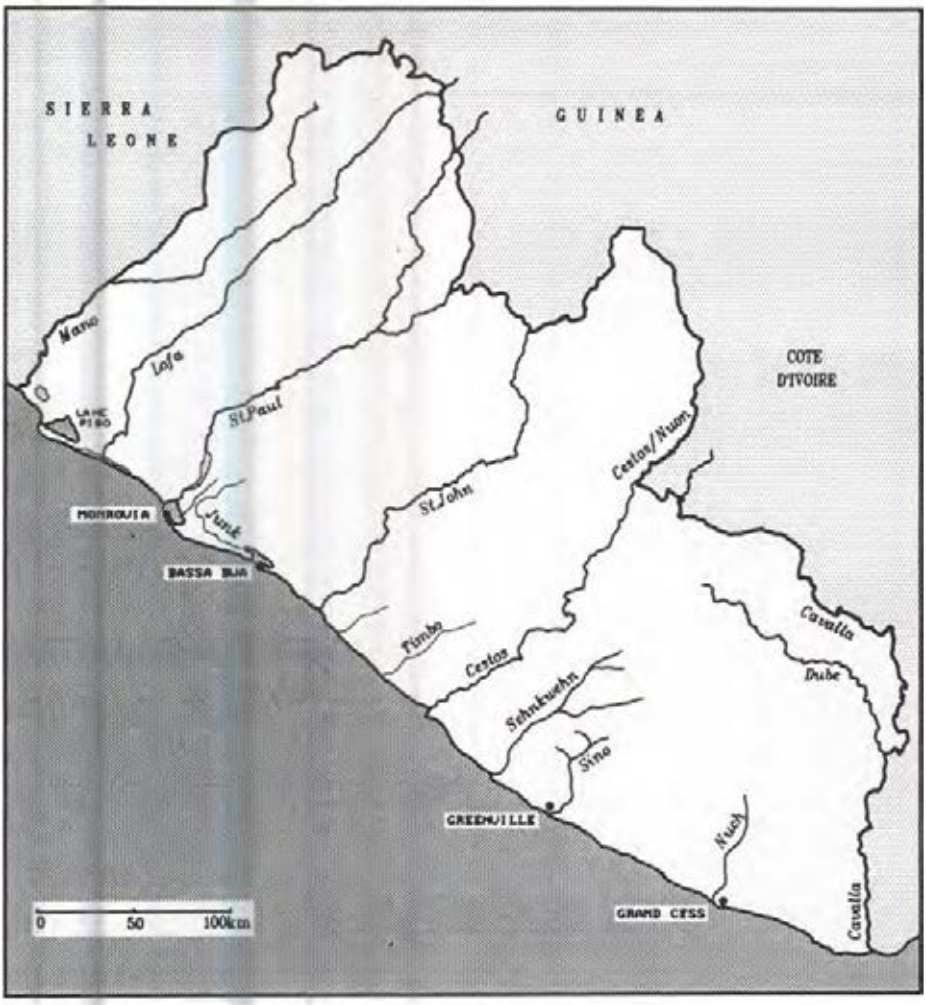

Map of Liberia

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3.9 LIBERIA

Introduction

Liberia has an area of 111 370 km^2, a population of 1 990 000 (1982) and thus, a mean population density of 17.9 persons/km^2. It is situated on the Gulf of Guinea, being bounded by Côte d'Ivoire in the east, Guinea in the north and Sierra Leone in the west. The country extends between 4°21' and 8°34'N and between 7°27' and 11°31'W. It is 510 km wide from NW-SE, and has a maximum depth of 275 km from SW-NE. The coastline is 680 km long, measured up inlets to the point at which their width diminishes below 1 km.

The coast is low and sandy in the west, but over most of the central and eastern sections it is sandy/rocky and of moderately high relief, broken by numerous river mouths. The land rises from the sea into a lowland coastal belt and reaches the 100 m contour some 50 km inland in the west. However, between Monrovia (6°20'N/10°46'W) and Buchanan (5°57'N/10°02'W) highlands approach to within 25 km of the coast. East of Buchanan the lowlands reach nearly 100 km inland, in the Cestos Valley, but narrow again to 30 km towards the eastern border. Farther inland the ground rises more steeply, often with scarps, to an interior plateau between 300-400 m asl. This is dissected by the valleys of the major rivers which flow in parallel across the country from NE-SW. Several hilly ridges, also trending NE-SW, rise from the plateau between rivers to heights of 500-600 m asl, while the plateau itself rises into mountains along the northern and northwestern borders. In these places several peaks exceed 1000 m asl, the highest point in the country (1194 m) being located in the far north (8°10'N/9°55'W) in the Wologizi Range.

Drainage of the entire country is directly to the sea. The major rivers rise in the northern highlands, or in Guinea, and are from west to east, the Mano, Lofa, St. Paul, St. John, Cestos and Cavalla (Cavally) Rivers. The first forming part of the border with Sierra Leone and the last part of the border with Côte d'Ivoire. Numerous lesser streams rise in the interior and either join the major streams as affluents, or find their own way directly to the sea. Almost without exception, the rivers are full of cataracts in their lower courses, mostly to within 30-40 km of the sea.

Climate

Liberia is one of the wettest countries in Africa. The coast is oriented at right angles to the prevailing SW Trade Winds and most of the coast receives more than 4000 mm of rain/yr. Only at the eastern border does it receive less, c. 2800 mm. Precipitation decreases progressively in passing inland, but even the northern border receives over 2000 mm. The climate is almost continuously wet. There is no discernible dry period along the central part of the coast, but on the western border January is dry, while on the eastern border February is dry. Greenville (5°01'N/9°03'W) has no dry month and experiences 185 rainy days/yr. Along most of the northern border January is dry, and there are 170–180 rainy days/yr.

Temperature regimes are remarkably constant across the country. Along the coast, e.g. at Bendaja (7°16'N/11°13'W), Harbel (6°19'N/10°20'W) and Greenville the mean

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temperature of the coolest month is 24°C and that of the warmest month 27°C. Along the northern border corresponding figures are 24 and 26°C for Voinjama (8°25'N/9°42'W) and 24 and 27°C for Sarniquellie (7°24'N/8°45'W).

Wetlands

Liberia does not have any extensive wetlands, which is surprising in view of the humidity of the climate, but this is a consequence of the fact that the terrain slopes fairly constantly from the high northern border to the sea, and that the coast is mostly of high relief. The only part of the coast which is consistently flat is the stretch from the western border, eastwards to Monrovia, and in this forested sector there are lagoons and coastal swamps. Another substantial wetland occurs to the east of this, around the lagoon at Bassa Bwa, but from this point eastwards the coastline becomes rocky or rocky/sandy. Mangroves occur at all river mouths and there is a substantial swamp at the mouth of the Schnkwehn River. There are no important wetlands inland, although narrow zones of inundation are found along some rivers, but since precipitation is not markedly seasonal, major floodplains do not occur here.

List of Wetlands Described

Coastal Wetlands

(a) The Mano River
(b) Lake Piso
(c) The Lofa River
(d) The St Paul River
(e) Bassa Bwa Lagoon
(f) St John River & Buchanan District
(g) The Cestos River
(h) The Schnkwehn River to Greenville
(i) Greenville to the Cavalla River

Coastal Wetlands

(A) THE MANO RIVER

General: This river descends 15 sets of rapids above the parallel 7°N. Close to this latitude it receives several small tributaries from the east which all carry narrow strip swamps, notably the Maa River, which has swamps 100-200 m wide for 15 km above its confluence with the Mano, while other swampy patches occur around the sources of these streams. A sand-bar partly obstructs the Mano River mouth on the Liberian side, while the Sierra Leone side carries a mangrove swamp.

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(B) LAKE PISO

General: This is an open lagoon rather than a lake and is the largest such inlet on the Liberian coast with an open water surface close to 11 000 ha at low tide. Mole Creek empties into the lagoon, while the Mafa River discharges very close to the mouth of the lagoon. This latter stream and its affluent Mani Creek drain a series of swamps above the lagoon, the lower ones of which are tidal and support mangrove vegetation. The upstream mangroves on the Mafa River, some 7 km from the sea, are separated from the mangroves at the mouth by a block of terrestrial forest. Other mangrove swamps occur behind the dune ridge on the west side of the Piso Lake mouth, and at several sites around the lake itself. Here the mangroves are best developed at creek mouths and are then backed in most places by *Raphia* swamps, while elsewhere palm-pandan swamps provide the frontal swamp system. A series of small lakes occurs on the sandy forested spit which separates the south shore of Lake Piso from the sea, and most of these have swampy margins.

(C) THE LOFA RIVER

General: Swamps occur on either side of the mouth of the Lofa River, in a belt 37 km long and 2-3 km deep along the coast immediately behind the beach. A small lake, Lake Mama, is enclosed by these swamps on the west of the river (6°36'N/11°06'W). Swamps and mangrove swamps also occur on the Wain River, which shares a mouth with the Lofa River, and on Mando Creek, an affluent of the Wain. Some way eastwards along the coast a small mangrove stand occurs at the mouth of the Po River (6°31'N/10°56'W), but no swamps spread laterally behind the sand beach at this point.

(D) THE ST PAUL RIVER

General: The river descends many rapids before reaching the coast and is rocky right to its mouth. There is a small mangrove stand behind the beach on the west bank. However, close by at Monrovia, there is an extensive mangrove swamp in the bay behind the peninsula on which the city is built. Mangroves also occur on the Mesurado River, and its affluents, Stockton and Warner Creeks, which enter the bay. There are at least 6000 ha of mangrove swamp here, with other wetland types behind. To the southeast of Monrovia a series of un-named swamp-fringed lakes occurs behind the beach.

(E) BASSA BWA LAGOON

General: Some 1400 ha of periodically inundated forest occurs on the Junk River, between Monrovia and Bassa Bwa, below which, behind the beach at the confluence of the Junk and Bo Rivers, there are mangrove swamps 6 km long and 0.5 km wide. Thereafter the Junk River flows SE, behind the beach, to enter the west end of Bassa Bwa Lagoon at Snafu (6°10'N/10°23'W). The swampy lagoon at Bassa Bwa lies parallel with the coast. It is 17 km long, nearly 4 km wide at maximum, and opens to the sea centrally on the south side. It is almost entirely occluded by tidal swamps, backed by freshwater swamp forests on tributary streams. The Farmington River enters the lagoon on its northern side and the Little Bassa River enters the eastern extremity. The lagoon mouth is permanently open and the open water area is usually about 600 m wide and 10 km long.

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(F) ST JOHN RIVER & BUCHANAN DISTRICT

General: There are small patches of mangrove swamp at the St John River mouth, but more extensive stands on two affluents, the Mechlin River which enters on the north bank and the Benson River which enters on the south side. There are probably 2500 ha of mangrove swamp on this system. Passing southeastwards, a small mangrove stand occurs at the Bo River mouth (5°44'N/9°54'W), another lies parallel to the beach at the mouth of the Kola River, while other small stands occur upstream of the sandy mouth of the Timbo River. Yet another small stand is located at the mouth of Fewehn Creek (5°33'N/9°42'W).

(G) THE CESTOS RIVER

General: The mouth of this river is sheltered behind the rocky Cestos Point, and there are extensive shoals, as well as sand, gravel and mudbanks. Mangrove vegetation is restricted to occasional trees, but stands occur up tributary streams on both banks, with a total area of 1200 ha.

(H) THE SEHNKWEHN RIVER TO GREENVILLE

General: The Sehnkwehn River reaches the sea (5°13'N/9°21'W) near the town of that name, where a tidal swamp extends for 6 km on either side of the channel and 5 km upstream. The 5000 ha swamp extends behind the beach. Small mangrove stands occur at the mouth of the stream at Taso Beach (5°07'N/9°12'W) and also at Greenville at the mouth of the Sino River.

(I) GREENVILLE TO THE CAVALLA RIVER

General: The section of coast immediately east of Greenville is devoid of wetlands, and there is only a very small mangrove stand at the mouth of the Dubo River (4°44'N/8°28'W). However, a series of tidal swamps occurs between Grand Cess (4°35'N/8°13'W) where the Nuch River reaches the sea, and the mouth of the Cavalla River on the Côte d'Ivoire border. At the mouth of the Joda River (4°32'N/8°03'W), near Juduke, there is a substantial mangrove stand covering some 2400 ha. Another tidal swamp occurs for a distance of 6 km up the small river which enters the sea near Garawe (4°30'N/7°56'W). East of this, Lake Jede (4°28'N/7°52'W), with some fringing mangroves, spreads behind a sandspit at the mouth of a small river immediately to the west of the Decoris River mouth. Mangroves also occur on the the Decoris River, reaching 5 km upstream, and a further 5 km up two affluent creeks. Another tidal swamp occurs on the Hoffman River at Harper (4°22'N/7°42'W), and again reaches 5 km inland. Non-tidal swamps occur behind the beaches at Fish Town, Rock Town and Harper, and to the east of Harper, Shepard Lake extends along shore for 9 km. It has an open water surface about 0.5 km wide. Scanty mangroves occur at the Cavalla River mouth.

Flora & Fauna: As described in the regional introduction for coastal wetlands. *Crocodylus niloticus* and *Osteolaemus tetraspis* occur in the mangroves near Monrovia and in similar sites along the coast, but are uncommon. *Crocodylus cataphractus* is more common, but in freshwaters. Upriver, *Choeropsis liberiensis* still survives, e.g. in forests on the Mano, Lofa, Cestos, Sehnkwehn, Sino, Dugbe and Cavalla Rivers.

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Human Impact & Utilisation: Hunting and fishing pressures in the mangroves are intense, as is the exploitation of mangroves for fuelwood. Clearing of mangrove sites for habitation and agriculture (rice) is increasing.

Conservation Status: Presently unprotected, but a national park has been proposed, and is intended to cover a large area between the Cestos and Sehnkwehn Rivers. This will include the mangroves at the mouth of the Sehnkwehn, and a 20 km section of this river above the mouth. It will also include a 60 km upstream section of the Cestos River and several minor streams. In the west of Liberia, a nature reserve has been proposed at Robertsport along the southern shore of Lake Piso. This reserve will include Lakes Mono, Makasa, Jaa, Jukanu, Danu and Zontoni, and a small stream on the forested slope of the hill at the western end of the spit.

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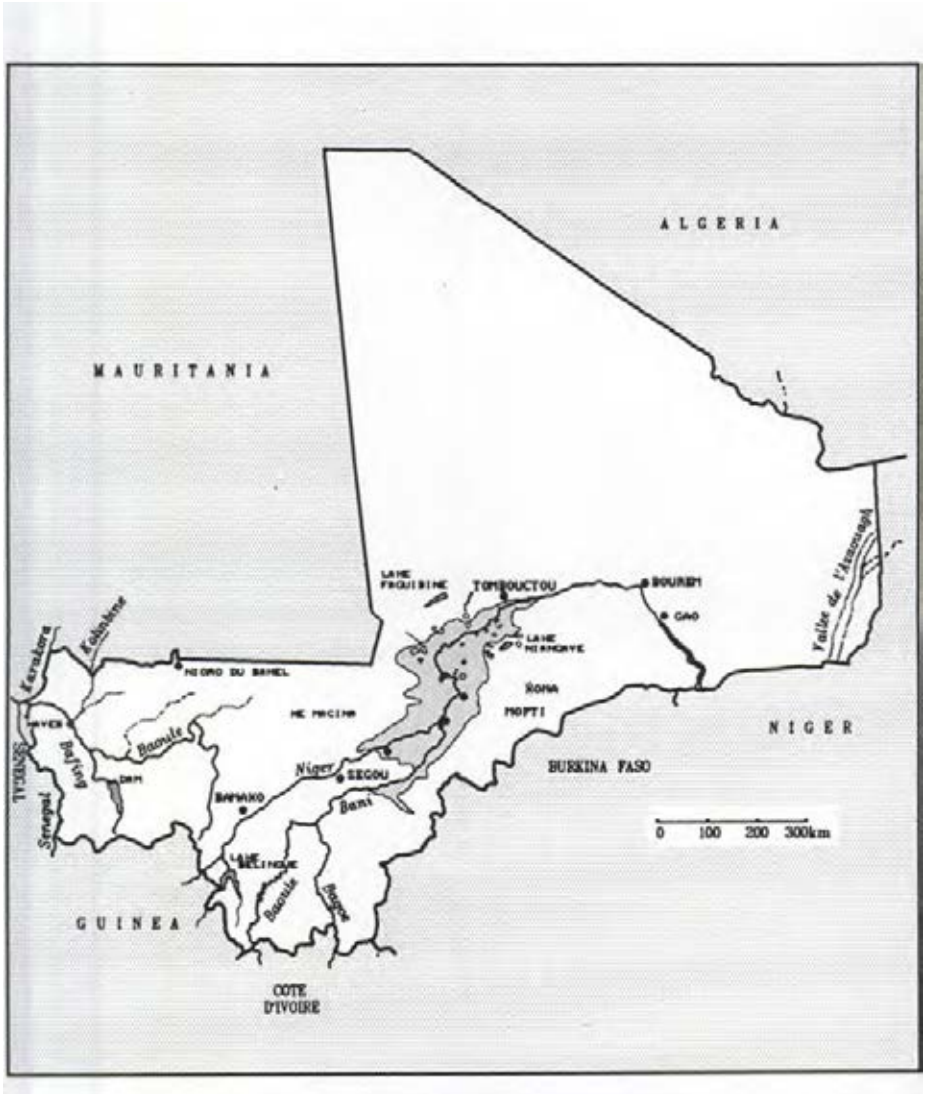

Map of Mali

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3.10 MALI

Introduction

Mali has an area of 1 240 140 km^2, a population of 7 492 000 (1983) and a mean population density of only 6 persons/km^2. It is land-locked, being bounded by Niger, Burkina Faso, Côte d'Ivoire and Guinea in the south, by Senegal and Mauritania in the west, by Algeria in the north, and by Niger in the east. It extends from 10°04'N, at a triple junction with Guinea and Côte d'Ivoire, northwards across the Tropic of Cancer to 25°00'N at another triple junction with Mauritania and Algeria, a distance of approximately 1675 km. The extreme western point is at a longitude of 12°11'W at the confluence of the Senegal and Bafing Rivers, and the extreme eastern point is 4°14'E on the border with Niger, an E-W distance close to 1745 km. The country thus spans 14°56' of latitude and 16°17' of longitude.

The lowest land in Mali is in the far west, in the valley of the Bafing River. Here the Bafing flows northwest along the eastern side of the Bambouk Hills which lie along the border with Senegal, and an expanse of lowland, under 100 m asl, extends away from the river to the northeast. This is in fact the valley of an intermittent tributary stream, with some extensive lakes, e.g. the Mare de Magui, along its length. The lowlands here occupy some 20 000 km^2, all below the 100 m contour. Other low land, between 100-200 m asl, extends up the valley of the Bafing for 200 km to the border with Guinea in the south, and up the valley of the Baoulé River, a tributary, towards Bamako (12°40'N/7°59'W). This valley opens into a wide basin laced with intermittent watercourses on longitude 10°00'W, and this then extends eastwards to 8°40'W.

The other low lying land in Mali is situated in the Sahara, in the far north. Here, in the desert, two parallel depressions, below the 200 m contour, are oriented SE-NW. They are each close to 150 km in length, and both exceed 25 km in maximum width. Ephemeral watercourses enter these depressions and they contain large areas of saline marsh, kept moist in large part by subterranean water.

Apart from these two lowland areas the rest of Mali lies almost exclusively between 200-500 m asl, and presents a monotonous flat or gently undulating landscape. The only patches of highland are along the southern and eastern boundaries. In the south the Manding Plateau near Bamako is an extension of the Fouta Djallon Mountains of Guinea. This is a sandstone area, deeply incised by the valleys of the Niger and Senegal Rivers and their affluents, with plateau edges that fall away in steep cliffs. Both here and in the hills around Sikasso (11°19'N/5°40'W) land rises above 760 m, while to the northeast, along the south side of the middle course of the Niger River, the Dogon Plateau rises to 777 m, and Hombori Mountain (15°15'N/1°40'W) rises to a height of 1155 m asl, this being the highest point in Mali. In the northeast, on the border with Algeria, the Adrar des Iforas Massif rises to 980 m asl.

Drainage in the extreme southwest is to the Senegal and Bafing Rivers and thus to the Atlantic Ocean. The other highlands along the southern border drain to the Niger, and run-off from here thus reaches the Atlantic in the Gulf of Guinea. The vast northern areas are virtually rainless and have no important drainage system, apart from that leading to the two depressions mentioned above.

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Vegetation

Vegetational zones cross the country in parallel from east to west. Localised forest occurs along the border with Guinea and galleries of forest line the perennial rivers which flow through Soudanian savanna country. Here in the south there is often a mosaic of open forest and savanna, the forests dominated by *Khaya senegalensis* and *Lophira lanceolata*. North of Bamako *Acacia albida*, *Adansonia digitata*, *Bombax costatum*, *Borassus aethiopum*, *Parkia biglobosa* and *Tamarindus indica* are the characteristic trees, while the principal Soudanian grasses are *Andropogon gayanus*, *Ctenium newtonii*, *Cymbopogon giganteus*, *Hyparrhenia dissoluta* and *Loudetia simplex*, and some annuals including *Andropogon pseudapricus*, *Ctenium elegans*, *Eragrostis remula* and *Pennisetum pedicellatum*. The tree flora becomes poorer and the trees more scarce towards the Sahelian zone where they become restricted to species such as *Acacia scorpioides*, *Adansonia digitata*, *Anogeissus leiocarpus*, *Balanites aegyptiaca*, *Commiphora africana*, *Hyphaene thebaïca* and *Ziziphus mauritiana* in wooded steppe country. The Sahelian zone proper is true steppe country in which *Cenchrus biflorus* (cram-cram) is dominant. In passing farther north permanent vegetation peters out and the north of Mali is in the Sahara. Here ephemeral plants such as *Aristida longiflora*, *A. pungens*, *Calligonum comosum*, *Cornulaca monocantha* and *Panicum turgidum* appear briefly after rain.

Climate

There are two seasons in the south, a wet and a dry season. Reduced pressure occurs over the Tropic of Cancer in July and August, and at this time the SW Trade winds blow across the southern regions bringing rain behind the intertropical convergence zone, which reaches its most northerly position at this time. The rains occur during July and August in Tombouctou (16°46'N/3°01'W) and Gao (16°16'N/0°03'W), but south and west of these places the season is longer, lasting 5 months at Bamako (12°39'N/7°59'W), from June to October, and 4 months at Kayes (14°27'N/11°26'W), from June to September. To the north of Tombouctou the rains soon peter out and there is no reliable wet season.

In the Soudanian zone rainfall is between 600-1275 mm, while in the Sahelian zone it is 200-600 mm. Bamako has a mean annual rainfall of 1037 mm, with falls of 340 mm in August and over 200 mm in both July and September, while December-March are rainless. Sikasso is among the wettest places with a mean annual total close to 1400 mm. At Kayes, in the middle west, mean annual rainfall is 790 mm, while at Gao, in the middle east, it is 261 mm. In the latter place 8 months of the year (October-May) are virtually rainless, the mean 8 monthly total being 13 mm averaged over 64 years. Tessalit (20°12'N/1°00'E) in the far north has a mean annual rainfall of 82 mm. It rains on 79 days each year at Bamako, on 50 days at Mopti (14°30'N/4°12'W) in the Interior Delta of the Niger, and for 25 days at Tombouctou.

Two winds influence the country during the dry season. The hot dusty Harmattan blows from the northeast and east, bringing temperatures in excess of 40°C in the south of the country from March to June. During the December-February period, a northwesterly wind, the Alize, may bring cooler weather, but this wind becomes less reliable in passing east. In the far north temperatures are extreme, readings of 58°C having been made, and

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47°C being a common shade temperature. The mean temperature of the coolest month at Bamako is 25°C and that of the warmest month 32°C, with similar figures for Sikasso. Corresponding figures for Tombouctou and Gao are 23 and 35°C, while for Kayes they are 24 and 35°C.

Relative humidity seldom reaches 20% over the northern half of the country in January, but may approach 40% in August, while in the south it reaches 80% along the Guinea border in August, falling to 40% in January. Most of the south experiences relative humidities of 50-70% during August and 20-30% during January. Potential evapo-transpiration exceeds 2000 mm over the delta.

Wetlands

The principal wetlands are riverine. Precipitation is highly seasonal over the southern catchments and almost all the southern rivers flood. Small floodplains are found on the rivers of the Senegal system, and on the affluents of the Niger. The major wetland occurs where the Niger crosses the bed of a prehistoric lake and because of the flatness of the terrain, divides into many channels and lakes in what is often referred to as the 'inland delta'. Elsewhere, daias, zones of moist soil and waterholes, are found along fossil watercourses, while others appear to occupy isolated depressions.

List of Wetlands Described

1. The Internal Delta of the Niger River
   (a) The Delta
   (b) Tributary Rivers
2. Minor Wetlands
   (a) Wetlands of the Senegal River System
   (b) Daias
3. Artificial Impoundments
4. Oases

1. The Internal Delta of the Niger River

(A) THE DELTA

Location: 13°34'-16°51'N/2°28'-5°45'W (delta + lakes)
Area: 3 200 000 ha (main delta + associated wetlands)
Altitude: 263-271 m asl
Nearest Towns: Bamako (325 km SW); Tombouctou (on N delta)

General: The delta proper is 425 km long, oriented SW-NE, with a mean width of 87 km. The gradient of the delta plain is greater than 1:50 000, i.e. it drops only 8 metres over its entire length. It ends at Tombouctou, where the river swings eastwards and the floodplain is reduced to a width of 10 km. The area comprises a network of river channels with levées, and low clay-based inter-distributary floodplains between. On these areas there are numerous ponds of varying permanence. There is also a system of marigots,

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small channels in which water is carried to the floodplain in the rainy season and back to the rivers in the dry season. At this time the marigots frequently dry out to a series of stagnant pools. Levées are not pronounced along marigots.

The plateau of Dogonland lies along the southeastern flank of the delta and to the north and west are the huge dune areas of late Pleistocene age, the Erg Ouagadou, which obstructed the ancient course of the Niger, causing it to flow north and east instead of west through Senegal. The delta consists of Pleistocene and Recent alluvium overlying Palaeozoic sandstones. These latter rocks dip under the delta and emerge on the western side in low hills. Lake Faguibine, mentioned later, lies in another parallel fold farther to the northwest.

In the southwestern part of the delta both the Niger and Bani Rivers divide into several channels. Those from the Bani join the main channel of the Niger on its south bank, while those from the Niger leave its north bank. The main channel of the Niger flows obliquely across the delta towards its northeastern edge, while the distributaries from the north bank meander towards and along the northwestern part of the delta. In the lower half of the delta there are several lakes, and two external lake systems, one along the southeastern flank and one along the northwestern flank. Beginning on the northwestern flank, Lake Faguibine is a triangular expanse of water, 75 km long, oriented almost due SW-NE parallel with the delta. It has an open water surface of 45 000 ha at high water, a maximum depth of 15 m, and reaches 12 km in width at the northeastern end. From here it connects through a permanent swamp running N-S, with Lake Télé near Goundam (16°25'N/ 3°40'W). From Lake Télé an intermittent drainage system connects with the delta. A series of ephemeral lakes lies to the south of Lake Faguibine, known as daouras, e.g. Daouna Beri and Daouna Keino. Several other lakes, partially enclosed by the delta, lie along the northwestern flank. These are found below Goundam, and are Lakes Kande, Kabara, Oro and Fati.

Lake Débo is situated in the central delta, and is the largest of the lakes enclosed by the delta, while along the southeastern margin, partially enclosed by the delta, are Lakes Korientzé, Aougoundou and Garou. Lakes Niangay, Dö and Haribomo are separate from the delta on the southeastern side, and are situated in dune swales. They are partly filled by runoff from Dogonland and partly from a high ground water table, but at high water they are in connection with the delta.

Topography within the delta is complex. The flood dominated lower areas contrast visually with the higher unflooded, areas known locally as tougérés, in a mosaic of wet and dry patches. The delta is a network of meandering creeks, especially in the south, with coarse sands forming the river beds and levées, and finer grained alluvium the interdistributary flats. Lake Débo is really a widening of the main river channel which expands and contracts as river levels fluctuate. Some way north of Lake Débo, the Erg of Niafounké, a system of wind-blown sand dunes, crosses the delta obliquely, obstructing waterflow and causing the delta to widen.

Below the delta, from Tombouctou to the border with Niger, a river distance of 550 km, the river has a braided course and has a floodplain of varying width on either bank. At maximum it is 10 km wide, at minimum less than 1 km wide.

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Hydrology & Water Quality: Every year the Niger inundates an area between Ké Macina (13°58'N/5°22'W) and Tombouctou (16°46'N/3°01'W). In a wet year the total area of inundation may exceed 3 200 000 ha, including peripheral lakes, and during the dry season some 1 600 000 ha of lakes and permanent swamps remain, mainly in the northern half of the delta. Some lakes are replenished regularly, e.g. Fati, Horo, Kabara and Tanda, but others fill less regularly and may even dry out in dry cycles, e.g. Faguibine and Niangay. The inundation commences in the south, in August-September, and watercourses overflow progressively from south to north as the flood crest moves towards Tombouctou which it reaches in December.

The flood waters are contributed by the Niger and its principal affluent the Bani, and numerous short streams which drain the Dogonland Plateau. The Niger contributes 50 billion m^3 of water to the delta each year, with a mean discharge rate at Ségou of 1585 m^3/sec, with peak flows of c. 5000 m^3/sec in August and 70 m^3/sec in October. The Bani contributes about 20 billion m^3 with a mean discharge rate of 634 m^3/sec, but also with peak rates of 5000 m^3/sec in August. The contribution of the Dogonland streams to the delta is insignificant, but they do serve to fill the southwestern lakes. The largest of these rivers, the Yamé contributes 250-500 million m^3 of water/yr to the system. Because of the vagaries of rainfall over the catchments, annual variations in riverine inflow are great, as in consequence, are the total areas flooded each year and the depth and duration of the floods. Of the mean annual riverine influx of 70 billion m^3, almost half is lost by evaporation and infiltration during the transit of the delta. Class A Pan evaporation has been estimated at 2300 mm/yr in the north of the delta.

Direct precipitation over the delta varies from year to year and place to place, with annual totals ranging from 200-600mm. The rainy season usually begins in July and lasts until mid-October in the south, and from mid-July to mid-September in the north. Mean annual precipitation is 750 mm over 53 days at San (13°18'N/4°54'W) at the southeastern extremity of the delta, but this is reduced to 300 mm/yr at Niafounké (15°56'N/4°00'W) and to less than 250 mm/yr in the far north of the delta.

The flood is slowed on entering the delta and the crest proceeds northwards at a rate of approximately 5 km/day. It takes a month to travel from Ké Macina to Mopti (14°30'N/4°12'W), another month to reach Lake Débo, another month to reach Goundam and yet another month to reach Tombouctou. Discharge from the delta is 35 billion m^3/yr giving a mean flow rate of 1110 m^3/sec in the Niger below Tombouctou. However, dry season flow falls as low as 60 m^3/sec and the river surface may, at such times, drop below the water table in the delta.

The chemistry of the water and its temperature varies from place to place in the delta, and fluctuates through the year. The temperature of affluent Niger water ranges from a maximum of 30°C, which may be reached between April and October and a minimum of 19°C, which may be reached in December-January. Temperatures over 32°C have been measured in stagnant delta pools. The incoming waters carry fine clay particles and are moderately turbid throughout the year, giving Secchi depths of around 90 cm. The pools of the delta are very turbid with Secchi depths of only 3 cm. The affluent waters are low in minerals.

Flora & Fauna: *Typha* swamps are common on the Niger above and below the delta. The southern half of the delta is mostly low lying floodplain, with low river levées. The

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floodplain is covered by typical floodplain grasses such as *Acroceras amplectens*, *Echinochloa pyramidalis*, *E. stagnina*, *Eragrostis atroviriens*, *Oryza barthii*, *Panicum anabaptistum* and *Vetiveria nigritana*, with *Andropogon gayanus*, *Cynodon dactylon* and *Hyparrhenia dissoluta* dominant on the much grazed outer fringes. Along the rivers a scrubby gallery of *Mimosa asperata* and *Salix chevalieri* occurs, with an undergrowth of *Cyperus maculatus*. In the south, sparse gallery forest penetrates the delta along watercourses in places, and here trees such as *Diospyros* sp. and *Kigelia africana* are to be found on higher levées, their existence in many places probably due to human activity. Permanent pools contain *Ceratophyllum demersum* and *Nymphaea* spp., but pools in the channel beds, which dry out or shrink dramatically during the dry season, are often too turbid to support macrophytes. They may however, become fringed by *Echinochloa stagnina* and *Polygonum senegalense* during periods of low water. The lakes are fringed by *Typha australis*, and sometimes by *Phragmites mauritianus*, frequently with species such as *Echinochloa pyramidalis*, *E. stagnina* and *Vossia cuspidata*. Algal blooms are common in the lakes and greatly reduce the transparency of the water. The northern half of the delta has many emergent sand ridges on which the palms *Hyphaene thebaïca* and *Borassus aethiopum* are common, particularly in the vicinity of villages. Other common trees or shrubs of elevated areas are *Acacia nilotica*, *Guarea senegalensis*, *Mimosa asperata* and *Ziziphus mauritiana*. The dune swales in the north are flooded at high water, and retain moisture during the dry season so that they contain sedges, reeds and other hygrophilic grasses.

Although over 100 fish species have been found in the delta, there are few endemics. One of these however, is remarkable in being a planktivorous clupeid, *Microthrissa miri*. Many typical swamp fish are present including *Clarias* spp., *Gymnarchus niloticus*, *Heterotis niloticus*, *Polypterus ansorgei*, *P. senegalus* and *Protopterus annectens*. The avifauna is very important in the ecology of the delta. Owing to its geographical position, in the Sahelian zone on the edge of the Sahara, the delta provides a winter habitat for vast numbers of palearctic migrants. Over 350 bird species have been identified in the delta, 108 are of palearctic origin. Some species are present in very large numbers, e.g. 1 000 000 *Anas querquedula* may be present, and over 400 000 *Anas acuta* have been recorded. Numbers of ruff are known to have exceeded 300 000. The delta is also an important breeding ground for pelicans, herons, cormorants and pratincoles. At least 13 species of heron have been recorded in the delta, and *Comatibis eremita*, an endangered species, has been recorded from both Lakes Faguibine and Oro. Curry & Sayer (1979) and Lamarche (1980) give details of palearctic migrants in the delta. Among mammals, *Hippopotamus amphibius* and *Trichechus senegalensis* still survive in the delta, but they are both now rare and in danger of extinction. The small mammals associated with Soudanian-Sahelian wetlands are common, but other large mammals have been hunted out and their place taken by domestic cattle.

Human Impact & Utilisation: The delta is quite densely populated with an estimated resident population of 580 000. This gives a mean population density of 16 persons/km^2, or 2.7 times the national average. Semi-nomadic Peuhl cattle herders comprise about 35% of the population, and some 1 200 000 cattle and 1 500 000 sheep and goats use the pastures for 7-8 months of the year. Occasionally Touaregs bring their cattle to the delta as well. There is an agro-pastoral system in operation which is becoming increasingly important, whereby resident farmers growing rice and millet also own cattle. Traditional

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crop production is mainly carried out by the Bambara and Marka people who comprise about 33% of the delta population. Approximately 120 000 ha of land is used for rice production (1985), using both rain fed and flood dependent methods. Certain herbivorous fish, e.g. *Alestes baremose*, *Distichodus brevipinnis* and *Tilapia zillii*, have however, wreaked havoc on young rice crops in newly flooded fields and have caused serious reductions in harvests. Other rain fed and flood dependent crops include sorghum and manioc. With the spread of irrigation agriculture there has come an additional spread of bilharzia, and as much as 90% of the delta population is affected. Malaria is another major health hazard.

Fishing in the delta is almost exclusively in the hands of the Bozo and Somono people. The delta produces 90% of the national catch, which itself accounts for 3% of the gross national product and 8% of its exports. Fish is exported from Mali to Niger and Burkina Faso. The mean annual catch is close to 100 000 tonnes, but annual deviations from this figure are large. Fish concentrations vary enormously from place to place in the delta and from season to season and the fishermen who follow the fish are semi-nomadic. The catch has declined considerably since 1969, and this is to be attributed in part to the series of drought years in the Sahel and thus diminished flooding, but also to over-fishing, as is evident from the fact that the size of the individual fish has also declined. Traditional methods of catching and trapping fish are still widely used, especially during the dry season when the fish are concentrated in the channels and lakes, but modern gear, including nylon nets, is beginning to become common.

Water is carried from the barrage at Markala to Niono (14°15'N/6°00'W), in canals and an old channel of the river, and is then used to irrigate rice fields in the ancient delta at Niono. Drijver & Marchand (1985) discuss socio-economic conditions in the delta and plans for the development of the delta, together with an assessment of problems which may arise upon the implementation of the plans.

Conservation Status: Unprotected.

(B) TRIBUTARY RIVERS

General: A floodplain occurs on the Niger all the way from the Guinean border to Bamako (12°40'N/7°59'W), but most of this has now been converted for the cultivation of rice. The channel of the Niger is divided by numerous islands both above and below Bamako, and a natural floodplain again appears below Bamako where the slope of the land flattens about 100 km south of Ségou (13°27'N/6°16'W). In this section the floodplain is up to 5 km wide, but is at first discontinuous. The river continues, with many large islands in its channel, until the barrage at Markala (13°39'N/6°04'W), some 60 km downstream of Ségou. The barrage raises the level of the Niger 4.3 m, and from here the Canal du Sahel takes water to an ancient course of the river leading to the fossil delta and rice fields at Niono. The Niger enters its internal delta at a point 88 km below Ségou and 10 km above the town of Kotongotomo.

To the southeast of the Niger there are numerous tributary streams with floodplains.

There is a floodplain on the Lolio River north of Sikasso (11°19'N/5°40'W) for 60 km, to the confluence with the Ngorolaka River. Another floodplain occurs upstream of the confluence on the Ngorolaka, and at the junction the inundated area spreads 3.5 km on

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either side of the river, which is then known as the Banifing River. The Ngorolaka floodplain extends upstream for 61 km above the confluence, but is thereafter discontinuous. It nevertheless extends for a further 40 km along the border with Burkina Faso. Minor floodplains also occur on affluents of the Ngorolaka, e.g. on the Oroumbo, Sélédoga and Longo Rivers.

A floodplain occurs on the Bafini River, and on its two affluents, the Nié and Boin Rivers to the south of Sikasso between the co-ordinates (10°38'-10°55'N/5°33'-6°00'W). The total length of the floodplains is 70 km and the total area 21 000 ha. The Bafini then joins the Bagoé River at a point 10°53'N/6°12'W. The floodplain on the Bagoé is 150 km long and 0.5-9 km wide above its confluence with the Baoulé River (12°36'N/6°35'W), with a total flooded area exceeding 40 000 ha. A small floodplain also occurs on the Baoulé, about 40 km long and 1 km wide, some way upstream of the confluence (12°00'-12°16'N/7°05'-7°10'W). The Bagoé then flows on for 25 km when it joins the Banifing to form the Bani River (12°44'N/6°23'W), the other major affluent of the internal delta.

It is 250 km from the Bagoé/Banifing confluence to the beginning of the delta, and over this distance the floodplain on the Bani is continuous. Locally it is better developed on one bank than the other, and about 60% is to be found on the right bank. From a point 50 km southeast of Ségou, the Bani flows northeastwards in parallel with the Niger, and over this last section the floodplain is 8-12 km wide, until it merges with the inundated zone of the delta. There are close to 125 000 ha of floodplain on the Bani in this final sector.

2. Minor Wetlands

(A) WETLANDS OF THE SENEGAL RIVER SYSTEM

General: Some wetland exists in the lowlands in the extreme west of Mali which drain to the Senegal River. In the past, in times of more pluvial climates, large rivers with broad floodplains traversed these valley lowlands, depositing great tracts of alluvium. Today however, the streams which flow through the ancient floodplains are small and the modern floodplains narrow. There is such a floodplain on the Kolinbine River above its confluence with the Bafing River at Kayes (14°27'N/11°26'W). Another floodplain, situated 14°29'-15°13'N/10°35'-11°14'W, includes several small lakes. These are known collectively as the Mare de Magui if they become continuous during the rains, but with the recent drying of the Sahel this has not happened for several years. The floodplain is 6 km wide locally and stretches upstream for 135 km, beginning 30 km upstream of Kayes. It also spreads for short distances up two affluents of the Kolinbine and covers, in total, some 24 000 ha.

Another small floodplain (15°22'N/9°29'-9°42'W) with some permanent swamp land is situated on the border with Mauritania, immediately to the north of the town of N'oro du Sahel (15°15'N/9°35'W). The wetland area is at the head of a valley, less than 100 m asl, below the source of an ephemeral stream which flows into Mauritania and then loops back into Mali to join the Kolinbine River.

Yet another narrow and discontinuous floodplain occurs on the Karakoro River, which flows SSW from Mauritania through Mali and joins the Bafing River on the Mali/Mauri-

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tania border, just 25 km above the confluence of the Bafing and Senegal Rivers. This floodplain is 3 km wide locally and extends across the border into Mauritania. Another small floodplain, 22 km long and up to 2 km wide, is situated 15°23'N/11°30'-11°41'W on an affluent of the Karakoro River.

Small floodplains occur on the Baoulé River, and its affluent the Darooma River, in the 'Boucle du Baoulé' region, e.g. at 13°53'N/9°50'W on the Darooma and at 13°47'N/9°25'W on the Baoulé. This is another region where more water flowed in the past and it has been suggested that a former course of the Niger, which was certainly to the sea via the Senegal River, was through the Baoulé Valley.

(B) DAIAS

General: Areas of wet sand occur in troughs between dunes and along fossil watercourses where the water table reaches or approaches the surface for part of the year. These areas are known locally as daias and they are common in three principal areas. Some large daias occur in parallel with the internal delta of the Niger, along its northwestern flank. The largest of these measures 25 km in length and 10 km in width, and in wet years some contain ephemeral ponds known as douanas.

In the far east of Mali, the great Vallée de l'Azaouagh, the site of a fossil watercourse, crosses a corner of the country from SW-NE (15°30'-17°19'N/3°28'-4°16'E). The valley is 250 km long in Mali and decreases in width from 14 km in the northeast to 2 km in the southwest. It is floored by humid sands. Other daias are found in a crescent 50 - 125 km west of the valley in the Tidarméné (16°34'N/2°17'E) district. The nine largest of these each covers approximately 4000 ha.

Yet other daias, oriented NE-SW, occur on the fringes of the Adrar des Iforas Massif, and others in the far north of Mali, north of latitude 22°N in two major lowland depressions. These latter daias are saline.

3. Artificial Impoundments

General: There is a dam (13°13'N/10°29'W) on the Bafing River in southwest Mali, which provides an open water surface of 69 000 ha. The lake is 67.5 km long and has a mean width of 10 km.

4. Oases

General: There is an oases at Tessalit (20°11'N/0°59'E), the natural vegetation of which includes *Acacia nilotica*, *Hyphaene thebaica* and *Tamarix africana*, but this has largely been replaced by groves of *Phoenix dactylifera*.

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Map of Niger

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3.11 NIGER

Introduction

Niger is a landlocked country bounded by Nigeria and Benin in the south, Burkina Faso and Mali in the west, Algeria and Libya in the north, and Chad in the east. It has an area of 1 186 410 km^2, a population of 6 040 000 (1983) and therefore, a mean population density of 5 persons/km^2. 20% of the population are nomads and less than 5% live in towns. The population is heavily concentrated along the southern border where 70% of the people live. Niger spans 15°51' of longitude between 0°09'E and 16°00'E, and 11°53' of latitude between 11°37'N and the Tropic of Cancer (23°30'N).

The lowest land, below the 200 m contour, penetrates the country in the extreme southwest along the valleys of the Niger River and its affluents. Most of southern Niger is a sandy plateau, 200-500 m asl, with lowlands around Lake Chad in the southeastern corner. The Aïr Mountains, a chain of isolated massifs, reach southwards into the country from Algeria as an extension of the A'Haggar Mountains. The interior plateau of Niger, 400-700 m asl, is part of the Precambrian granitic shield, and is a peneplain, topped in the Aïr region by a number of roughly circular table mountains covered by recent (Pleistocene) basalts. These, from south to north, are the Ates, Fadei, Adrar Tamgak, Taghmer, Agueraguer, Takolokouzet, Goundj, Mazel, Adrar Egalah, Angour-n-Akau and Bagzane Table Mountains. The highest point in Niger, 2022 m asl is reached here (17°54'N/8°45'E), on Bagzane Mountain, while a point on the Adrar Tamgak (19°03'N/8°34'E) rises to 1988 m asl. Another peak on the Fadei reaches 1944 m asl and there are half a dozen peaks over 1750 m asl. Outliers of the Aïr Mountains reach almost to the central southern border, while another small outlier is situated at 17°30'N adjacent to the western border with Mali.

Farther east, a highland block comprising the Manguéni Plateau and its extension, the Djado Plateau, reach south from Libya, onto the interior peneplain which here lies at 450 m. The plateau rises abruptly above the plain by steep scarps which reach a maximum altitude of 1054 m on the western side of the Manguéni Plateau. These highlands occupy the northeastern corner of the country with their southern edges reaching the 20th parallel, but with a lower narrow ridge, reaching 575 m, running due south to the 18th parallel. The cliffs of Kaouar form the western side of this ridge which dips gently to the desert in the east.

Niger is a desert country, the only perennial watercourses being the Niger River, which crosses the southwestern extremity from Mali into Nigeria, and the Gada, which loops briefly into southern Niger from Nigeria. This latter stream is part of the Niger drainage system. Drainage of the western part of Niger is by intermittent streams to the Niger River, while the eastern part drains to Lake Chad, also by intermittent and ephemeral streams. However, there are a number of oases in the interior.

Climate

Niger is one of the hottest countries in the world but the northern interior is characterised by extreme temperature fluctuations. For example, at stations in the Aïr Mountains absolute maxima and minima of +50°C and -31°C have been recorded. The mean

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maximum temperature of the warmest month at Niamey (13°31'N/2°07'E), on the Niger River in the southwest, is 34°C, while that of the coolest month is 25°C. The absolute maximum recorded at this centre is 46°C and the absolute minimum 8°C. The mean maximum of the warmest month at Nguigmi (14°15'N/13°07'E) in the southeast, on the north shore of Lake Chad, is 32°C, while the mean maximum of the coolest month is 21°C. In passing north, comparable figures are 34 and 25°C for Tahoua (14°54'N/5°16'E); 33°C and 20°C for Agadez (16°58'N/7°59'E); and 33°C and 17°C for Bilma (18°41'N/12°56'E).

Precipitation decreases in passing north and east, and there is no assured rainfall north of Agadez. Bilma has a mean annual rainfall of 26 mm, but some years may be rainless. Agadez has one wet month, August, during which some 125 mm of rain fall each year, over an average of 18 days. There are two wet months at Nguigmi (July and August) where the mean annual rainfall is 235 mm, with 141 mm in August and about 25 rainy days each year. There are three wet months at Tahoua, July-September, and here annual totals are over 400 mm with 40 rainy days each year. Mean annual rainfall is close to 650 mm at Niamey and over 800 mm at Gaya (11°53'N/3°27'E) in the extreme southwest. Gaya is the first place to receive rains as the intertropical convergence moves north each year, and the last place to lose the rains as it retreats south some 5 months later.

Vegetation

The south of the country is occupied by Sahelian savanna, with small, gnarled and thorny trees and bushes. Taller savanna woodland with *Adansonia digitata*, *Ceiba pentandra*, *Tamarix spp.*, and some *Borassus* and *Hyphaene* palms is found in the southwest, with gallery forests along the Niger. The centre supports steppe vegetation and the north is virtually unvegetated, except for ephemerals which appear after rain. In the gorges of the Aïr Mountains areas of moist sand and semi-permanent ponds support oasis vegetation. Here *Phragmites australis*, *Typha latifolia*, *Scirpus holoschoenus* fringe ponds (gueltas) and marshy streamlets, with *Acacia nilotica* and *Tamarix gallica* behind. There seems good reason to believe that the original arborescent vegetation of many oases comprised *Acacia nilotica*, *A. seyal*, *A. tortilis*, *Ficus sycomorus*, *Hyphaene thebaica*, *Maerua* sp. and *Tamarix* spp., with *Citrullus colocynthis* and *Capparis* spp., but this has largely given way to plantations of *Phoenix dactylifera*. Relict stands of native vegetation do however persist in some sites.

Wetlands

The Niger flows for 570 km across the southwestern corner of Niger, over which distance it floods its banks only very locally, while a narrow floodplain occurs along the loop of the Gaba (Korama) River in central southern Niger. In a few places rain water collects in shallow basins to form semi-permanent lakes or ponds. Other wetlands are known as dallols, gulbis and koris. These are all fossil watercourses, but a dallol consists of moist sands over which surface flow may very rarely occur and in which there may be occasional pools. A gulbi has moist sands and a regular annual surface flow; it is thus an intermittent watercourse, but it may never flow as a continuous river from source to

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sink. A korri is a predominantly rocky watercourse, such as is found on flanks of mountains and escarpments, and flows only intermittently following rain. In places, a fall as light as 5 mm will set the koris flowing, even after prolonged drought, because the impermeability of the local rocks produces rapid run-off.

List of Wetlands Described

1. Wetlands of the Niger Valley
2. Wetlands of the Korama & Komadougou Yobe Systems
3. Natural Lakes
   (a) Lake Chad
   (b) Other Lakes
4. Fossil Watercourses
5. Oases
   (a) Oases of the Aïr Mountains
   (b) Oases of the Djado, Kaouar & Fachi Massifs

1. Wetlands of the Niger Valley

General: The bed of the Niger is wide and island studded north of Tillabéri (14°13'N/1°27'E), but becomes constricted downstream. However, two short floodplains occur, one above and one below Gothèye (13°52'N/1°35'E). The upper floodplain is 12 km long and the lower one 5 km long. Neither exceeds 1 km in width. Another floodplain stretches along the river for 33 km between 12°03' and 12°15'N. Here the river is shallow and over 1.5 km wide. Finally a floodplain develops below Gaya (11°53'N/3°27'E), some 13 km wide, and extends into Nigeria. This wetland develops at the confluence of the Niger and the Dallol Maouri, and extends for several kilometres up the valley of the Maouri.

Flora & Fauna: Gallery forest, typical of the Soudanian zone, extends along the Niger containing such species as *Anogeissus leiocarpus*, *Balanites aegyptiacus*, *Barassus aethiopum*, *Cola laurifolia*, *Diospyros mespiliformis*, *Mitragyna inermis*, *Parkia biglabosa*, *Tamarindus indica*, *Terminalia avicennioides* and *Vitex chrysoclada*. The large mammal populations close to the Niger are typical of Soudanian savannas, as described in the regional introduction, but have been intensively hunted and most survive only in the National Park and Nature Reserve on the river.

Human Impact & Utilisation: Some rice and other crops are grown on the floodplains and cattle are grazed on them. Rice is chiefly produced in the Tillabéri district. The river is fished intensively along its entire length in Niger. Timber for construction purposes and for fuel is constantly harvested from the gallery forests, especially *Barassus aethiopum* which is used for construction. *Andropogon gayanus* which grows on the flooded areas is used as a thatching material.

Conservation Status: The floodplains as such are unprotected. However, a section of the Niger is protected in the National Park du 'W', upstream of which for some 35 km

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the right bank is protected in the Tamou Nature Reserve. In both of these reserves the landscape is deeply dissected by tributaries of the Niger and all these have minor floodplains and strips of gallery forest subject to seasonal inundation.

2. Wetlands of the Korama & Komadougou Yobe Systems

General: The Korama River enters Niger at a point 9°32'E and then flows north, west and south in a crescent, leaving the country at a point 8°28'E. The river has a floodplain over the entire distance of 125 km, but this is barely 0.5 km wide and is inundated for only 4-6 weeks of each year.

The floodplain and swamps on the Komadougou Yobe have been described in some detail in section 3.12 Nigeria, in which country they mostly lie. However, in the lower reaches of the river, near Lake Chad, the floodplain extends north of the border into Niger, from a point 12°29'E to a point 13°22'E where the river enters the lake. Over this distance the width of the floodplain in Niger is generally 0.5 km or less, but locally patches of inundation cross the border for up to 2.5 km.

Human Impact & Utilisation: Cattle are grazed on the floodplains and recession agriculture is practised locally. The rivers are fished.

Conservation Status: Unprotected.

3. Natural Lakes

(A) LAKE CHAD

Location: 12°29'-14°29'N/13°02'-15°21'E
Area: 2 500 000 ha at high water (421 250 ha in Niger)
Altitude: 282 m asl (when lake surface covers 2 000 000 ha)
Nearest Towns: Nguigmi (on lake); Niamey (612 km W)

General: Some 421 250 ha of Lake Chad and its peripheral marshes is situated in Niger. The lake is shallow with many emergent sand ridges, and the shoreline, which is highly indented, is more than 225 km long, although the straight line distance along the shore is approximately half of this. Reed-clad marshes fringe the shore in a belt up to 6 km deep and cover some 42 000 ha. A detailed account of the lake is given in section 3.3 Chad.

Hydrology: The lake water is well mixed and well oxygenated, and has a salinity of less than 1‰. The lake is endorheic and occupies part of a great inland basin of more than 2 500 000 km^2. The basin and lake are very shallow, explaining why the surface area of the lake is so variable. Rainfall presently averages about 300 mm/yr over the basin, and is greatly exceeded by evaporation which has been estimated as 2000 mm/yr. Of the total riverine inflow, 95% comes from the Logone/Chari system, the catchments of which lie in the humid highlands of Cameroon, Chad and the The Central African Republic, and represent about 25% of the total catchment. The contribution of the El Beid River is minimal, possibly 2.5% of the total inflow, while the remaining 2.5% is contributed by the Komadougou Yobe, Yedseram, Ngadda and several ephemeral streams. A brief account of the hydrology, geomorphology and history of the lake is given by Beadle (1981) who refers to more detailed studies.

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Flora & Fauna: As described in the regional introduction, but see the account in Section 3.3 Chad.

Human Impact & Utilisation: The lake is fished intensively from the town of Nguigmi on the northern shore. We have no details of the catches landed at this port in recent years but it is estimated that an annual catch of 10 000 tonnes should be sustainable.

Conservation Status: Unprotected.

(B) OTHER LAKES

General: There are small lakes at Keïla (14°46'N/5°46'E), Madarounfa (13°18'N/7°09'E) and Guidimouni (13°42'N/9°30'E). The lake at Madarounfa is situated in the Maradi Gulbi. All are small lakes with surface areas of a few hectares to a few tens of hectares.

Human Impact & Utilisation: Water from all these lakes is used for domestic purposes and some crops are cultivated on the banks.

Conservation Status: Unprotected.

4. Fossil Watercourses

General: The fossil watercourses are relics of a former pluvial age. The principal system runs southwestwards in a great arc from the Aïr Mountains to join the Niger in the Dallol Bosso, while the Dallol Maouri, a little to the east, represents a subsidiary system. The Dallol Bosso is 775 km long, but is discontinuous over stretches of 30-125 km in its middle course. The lower 375 km are continuous, with a damp sandy floor 15 km wide in places. There are occasional waterholes towards the junction with the Niger. In the upper course the system is dendritic, clearly draining the southwestern part of the Aïr Mountains with dallols (barren watercourses with humid sands) converging from 140 km north and 200 km south, to meet at the upper end of the Dallol Bosso. The entire system probably comprises 750 000 ha.

Other strips of damp sand (14°26'-15°49'N/11°32'-13°00'E) and (14°19'-14°56'N/10°42'-11°46'E) are oriented NW-SE, and represent a former course of drainage from the Massif de Termit to Lake Chad. These cover 376 000 and 113 700 ha respectively. Another such area (18°42'-19°25'N/12°53'E) is situated 6 km north of Bilma covering 28 000 ha. It is oriented due N-S and lies immediately under the N-S scarp of the Kaouar for 75 km. Here there are springs in the cliffs, dealt with under oases (below).

Further patches occur at the northern extremity (23°08'N/12°00'E and 23°30'N/11°48'E), extending into Niger from Algeria. They are situated immediately beneath the scarp at the western side of the Plateau of Manguéni, occupying 9000 ha and 25 000 ha respectively, and are again associated with springs.

Flora & Fauna: The banks or fringes of the dallols are green, with stunted riverine trees, grasses and sedges.

Human Impact & Utilisation: Crops are grown in the moist sands of some of these systems and the waterholes are utilised by nomads for domestic water supplies.

Conservation Status: Unprotected.

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5. Oases

(A) OASES OF THE AÏR MOUNTAINS

General: Any site at which freshwater occurs in the desert may be referred to as an oasis. The drainage of past pluvial times has deeply gullied the edges of the table mountains of the Aïr Massif and the canyons so formed provide good sites for the conservation of surface water. The watercourses, entrenched in canyons are known as koris and gueltas (standing ponds), and springs are found in most of the deeper canyons of the massif. For example, the table top of Bagzane Mountain is 1500 m asl and 750 m above the surrounding plain. The scarp walls fall very steeply to this plain, and a number of gorges appear as near vertical incisions in them, such as Nabarou Canyon (17°39'N/ 8°49'E). This is very narrow and contains a permanent pond several hundred metres long and a few metres wide. Farther north, Ighalabelabene Canyon (17°42'N/8°49'E), which is more open at the top, supports a string of small springs and ponds along its length. The spring water is slightly brackish. A dry lake bed (egharghar) is situated on the flat top of the mountain, containing a thick layer of sediment with fossil molluscs, 5000-10 000 years old. Drainage from the Nabarou and Ighalabelabene Canyons merges on the peneplain in a dallol which supports woodland, but this, together with the water supply, is quickly attenuated in passing downstream. Similar streams and gueltas occur on the other mountains of the Aïr Massif, but Bagzane, being the most southerly, is the wettest with a mean annual rainfall of 170 mm. Rain is heavily concentrated in the July-September period, and the watercourses begin to flow after falls of 5 mm. Rainfall is subject to great annual variations, and in dry years little more than 100 mm may fall on Bagzane, while over 250 mm fell in 1978.

A permanent stream and gueltas occur near the headwaters of the Kori Timia (18°06'N/8°46'E) which drains the southeastern flank of the Adrar Egalah Mountain. A fault across the bed of the watercourse has caused water to be diverted and it has subsequently eroded a narrow channel through the basalt rock. Finally the stream descends by a waterfall to a circular guelta, 30 m in diameter. Farther downstream in the canyon there are numerous little cascades with plunge pools at their feet. The waters are fresh, but the lowest pools tend to dry up periodically and are thus slightly saline. However, several floods occur each year and flush them out so that salinities are never high.

A number of deep gorges have been cut in Adrar Tamgak, one of the central eastern mountains. Here the table top is situated 1600 m asl and the surrounding Tenere Plain is almost 1000 m lower. The largest gorge, that of the Kori Tamgak, is crescent shaped, and runs from east to west across the mountain. It receives several tributary canyons en route to the western edge, towards which it is sometimes labelled Ougourou on maps. In traversing the outer and more gentle slopes of the mountain it widens to about 2 km and has a wet and wooded floor. Upstream in the mountain the complex of canyons supports at least 50 ponds, with numerous cascades and plunge pools, but the streams flow only intermittently, except in depressions where the groundwater flow comes to the surface. Being farther north than Bagzane, precipitation is much lower, 63 mm/yr at the nearby settlement of Iferouâne (19°04'N/8°25'E). Here an absolute minimum temperature of 1.5°C has been recorded and July temperatures regularly exceed 41°C.

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Flora & Fauna: The natural vegetation of these desert wetlands is as described for oases in the regional introduction. Emergent macrophytes are scarce at Nabarou, but *Phragmites* and *Typha* fringe some gueltas, and species of *Juncus* and *Scirpus* occur locally. *Potamogeton* spp. are the principal submerged plants. Those trees and palms typically associated with desert watercourses are abundant, especially near Iferouâne.

A mollusc, *Bulinus truncatus*, is found in the Bagzane gueltas and is abundant at Timia where the local population suffer from bilharzia. Mosquitoes are a problem in every gorge, and settlements tend to be on the mountain plateaux to avoid them. At least two amphibians are present in the Aïr Mountains. *Bufo regularis* occurs in the vicinity of most ponds, and *Tomopterna cryptotis* has been recorded at a number of sites. *Varanus niloticus* is locally abundant and there are some unidentified rodents.

Human Impact & Utilisation: There is a settlement on the top of Bagzane Mountain and the people from it travel down to the plain regularly, using the Ighalabelabene Canyon. They trade with the settlement at Tabelot. The spring at Thagar is dammed and used for small scale irrigation, but otherwise the gueltas are not interfered with.

Conservation Status: Unprotected.

(B) OASES OF THE DJADO, KAOUAR & FACHI MASSIFS

General: There are other oases at Chirfa (20°56'N/12°20'E) and Sara (20°47'N/12°28'E), on the western side of the Djado Plateau, while a string of springs runs along the foot of the Kaouar Cliffs (18°00'-20°00'N/12°54'E). Settlements have also grown up around these, the principal ones being at Bilma (18°40'N/12°53'E), Dirkou (19°01'N/12°54'E), Achénouma (19°07'N/12°54'E) and Emi Tchouma (19°17'N/12°54'E). An isolated oasis occurs at Fachi (18°00'N/11°36'E) where there is a hilly outcrop, reaching 179 m above the Tenere Plain which is 400 m asl in that vicinity.

The springs at these places are principally fed by underground aquifers, and the discharge from those at Bilma increases noticeably 3-4 weeks after the onset of rains in the Tibesti Mountains to the northeast.

Flora & Fauna: The natural vegetation of all the oases has been largely replaced by plantations of *Phoenix dactylifera*.

Human Impact & Utilisation: The natural springs along the Kaouar Cliffs have been augmented by numerous wells. Using deep boreholes, an artificial lake was created at Dirkou, and in 1981 a deep bore at Bilma began to discharge and to inundate the surrounding depression, and could not at first be stopped. In addition to date production, some horticulture is carried out at all oases, and camels and goats are kept at them. Some salt is extracted from artificial saline pools at Bilma.

Conservation Status: Unprotected.

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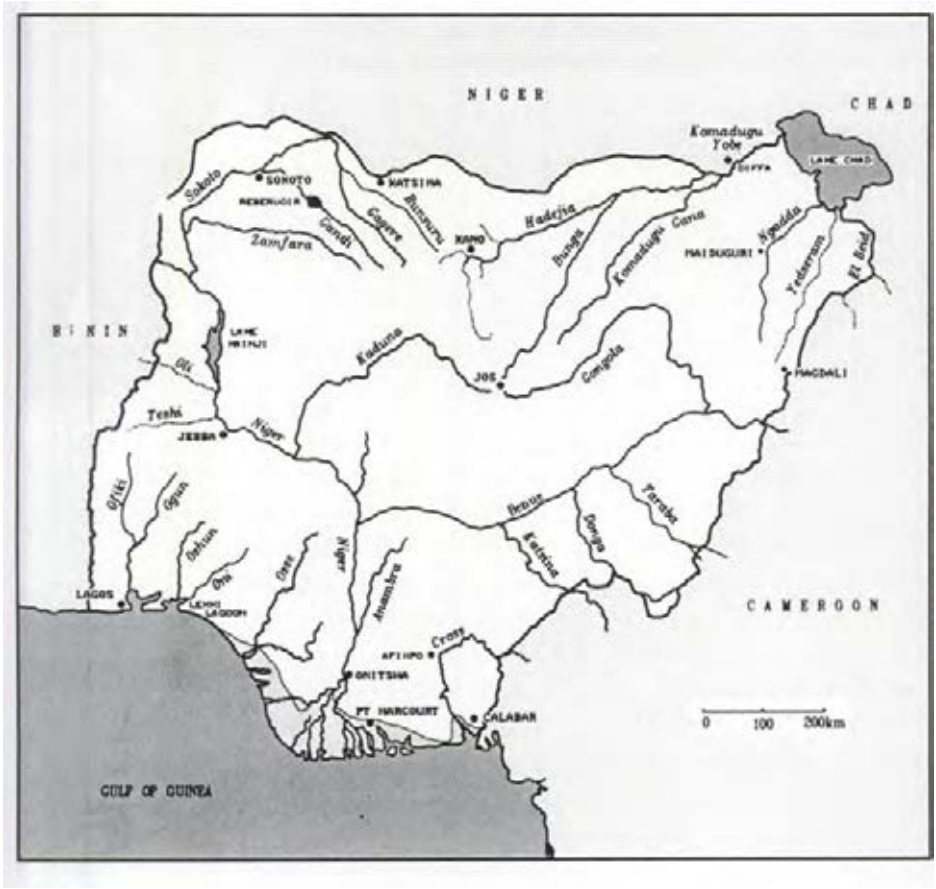

Map of Nigeria

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3.12 NIGERIA

Introduction

Nigeria is the most populous country in Africa. It has an area of 923 850 km^2, a population of 82 390 000 and thus a mean population density of 89 persons/km^2. It extends between the latitudes 4°16'N (at the tip of the Niger Delta) and 13°52'N, and between longitudes 2°49'E (on the Okpara River) and 14°37'E (on the El Beid River). It has maximum dimensions of 1200 km from east to west and 1000 km from north to south and is bounded by Cameroon and Chad in the east, Niger in the north and Benin in the west. The coastline is 780 km long, excluding the indentations of Lagos Lagoon, the Niger Delta and the Cross River Estuary, which add at least 1300 km to this.

The principal physiographic feature is the Niger/Benue River system which separates three highland blocks. The southern coastline is dominated by the delta of the Niger River (36 260 km^2), and inland from this the coastal plain, less than 100 m asl, is 75-125 km wide, except in the southeast where it contracts to 50 km. Lowlands below the 100 m contour accompany the Niger inland for 400 km to its confluence with the Benue. From here the lowlands continue northeast up the Benue for a further 550 km, and northwest up the Niger for 210 km. The lower Niger system forms a great Y shape, with the delta at the base of the Y, the Niger River forming the stem and left hand branch and the Benue, the right hand branch. The Jos Plateau (1200 m asl), which rises to occasional high peaks, e.g. 1698 m at Wadi Hill and 1781 m at Shere Hill, lies between the arms of the Y and continues northwestwards as the Funtua Plateau. To the east of the Y are the mountains along the border with Cameroon, which rise to 2419 m asl at Chappal Wade, the highest point in Nigeria. To the west of the Y are the Yoruba Highlands. Other lowland areas are the Sokoto (Rima) Basin in the northwest, and around Lake Chad in the northeast.

Drainage from the Jos-Funtua Plateau is either northeastwards to Lake Chad, via the Komadugu Yobe, or northwest, south or southwest to the Niger/Benue River. From most of the eastern highland block along the Cameroon frontier, drainage is northeastwards to the Benue, but the southernmost ranges drain to the Bight of Biafra via the Cross River. The Yoruba Highlands drain northeastwards to the Niger or southwards to the Bight of Benin.

Climate

Mean annual rainfall decreases progressively in passing inland, but it is generally wetter in the east than the west. On the coast at the border with Benin, mean annual rainfall is close to 1750 mm, but this rises to 1836 mm at Lagos (6°27'N/3°34'E) and to 3800 mm at Forcados (5°21'N/5°25'E) on the Niger Delta but it falls to 2483 mm at Port Harcourt in the eastern delta. Forcados averages 180 rainy days each year and Port Harcourt 170. There is less disparity in rainfall from west to east inland, however. Mean annual rainfall is 1378 mm at Makurdi (7°45'N/8°32'E) on the Benue River, and 1257 mm at Ilorin (8°30'N/4°32'E). In the centre it rises slightly to 1431 mm at Jos (9°55'N/8°53'E), which is situated in a wet pocket, and is 1000 m higher than Makurdi. From here rainfall declines to 865 mm at Kano (12°00'N/8°30'E) and 600 mm at Maiduguri (11°53'N/13°16'E) in the northeast.

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The wet season is 10-11 months long on the delta, with a short dry period in December or December-January, depending upon station. On the western coast, near Lagos (6°27'N/3°24'E), the three months December-February are dry, and there is often a second dry period in August. In passing inland the August dry period is lost, but the major dry season increases in length and severity. It is 6 months long at Jos and 7 months (October-April) at Kano and 8-9 months long at Lake Chad (September-May).

Temperature ranges are lower at the coast than inland. At Lagos the mean monthly temperature of the warmest month is 27°C and that of the coolest month is 24°C, while at Port Harcourt the corresponding figures are 26°C and 24°C. The figures for Jos are 24°C and 20°C, while those for both for Kano and Maiduguri are 31°C and 22°C. The prevailing winds at the coast are from the SW, and these bring the rains to the interior as the intertropical convergence moves north and south.

Vegetation

The coastal strip is Guinean, and either is, or was once, covered by Guinean rain forest. In passing north this grades through a Guinean-Soudanian transition zone, which may carry forest, into well wooded Soudanian savannas. Guinean species penetrate far into the savanna zones along the major rivers.

Wetlands

Coastal wetlands are the most extensive. In the west there are large lagoonal systems with mangrove swamps, palm-pandan swamps and reed swamps. In the east the Niger Delta and Cross Estuary both carry large areas of mangrove forest, and both permanent and seasonally inundated freshwater swamp forest. Inland there are floodplains on many rivers, as a consequence of the increasing seasonality of the rainfall in passing north. For example, although mean annual rainfall is only 653 mm at Maiduguri, some 90% of this falls in two months. In the Soudanian zone, forest on the levees is inundated at the time of flooding, as are broad grasslands behind them. Elsewhere in the north, away from rivers, there are other seasonal wetlands. These are chiefly clay-based pans and ponds which fill with water in most years.

List of Wetlands Described

1. Coastal Wetlands
    (a) Lagos & Lekki Lagoons & Affluents
    (b) The Niger Delta
    (c) Wetlands of the Cross River
2. Riverine Wetlands
    (a) The Niger/Benue River System
    (b) The Komadugu Yobe
    (c) The Ngadda, Yedseram & El Beid Rivers
3. Lake Chad
4. Other Interior Wetlands

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5. Artificial Impoundments
   (a) Lake Kainji
   (b) Other Impoundments

1. Coastal Wetlands

(A) LAGOS & LEKKI LAGOONS & AFFLUENTS

Location: 6°22'-6°38'N/2°48'-4°36'E
Area: 155 335 ha (99 875 ha open water + 55 460 swamp)
Altitude: sea level
Nearest Town: Lagos (on lagoon)

General: The lagoons lie behind the barrier beach and extend for 210 km along the coast. They are flanked by tidal wetlands and the permanent swamps at the eastern end are contiguous with those of the lower Niger Delta. There are two major lagoons, Lagos Lagoon in the west and Lekki Lagoon in the east. These are connected by a narrow channel, and Lagos Lagoon is also connected by a long narrow navigable channel with Cotonou Lagoon in Benin. The open water area given above represents that of all the lagoons and channels in the system and does not allow for islands, of which there are several. Lagos Lagoon averages 2-4 m deep, but is 10 m deep in the entrance channel. The mean depth of Lekki Lagoon is 3.1 m, and the maximum depth is 6.4 m at low tide. The complex is isolated from the sea by the beach barrier ridges. The western channels approach to within a few dozen metres of the sea, but in the east, much of Lagos and Lekki Lagoons are situated 3-4 km inland.

Hydrology & Water Quality: The system is tidal. Lagos Lagoon is open to the sea through a channel some 10 m deep near the city of Lagos. This is kept open, despite the powerful longshore drift, by artificial breakwaters. Normal tidal amplitude is 1.2 m, hence the tidal zones around the shores are not very wide. Tidal influence is pronounced in Lagos Lagoon, but is far less in Lekki Lagoon. The system is fed by several rivers, the most important of which are, from west to east, the Yewa, Ogun, Ona/Ibu, Oshun, Shasha and Oni. The Yewa discharges into the channel between Cotonou and Lagos Lagoons, and the Ogun and Ona/Ibu into Lagos Lagoon. The Oshun, Shasha and Oni flow into Lekki Lagoon, from where water escapes to the sea, either via Lagos Lagoon, or through the swamps to the east.

Salinity varies from site to site and with the seasons. In the wet season the influx of river water is so great that the lagoons are fresh to brackish throughout, with salinities of 5-10‰ in seaward sites and 0‰ near the river mouths. At this time of the year salinity in the main basin of Lagos Lagoon is always below 3‰, while that of Lekki Lagoon is generally 0‰. During the dry season however, salinities rise to 30‰ in the entrance channel, and to 8-10‰ in the main basin of Lagos Lagoon and to 5‰ in Lekki Lagoon. The surface water temperature of the main basin near Lagos varies from 26°-31.5°C throughout the year, reaching maxima during the wet season. Transparency is lowest in the wet season when Secchi depths may be less than 1 m, but it increases to as much as 3 m during the dry season. pH values are close to 7.0 throughout the system during the rains, but the values can rise to 8.0 during the dry season.

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Flora & Fauna: Mangroves, dominated by *Rhizophora racemosa*, cover the flat shores, with *Avicennia africana* and *Hibiscus tiliaceus* other common species on the shoreline. In many of the landward sites, and in the vicinities of affluent river mouths, the mangroves grow tall and are backed by freshwater swamp forests or *Raphia* swamps. *Rhizophora* grows in sites which are never very saline, c. 10‰ maximum. There has been much clearance of the mangrove, and in many places, where the forest has been exploited for fuelwood and construction timber, or destroyed for other purposes but then left, secondary vegetation has appeared, dominated by *Cyperus articulatus* and *Paspalum distichum* (= *P. vaginatum*).

Among the fishes, there are some species which appear in the lagoons only at certain seasons of the year. Some come from the sea, others from the rivers. 79 species have been identified in the system, of which *Caranx hippos, Chrysichthys nigrodigitatus, C. walkeri, Citharichthys stamflii, Cynoglossus senegalensis, Elops lacerta, Epinepeleus aeneus, Ethmalosa fimbriata, Gerres melanopterus, Ilisha africana, Liza falcipinnis, Lutjanus eutactus, L. goreensis, Mugil bananensis, Pellonulo afeluisi, Polydactylus quadrifilis, Pomadasys jubelini, Scomberomorus maculatus, Sphyraena barracuda* and *Tilapia* spp. are perhaps the most important.

Human Impact & Utilisation: The waterway system is used for the transport of passengers and cargoes, and there is a port at Lagos. Fishing pressure in the lagoons is high and there have been clearances on the landward side for agriculture. Industrial wastes are discharged into Lagos Lagoon. Population density on the northern margins locally exceeds 250 persons/km^2 and the swamp forests and rain forests of these areas have been very largely destroyed.

Conservation Status: Unprotected.

(8) THE NIGER DELTA

Location: 4°16'-6°00'N/4°45'-8°00'E
Area: 3 226 000 ha (c. 2 000 000 ha wetland)
Altitude: 0-5 m asl
Nearest Towns: Lagos (325 km NW); Port Harcourt (on E delta)

General: The Niger Delta is of Holocene age and occupies an area of continued subsidence. It comprises an upper riverine floodplain, a lower tidal floodplain and an outer chain of barrier islands. The riverine floodplain occupies about 1 000 000 ha, and extends seawards from the head of the delta at Onitsha (6°09'N/6°47'E) for 168 km. Two local streams rise to east and west of Onitsha and flow into the delta. Their courses are parallel to that of the Niger and in the upper delta they delimit the riverine floodplain to east and west. In this region the riverine floodplain is approximately 40 km wide, but down delta it widens to 200 km where it merges into the tidal floodplain.

The tidal plain is close to 450 km long around the delta face, and slopes more gently towards the sea than the riverine plain. It is widest on the flanks of the delta, reaching 38 km in the west, near the Benin Channel, and 43 km in the east along Sombreiro Channel. Along the central sector the tide penetrates less far inland, only 16 km in places, but up the Nun River, which is considered to be the continuation of the main channel of the Niger, tidal influence extends farther upstream into the seasonally flooded riverine

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floodplain. In total, the tidal floodplain occupies close to 1 503 000 ha, but about 160 000 ha of this overlaps the riverine floodplain on either side of the Nun River.

The alluvium of the lower delta is less coarse than that of the riverine floodplain. Tongues of riverine sediment penetrate into the tidal floodplain along distributaries, and between distributaries the tidal plain bulges into the riverine floodplain; thus the junction between the two is deeply embayed. Tides, however, tend to penetrate up distributaries farther than the inter-distributary plain, and the zone of vegetation which is transitional between the mangrove forest of the tidal plain is most evident along these watercourses. The mouths of the distributary rivers tend to silt up, but with the development of the petroleum industry in the delta, some are now dredged. However, a dentritic drainage system covers the lower (tidal) floodplain, and here the many channels are kept open by the powerful scouring action of the ebbing tides.

The outer face of the delta consists of a series of sandy barrier islands. They comprise sand brought down by the Niger and redistributed by marine processes, principally the powerful longshore drift and the frontal wave attack. There are 20 major islands with a total landsurface of close to 200 000 ha. They vary in length from 5 to 37 km and in width from 0.5 to 12 km. They are higher than the tidal floodplain behind and emerge from the sea to heights up to 4 m asl and are covered by a dense littoral forest or scrub, very rich in species by contrast with the tidal floodplain to landward.

Within the delta the Niger River breaks up into a number of distributaries. The Nun River is regarded as the direct continuation of the mainstream, while the major distributaries are the Forcados, Brass, Bonny and Sombreiro Channels. The mouths of all these tend to be obstructed by sand-bars unless dredged. Allen (1964, 1965) and Allen & Wells (1962) give useful accounts of the geomorphology of the delta.

Flora & Fauna: Originally the entire lower delta plain was covered by mangrove forest and the seasonally inundated portion by freshwater swamp forest, but large areas of both vegetation types have been destroyed. It is not clear exactly how much tidal forest remains on the delta. Kinako (1977) states that there are 500 000 ha of mangrove forest of different types in the delta, but in the same paper indicates over 1 100 000 ha of mangrove in the delta on a map. Bartholomew's 1982 map shows some 670 000 ha of mangrove forest and 833 000 ha of other tidal land and this is approximately correct. Another problem arises with the distribution of mangrove forest in the delta, which is represented differently on different maps. Some maps show the mangrove belt to be more than 50 km deep on the central delta face, narrowing uniformly to a minimum depth of 12-15 km on the flanks which is incorrect. The mangrove belt is widest (c. 35-43 km) at the flanks and narrowest in the centre (c. 15 km), but there is deep tidal penetration in the central delta, up the channel of the Nun River.

Seasonal swamp forest is most extensively developed in the west and central delta regions; it is less well developed behind the mangroves of the eastern delta, which are, or were once, backed by terrestrial forest. The belt of seasonal and permanent freshwater swamp forests extends westwards from the central delta in semi-continuous fashion as far as Lagos Lagoon, the northern shores of which are fringed by freshwater swamp forests. In this type of forest inundation is mostly seasonal and the forest floor is generally dry during the dry season, but areas of permanent swamp forest do exist where distributary streams traverse depressions and the forest floor is permanently wet.

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As mentioned earlier, intermediate zones between tidal forest and seasonal swamp forest occur along watercourses in the junctional area between the two zones. In this transitional zone seasonal inundation is predominant, but when the ground is flooded because the river is in spate, it is subject to tidal rise and fall because of the back up of river water behind the tides. Details of the vegetational types are as described in the regional introduction for mangrove and freshwater swamp forest. As far as the fauna is concerned, most of the Guinean forest species occur in the delta, but much of the big game has been hunted out. Almost all the small mammals associated with wetlands are present.

Human Impact & Utilisation: The eastern side of the delta is more densely populated than the western sector, but there are many centres of population throughout the delta above the tidal zone. The waterways have always been fished intensively, and the mangroves and other forest types have been exploited for fuel and lumber. Mangroves and seasonal swamp forest have been cleared extensively in places, and seriously disturbed in others, but particularly along the landward side of the tidal zone, so that the mangrove belt has been shrinking in width for many years. The lost mangroves have been replaced by agriculture, or have given way to secondary vegetation, much of which is herbaceous, or have been cleared for communications or destroyed in the wake of oil exploration. Almost all the Nigerian oil palm plantations are situated in the delta, having replaced seasonal swamp forest, and much rice is also grown there. The delta is the centre of the Nigerian oil industry which has been developed since the early 1950s, and it is now criss-crossed by oil and gas pipelines. There are more than 30 oil fields in the delta, and as many more offshore. There are two major gasfields in the delta, at Rumuekpe (4°59'N/6°42'E) and Teeba (4°34'N/7°18'E). Four tanker ports have been constructed at the delta face, at Delta South (5°29'N/5°08'E), Forcados (5°21'N/5°21'E), Brass (4°19'N/6°14'E) and Bonny (4°27'N/7°10'E), and there has long been a major shipping terminal at Port Harcourt (4°43'N/7°10'E). Oil pipelines cross the tidal and seasonally flooded zones of the central delta, but the western delta is comparatively free of installations. Bonny has been a trading port since before colonial times.

Conservation Status: Unprotected.

(C) WETLANDS OF THE CROSS RIVER

General: The Cross River has sources north of Enugu (6°27'N/7°27'E) and in the high mountains of western Cameroon. Seasonally inundated areas occur on the branch entering the country from Cameroon, and reach a maximum width of 5 km at a point 6°04'N/8°15'E. Farther downstream there is a series of lakes or lagoons on the floodplain which are isolated from the river during the dry season. These are best developed south of Afikpo (5°53'N/7°57'E) and extend downstream to 5°35'N. The river receives several west bank tributaries and then enters a mangrove covered delta below Niwaniha (5°03'N/8°02'E) at the head of a broad (8 km wide) estuary. Other minor streams enter the east bank of the estuary from Cameroon. The mangrove forest extends around the estuary in a belt 7-8 km wide on both sides, deepening to 26 km in the deltaic zone at the head of the estuary. Altogether there are some 58 900 ha of mangrove forest on the system. The tidal plain on the western side of the Cross River Estuary is 6-9 km wide between landward and seaward faces and is continuous with the tidal plain of the Niger Delta 75 km to the west. There is a total of 46 000 ha of tidal land between the two systems.

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Flora & Fauna: As detailed in the regional introduction. The mangrove and freshwater swamp forest floras are richer here than elsewhere in West Africa and correspond quite closely with those described for the northwestern Cameroon coast in Section 4.1. *Osteolaemus tetraspis* is reputedly still quite common in the swamps around Calabar where the habitat is still intact.

Human Impact & Utilisation: Calabar (4°57'N/8°19'E) is an ancient pre-colonial trading town situated against the mangroves near the head of the estuary on the east bank, and the small fishing port of James Town (4°40'N /8°18'E) is situated near to the sea on the west bank of the estuary. Goods from the interior have long been transported down the Cross River to Calabar, and the estuary has traditionally been the scene of shipping activity. Modern roads connect both banks of the estuary with the road system serving the eastern partof the Niger Delta, and because of the density of population on the periphery of the swamps, the mangrove forest of the Cross River estuary is disturbed, but probably less so than in most other districts. The mangrove creeks are fished intensively, and crabs and shellfish are also regularly obtained from tidal creeks.

Conservation Status: Unprotected.

2. Riverine Wetlands

(A) THE NIGER/BENUE RIVER SYSTEM

General: The Niger River rises in the Fouta Djallon Mountains of Guinea and is 4180 km long, the lower third of its course being through Nigeria. It has a drainage basin of nearly 1 890 000 km^2 and most of the tributaries are extremely seasonal in their flow so that the river floods extensively in places throughout its course. The Niger/Benue System has a bankful open water area of 258 500 ha in Nigeria at a conservative estimate, excluding Lake Kainji, and floods over 1.3 million ha of land in that country in a wet year. Welcomme (1972) gives a figure of 480 000 ha for the total area inundated, but this seems too small.

The Niger enters Nigeria at an altitude of 161 m asl and a broad floodplain on both banks accompanies the river for 162 km downstream to Yelwa (10°51'N/4°46'E) through Soudanian savanna country. Some 75 km below the border it receives a major tributary on the north bank, the Sokoto River, which has several sources on the northwestern slopes of the Futua Plateau. Another floodplain extends back up the Sokoto River for 387 km above the confluence. This latter floodplain is continuous over the lowest 263 km and has a mean width of 11 km over this section, but in the upper section it is discontinuous and seldom more than 6 km wide. Minor floodplains occur on all the left bank tributaries of the Sokoto, but a large floodplain and permanent swamp area is situated upstream on the Zamfara River, 75-120 km above the confluence of this stream and the Sokoto. Altogether there are close to 470 000 ha of seasonal floodplain on the Niger/Sokoto system in this district. The rivers have pronounced levées locally, and carry levée and riverine forest, with floodplain grasses behind.

Below Yelwa the Niger expands into Kainji Lake, an artificial lake, dealt with in a subsequent section. Below Kainji Dam the waters of the river tend to be confined to their banks, but below Jebba (9°08'N/4°50'E) the river once again overflows its banks. From

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here the floodplain stretches to the confluence with the Benue River, a distance of over 300 km by river. The floodplain is widest in the upstream section where it reaches widths of 20 km, but it has a mean width of 15 km for the upper 225 km, then narrowing to 10 km over the final section. In this district the floodplain usually expands to 385 500 ha in most years. Minor floodplains and swamps occur on the tributaries in this district, but none is extensive.

Another extensive floodplain occurs above Onitsha at the head of the delta. Between Idah (7°07'N/6°43'E) and Onitsha (6°09'N/6°47'E) the river traverses a flat swampy plain. Affluent streams flow southwards, parallel with the Niger on either side of this plain, and the entire area, from western to eastern affluents, is subject to seasonal inundation. The floodplain is 100 km long with a mean width of 16.25 km and a maximum width of 22 km, and in most years provides a wetland of 165 000 ha.

Human Impact & Utilisation: The Niger River Commission was formed in 1963 by Cameroon, Chad, Benin, Burkina Faso, Guinea, Ivory Coast, Mali, Niger and Nigeria to co-ordinate efforts to develop the system. The river is navigable by ocean going vessels for 373 km above the mouth throughout the year, but above this point ocean going vessels are restricted to times of high water. Nevertheless they can reach the confluence of the Niger and Benue Rivers for 10 months each year. From here to Jebba the Niger is open to large craft only from October to the middle of November, but the river is an important thoroughfare for small craft for 60% of its length above Jebba.

Other floodplains occur on the Benue, right up to the Cameroon border, but these are discontinuous. After entering Nigeria at an altitude of 161 m asl, the Benue flows southwestwards between the Muri Mountains to the north and the Shebshi Mountains to the south. In this sector it receives many tributaries draining the mountains and the floodplain is almost continuous from the border, for 187 km. The upper floodplain varies in width from 3-10 km. Below this is a stretch of nearly 100 km where the river is confined to its banks, but then on either side of the confluence with the Taraba River, a floodplain, up to 10 km wide and best developed on the south bank, extends for 50 km along the river. Another large floodplain occurs on both banks of the Benue near Ibi (8°12'N/9°45'E). On this system the total floodplain area is approximately 312 000 ha, giving a figure of 1 333 400 ha for the entire system above the delta, but excluding Lake Kainji.

Hydrology & Water Quality: The Niger carries a suspended load of 5 000 000 tonnes/yr and has a mean year round discharge rate of 6092 m^3/sec at the mouth. The flood regime in Nigeria is bi-modal. A flood from the headwater regions reaches Nigeria in January and February, and another flood rises from local rains between August and October. The floods reach mean depths of 2 m over the floodplains, but deeper than this towards the lower end of the southernmost floodplain above Onitsha. The temperature of the river water varies between 22-28°C while the pH is consistently close to 6.7.

Flora & Fauna: The Niger and Benue Rivers traverse Soudanian savanna, but below the confluence the Niger traverses a Guinean-Soudanian forested zone. The flora and fauna are as described in the regional introduction for floodplains in these zones. *Crocodylus niloticus* survives throughout the system but is now rare and endangered. The status of *Crocodylus cataphractus* is not certain; it occurs in the system but is also rare.

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Human Impact & Utilisation: The floodplains have traditionally been used to graze cattle and for shifting cultivation, and have always been fished. The estimated catches from the Niger (in Nigeria) up until 1970 were 13 450 tonnes fish/yr, but it seems likely that they are now much larger than this.

Conservation Status: The Upper Ogun Game Reserve incorporates a stretch of the right bank of the Niger below Lake Kainji, but in an area that is essentially unflooded. There are other proposed game reserves along the river, some of which will incorporate floodplain, but none has yet obtained legal status. There are three proposed game reserves along the Benue River, which will, if established, extend to the river bank and include some floodplain areas. These will be the Ankwe and Pai River Game Reserves and the Damper Game Reserve.

(B) THE KOMADUGU YOBE

General: The Yobe Basin in the far northeast of Nigeria is almost entirely situated in Nigeria although the lower course of the Yobe River above Lake Chad marks the border with Niger. The basin is very flat and covered by formations of fluvial or lacustrine origin, sandy in some areas and clayey in others. Rainfall varies from about 850 mm/yr in the vicinity of Kano, and 1300 mm/yr in the vicinity of Jos, to 350 mm/yr at Lake Chad. It rains from May-September inclusive, with the heaviest falls in August. The basin is drained by several rivers which ultimately unite to form the Komadugu Yobe which discharges into Lake Chad. All rivers in the basin flood.

The Hadejia River has sources near Kano (12°00'N/8°30'E) and an intermittent source near Jos (9°55'N/8°53'E). It meanders for 500 km past the town of Hadejia (12°30'N/9°59'E) to a confluence with the Bunga River which drains the plateau near Jos. Towards the confluence, channels criss-cross the intervening land and the confluence is swampy. On the Hadejia River a floodplain begins 127 km above the confluence, and almost 100 km above it on the Bunga River. At the confluence the floodplain reaches a maximum width of 62 km, but quickly contracts to about 5 km and persists at this width for 135 km, to a point 105 km below Gashua (12°54'N/11°00'E). This area, which has many interlacing shallow watercourses running parallel to the main river channel from above the confluence to the end of the floodplain, has often been referred to as an inland delta. It provides a wetland of approximately 337 000 ha, with a further 89 000 ha on the Hadejia River and 63 000 ha on the Bunga River above the confluence. The first of the areas given is only approximate because many patches of higher, unflooded, ground occur within the floodplain, making accurate determinations of the inundated area difficult.

Another floodplain, the main part of which is 180 km long and 7 km wide (73 500 ha), occurs on the Komadugu Gana. This river also drains the Jos Plateau and joins the Hadejia/Bunga 30 km above Diffa (13°28'N/12°35'E) a town on the river across the border in Niger. From this confluence the river is known as the Komadugu Yobe, and a small floodplain on this, some 7 km wide and 20 km long, occurs immediately upstream of Diffa. No other major wetland occurs on the river until just before it enters Lake Chad, which it does through an extensive swamp zone which spreads on either side of the border with Niger. On the Nigerian side the swamp and floodplain system reaches southeastwards for 66 km behind the lakeshore, and later along it. There are some 10 100 ha of

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swamps along the lakeshore here, and a further 38 000 ha behind, separated from the lake by several kilometres of sandy country. There are thus no less than 610 500 ha of seasonal and permanent swamp lands on this system.

Hydrology: Mean discharge rate from the so-called 'inland delta' is 21 m^3/sec, but it is considerably less than this at Lake Chad. Flooding of the various wetlands occurs during the September-November period and seldom exceeds 1 m in depth.

Flora & Fauna: The western end of the basin is covered by Soudanian savanna, but this grades into Sahelian savanna in the vicinity of Diffa. The floodplains are covered by typical floodplain grasses, and trees occur on the river levées. Occasional trees of *Acacia nilotica* and *Acacia seyal* occur on the floodplain proper, usually on slightly elevated sandy patches. These species also occur on the levées together with *Diospyros mespiliformis* and *Mitragyna inermis* as described in the regional introduction. *Crocodylus niloticus* is now uncommon in the area although some re-stocking has taken place in recent years. Bird life is prolific and typical of floodplains, but large mammals have largely been replaced by domestic cattle.

Human Impact & Utilisation: Many cattle, probably 500 000, are grazed in the basin, moving onto the floodplains as the flood recedes. There is a deal of recession agriculture, and the area is fished. The largest catches are made while the flood recedes and the fish return from the shrinking floodplain to the watercourses. Large numbers of fish are stranded in pools of various sizes, and these are taken by birds and other piscivores as well as by man.

Conservation Status: The Baturiya Wetlands Game Reserve, which includes 29 700 ha of floodplain near Hadejia, was gazetted in 1985.

(C) THE NGADDA, YEDSERAM & EL BEID RIVERS

General: These three rivers all rise in the Mandara Mountains on the Cameroon border and flow into Lake Chad. Both the Ngadda and Yedseram Rivers rise to the north of Mubi (10°18'N/13°20'E) and initially flow due north in parallel some 20 km apart. The western stream, the Ngadda, traverses a large depression (11°33'N/13°14'E) containing 31 000 ha of permanent swamp south of Maiduguri. From this place it flows 120 km NE to reach Lake Chad in a great seasonal floodplain which extends around the southwestern corner of the lake.

The Yedseram sweeps east of Maiduguri and enters the floodplain 50 km SE of the Ngadda. The El Beid rises in Cameroon and forms the border between Cameroon and Nigeria for 400 km between Madagali (10°56'N/13°35'E) and Lake Chad. It has a floodplain over most of this distance, narrow in the upper reaches, but broadening towards the lake, and this lower portion is described in some detail in section 4.1 Cameroon. Two large permanent swamps occur in depressions between the El Beid and Yedseram Rivers, one at 11°53'N/14°19'E and another at 11°19'-11°41'N/14°16'E.

The great floodplain area around the southern tip of Lake Chad, which these three rivers traverse, is continuous with that in Cameroon and Chad supplied by the Chari/Logone system, and described in detail in sections 3.3 Chad and 4.1 Cameroon. In Nigeria the floodplain reaches 90 km south of Lake Chad and 112 km west. An arm of it fringes the lakeshore northwards, almost meeting the swamps of the Komadugu Yobe system. The

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main floodplain however, is south and southwest of the southern extremity of the lake and covers approximately 1 100 000 ha. The area subject to inundation is difficult to determine because it is repeatedly interrupted by patches of high ground which are never flooded.

Hydrology: The floods rise in August-September and areas close to Lake Chad are flooded to maximum depths of 2.5 m.

Flora & Fauna: As described in the regional introduction for Soudanian-Sahelian floodplains. A detailed description of the El Beid-Chari-Logone Floodplain is given in section 4.1 Cameroon. *Crocodylus niloticus* has become virtually extinct in the area.

Human Impact & Utilisation: The area is grazed intensively as the floods recede and this is perhaps the most important industry of the floodplain. Cattle move onto the floodplain from distant areas, and also move across the national boundary into Cameroon. There is also a large fishing industry, and a deal of small-scale recession agriculture.

Conservation Status: A substantial area of the southwestern side of Lake Chad is protected in the Lake Chad Game Reserve.

3. Lake Chad

Location: 12°29'-14°29'N/13°02'-15°21'E
Area: 2 500 000 ha at high water (c. 670 000 ha in Nigeria)
Altitude: 282 m asl (when lake surface covers 2 000 000 ha)
Nearest Towns: Maiduguri (110 km SW); Lagos (1360 km SW)

General: A description of Lake Chad is given in Section 3.3 Chad. Published accounts of the area of the lake vary between 1 379 200 ha (5325 square miles - Welcomme, 1972) and 2 500 000 ha (Beadle, 1981). Beadle states that the open water area has fluctuated between 1 000 000 ha and 2 500 000 ha this century. However, between July 1973 and November 1975 it had fallen below 250 000 ha, and in 1908 it was not much greater. Only the southwestern part of the lake is situated in Nigeria, with a shoreline of approximately 260 km.

Hydrology & Water Quality: The lake water is well mixed and well oxygenated, and has a salinity of less than 1‰. The lake is endorheic and occupies part of a great inland basin of more than 2 500 000 km^2. The basin and lake are shallow which is why the surface area of the lake is so variable. Rainfall presently averages about 300 mm/yr over the lake, which nowhere nearly balances evaporation, estimated at 2000 mm/yr by Dussart (quoted in Beadle, 1981). Of the total riverine inflow, 95% comes from the Logone/Chari system, the catchments of which lie in the humid highlands of Cameroon, Chad and the The Central African Republic, and represent about 25% of the total catchment. The contribution of the El Beid River is minimal, possibly 2.5% of the total inflow, while the remaining 2.5% is contributed by the Komadugu Yobe, Yedseram, Ngadda and several ephemeral streams. A brief account of the hydrology, geomorphology and history of the lake is given by Beadle (1981), who refers to more detailed studies.

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Flora & Fauna: As described in the regional introduction, but see the account in Section 3.3 Chad.

Human Impact & Utilisation: The lake is fished from villages in Nigeria, particularly Baga (13°06'N/13°54'E) on a peninsula extending into the lake. We do not have details of estimated annual catches.

Conservation Status: The Lake Chad Game Reserve occupies 704 480 ha with a frontage of over 150 km along the western shore of the lake, rather more than half the shoreline of the lake in Nigeria.

4. Other Interior Wetlands

General: Seasonal wetlands, not associated with rivers, occur throughout the Soudanian zone. They are mostly clay based pans. Large shallow basins, almost plains, on impermeable clay, are known as firiki. They are grass covered, and only the tips of the grasses emerge above the water during the rains. Other depressions known as fako, are also clay based, but are deeper than firiki. They support no grasses, and are devoid of vegetation except for stunted bushes. Semi-permanent pools are known as tabki.

Clay-pan wetlands are well developed to the north of Kano (12°00'N/8°30'E) and between Kano and Katsina (13°00'N/7°32'E). A collection of large shallow pans southeast of Katsina forms a mosaic over an area 61 km x 55 km, which contains a seasonally inundated area close to 190 000 ha. The shape of some pans, e.g. 37 km long by 3 km wide, suggests that they are depressions in fossil watercourses. Those for which the co-ordinates are given are the largest in the district, but there are several smaller ones, measuring about 15 km in length and 3 km in width, and a host of little pans.

Flora & Fauna: As described in the regional introduction.

Human Impact & Utilisation: Firiki may be cultivated, but fako are unproductive. Tabki (ponds) are utilised as waterholes for domestic cattle.

Conservation Status: Small clay-pans and ponds occur in several of the game reserves of Nigeria but none of the large areas between Kano and Katsina is protected.

5. Artificial Impoundments

(A) LAKE KAINJI

Location: 9°49'-10°40'N/4°19'-4°40'E
Area: 123 000 ha (water surface at capacity)
Altitude: 142 m asl (water level at capacity)
Nearest Towns: Ibadan (285 km SW); Lagos (405 km SSW)

General: The Niger River was dammed at Kainji (9°49'N/4°35'E) in 1968 and the reservoir created is some 135 km long at capacity, with a maximum width of 24 km, giving an open water surface close to 123 000 ha. The lake has a maximum depth of 59 m, a mean depth of 11 m, and a shoreline of 716 km at capacity. The lake occupies the site of a previous Pleistocene lake and the central section has submerged a large flat island which once divided the Niger into two branches. At both ends of the lake the river

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passes through narrow steep-sided valleys with widths of 1-5 km. The large seasonal draw-down results in the exposure of much land, both around the periphery and in the centre of the lake, where the top of the old island is uncovered. A general account of the lake is given by Imevbore & Adegoke (1975).

Hydrology & Water Quality: There are two floods each year. The so-called 'white flood', rich in suspended matter, lasts from August-October, and derives from local catchments. All the minor affluents are in flood together and at this time the Oli River, for example, discharges into the lake at a rate of 600-700 m^3/sec, while it ceases to flow altogether in the dry season. High water is attained in November-December and persists until April, being maintained by the so-called 'black flood' which derives from catchments on the Niger outside Nigeria. The waters are then virtually free of suspended matter, but are stained by humic compounds. The water level begins to fall noticeably in May, and by August it has fallen by 10-11 m to reach a minimum. The volume at peak water level is approximately 4.25 times greater than it is at low water level, and the throughflow to volume ratio is thus close to 4:1.

Flora & Fauna: The lake is not rich in macrophytes. The large draw-down each year, of 10-11 m, and the very large areas exposed on the margins have predisposed the periphery to floodplain vegetation. Imevbore & Adegoke (1975) discuss the vegetation of the lake. The lake is however, rich in invertebrates (Bidwell, 1976; Bidwell & Clarke, 1977). Of 113 fish species recorded in the Niger River locally, 82 species, belonging to 18 families were recorded in the lake in its early years. The most common species in the lake at this time were *Alestes baremose, Hydrocynus brevis, H. forskali, Labeo senegalensis, Lates niloticus* and *Synodontis membranaceus*. Less abundant species were *Alestes dentex, A. macrolepidotus, A. nurse, Chrysichthys nigrodigitatus, Citharinus distichodus, C. latus, Synodontis clarias, S. ocellifer* and *S. resupinatus*. Comparatively uncommon were *Auchenoglanis* spp., *Gnathonemus senegalensis, Hyperopisus bebe, Synodontis budgetti* and *Tilapia galilaea*. Reptiles associated with the lake and its affluents include *Crocodylus niloticus, Varanus niloticus*, and several aquatic snakes. An avifauna is still developing in association with the lake. Mammals present on the lake fringes, or in the gallery forests of affluent streams include *Felis caracal, F. lybica, Kobus ellipsiprymnus, K. kob, Manis gigantea, Redunca redunca*, and *Syncerus caffer*. Bidwell (1976) discusses the effect of water level fluctuations on the biology of the lake, while Lelek (1973), Lewis (1974) and Blake (1977a,b) discuss the changes that have occurred in the fish populations since impoundment.

Human Impact & Utilisation: The population density of the Kainji Basin was low prior to flooding, due to intertribal wars and disease, principally yellow fever, bilharzia and river blindness. Resettlement problems were therefore less great than those encountered in other parts of Africa, and a new town, New Bussa, has been created. However, cattle were brought into the basin each year by nomadic Fulani herdsmen, and these people still enter the area, including the National Park. It has been estimated that their arrival may increase the number of cattle in the area tenfold. The dam is used to generate hydroelectric power and has a planned capacity of 960 MW. A fishing industry has been established on the lake and total annual catches were at first very high, e.g. 17 000 tonnes in 1969 and 28 639 tonnes in 1970, but thereafter the catch declined dramatically to 11 037 tonnes in 1971 and 6048 tonnes in 1974. It had fallen to 4500 tonnes/yr by 1978.

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There were said to be 4867 fishermen operating 3331 boats on the lake in 1978-79, and it was recommended that the lake be closed to fishing for a period to allow fish stocks to recover. We do not have figures for subsequent years. It has been suggested that control of *Simulium* spp., by spraying with DDT, may be detrimental to fish in the lake and the Oli River, but no studies have been carried out so far as we are aware.

Conservation Status Lake Kainji National Park protects a stretch of lakeshore and sections of several affluent streams, principally the Oli River. However, the lake as such, is not protected. Some account of the protected areas is given by Brown (1967), while Wells & Walsh (1969) report on the avifauna.

(8) OTHER IMPOUNDMENTS

General There is a large reservoir (11°15'-11°27'N) on the Kano River at Tiga, with 48 600 ha of peripheral land under cultivation in the dry season. Another impoundment exists in Dedin Kowa Lake, and there are plans to generate hydroelectric power at Jebba and Shiroro.

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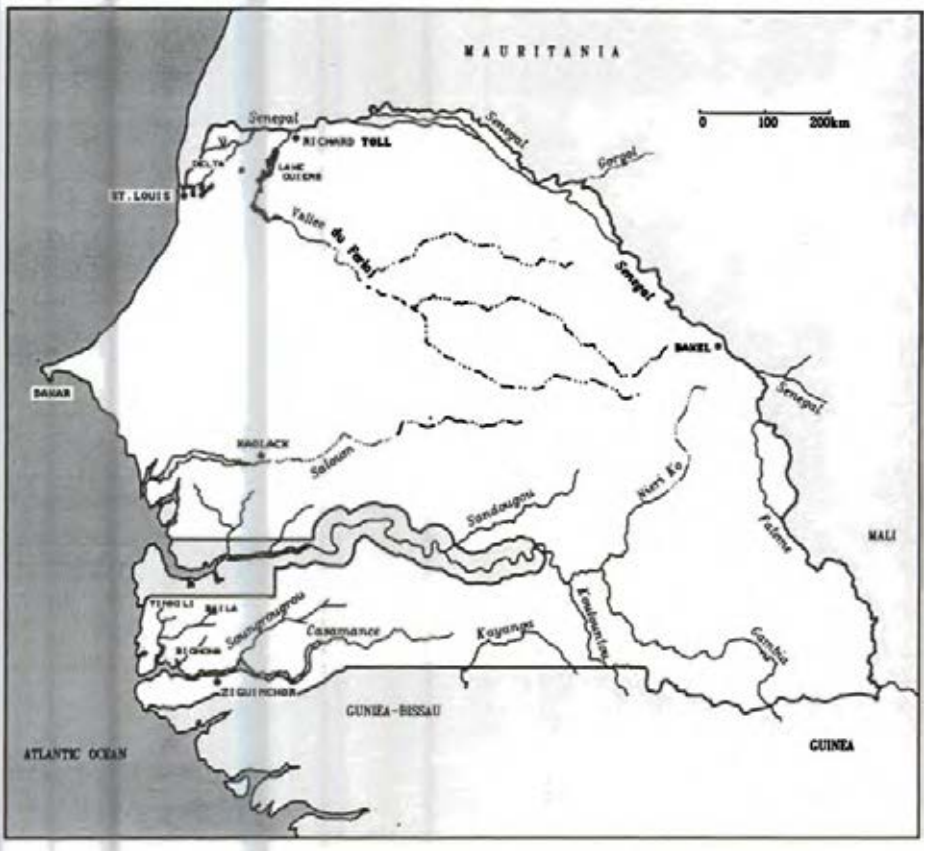

Map of Senegal

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3.13 SENEGAL

Introduction

Senegal has an area of 196 720 km^2, a population of 6 177 000 (1983) and therefore, a mean population density of 31.4 persons/km^2. It is bounded by Mauritania in the north, Mali in the east, Guinea and Guinea Bissau in the south and the Atlantic Ocean in the west. It encompasses Gambia except for the coastal section. About 90% of the land surface is less than 100 m asl, and the highest land is found in the extreme southeast where several hills exceed 400 m and a small area attains 500 m asl.

Drainage is entirely to the sea, principally via the Casamance, Gambia, Saloum and Senegal Rivers. The first and third of these streams rise in Senegal and are lowland rivers throughout, but the Gambia and Senegal Rivers both rise in the Fouta Djallon Mountains in Guinea. The Senegal River is the largest and forms the eastern and northern borders of the country over a distance of more than 1350 km, except for a 150 km section where the river is entirely situated within Senegal.

Climate

Three principal winds influence the climate. The hot dry Harmattan, which from the east or northeast off the Sahara, prevails over the country during the dry season. At this time the Alize blows down the coast from the north or northwest, and the warm air of the Harmattan rises over the cool air of the Alize along the coast, causing coastal cloud but little precipitation. Rain comes principally with the southwesterly trade winds which blow up from the South Atlantic, and which prevail over the country as the inter-tropical convergence moves north from June until October. Thus the wet season is longest at the coast in the southwest, and shortest in the north and northeast. At the coast Ziguinchor (12°35'N/16°20'W) has a 5 month wet season, Dakar (14°38'N/17°27'W) a 3 month wet season, and Saint Louis (16°01'N/16°30'W) only a 2 month wet season. Precisely the same pattern is followed inland. Mean annual precipitation decreases from south to north in a series of parallel bands across the country.

At Ziguinchor the mean annual rainfall is 1547 mm. No less then 99% of this (1527 mm) falls between June and October, with 1256 mm (81%) during July-September. Mean monthly precipitation is greatest in August (532 mm), while December, January, February and March are virtually rainless. The mean four monthly total for these months is less than 2 mm. There are close to 90 rainy days each year at Ziguinchor. Farther inland at a similar latitude, the rainy season is equally long, but less rain falls, e.g. close to 1300 mm at Kolda (12°56'N/14°55'W) and 1200 mm at Kédougou (12°35'N/12°09'W). The number of rainy days is also marginally fewer. At Dakar mean annual precipitation is only 578 mm, and 95% of this falls in the three months July to September. There are 42 rainy days/yr on average. At Saint Louis, mean annual precipitation is 381 mm. Virtually all of this falls in August and September and there are but 33 rainy days each year. Podor (16°35'N/15°02'W) in the far north receives 330 mm rain/yr and is the most arid station in Senegal.

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Temperatures are generally lower, and daily variations smaller, at the coast than inland. For example, at Dakar the mean monthly maxima range from 24-29°C throughout the year, while the minima range from 16-23°C. By contrast, at Matam (15°40'N/13°18'W) on the eastern border the corresponding figures are 30-41.5°C and 12-25°C.

Wetlands

The principal wetlands are the great floodplain of the Senegal River, and the estuarine and deltaic systems at several river mouths. There are numerous small seasonal and permanent swamps on the upper courses of the affluents of the major streams, and in the northwest, wetlands occur in the swales of extensive parallel dune systems.

List of Wetlands Described

1. The Senegal River Floodplain
2. The Senegal River Delta Complex
3. The Saloum River & Delta
4. The Gambia River Floodplains
5. The Casamance Estuary
6. Minor Coastal Wetlands

1. The Senegal River Floodplain

Location: 14°52'-16°39'N/12°23'-15°41'W
Area: 656 000 ha (c. 400 000 ha in Senegal)
Altitude: 7-30 m asl
Nearest Towns: Bakel (on N floodplain); Richard Toll (on S floodplain)

General: The Senegal River rises in the Fouta Djallon Mountains close to a point 12°03'N/11°18'W, but the principal tributary, the Bafing River, rises much farther south on the Guinean Dorsale (10°42'N/11°55'W). Because of the great seasonality of the precipitation over the entire catchment area, the river is very prone to flooding, and this is exacerbated by the fact that most of its course is very flat. Indeed along the entire Senegal border the river descends less than 200 m, and over its last 1000 km it falls only 100 m, thus having the very shallow mean gradient of 1:1000. In places it meanders exceedingly, and it spreads its floodwaters over a broad plain for much of its length. At first the floodplain is discontinuous, but from Bakel (14°54'N/12°26'W) downstream it is unbroken. From this place the river describes a great arc, northwestwards, westwards and finally southwestwards, to reach its delta at Saint Louis. The middle floodplain is approximately 410 km long between Bakel and Richard-Toll (16°25'N/15°42'W) and has a mean width of 16 km, and provides a seasonally inundated area of 656 000 ha above the delta. Over much of the floodplain the river flows in more than one channel and there are many anastomoses and numerous lakes in abandoned sections of channel. The delta complex which measures 80 km from base to apex, and almost 80 km along its base at the coast, provides a further 320 000 ha of seasonally inundated land. Of the total of 976 000 ha, approximately 40% is in Mauritania.

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Hydrology: Rainfall over the headwater catchments of the Senegal River is 1500-2000 mm/yr, but over the middle floodplain it ranges from 330-600 mm, while Class A Pan evaporation varies from 1600-2000 mm/yr. The flood from Guinea spreads over the plain between July and November when it peaks, and then begins to decline until February, by which time most of the plain is dry. During the flood, the mean peak volumetric flow in the river at Bakel, estimated over 64 years, is 4500 m^3/sec. It is estimated that in exceptionally wet years, such as may occur once a century, peak flow may rise to 10 000 m^3/sec, while in the drought year of 1913 it fell to just 1040 m^3/sec. The mean annual volumetric discharge, also averaged over 64 years up to 1980, is 780 m^3/sec, with an all time annual high of 1247 m^3/sec in 1924, and an all time annual low of 272 m^3/sec in 1913. During the dry season the flow is dramatically reduced, to a mere 10 m^3/sec at Bakel, and the river is then greatly contracted in its bed. At this time of year salt water penetrates far inland, regularly passing RichardToll, about 140 km upstream. Salt water intrusion to the floodplain is most noticeable during droughts.

Flora & Fauna: The river has pronounced levées and carries a belt of gallery forest. All the usual Soudanian species occur in this, together with some Sahelian species in the north. However, *Acacia nilotica* is predominant over very large areas, while *Cola laurifolia, Cynometra vogelii* and *Diospyros elliotii* are prominent in sites which are permanently moist. The lower parts of the floodplain have heavy clay soils and are covered by typical floodplain grasses, as described in the regional introduction, while the fringes and levées, which experience comparatively shallow and brief inundation, are sandy. These carry both herbaceous and arborescent vegetation. The vegetation of the numerous lakes and lagoons varies depending upon how permanent they are and how much the depth of the water fluctuates over a year. Permanent herb swamps around the larger water bodies are dominated by *Phragmites* and *Typha*.

Human Impact & Utilisation: About 550 000 people live on the floodplain, many in small towns like Richard Toll, Podor, Dagana and Boghé. The traditional industries practised on the floodplain are cattle herding, fishing and agriculture.

Fishing used to produce an annual catch of about 33 000 tonnes, but a series of dry years since the early 1970's has drastically reduced catches. Most fish are caught when they leave the floodplain and congregate in the channels as the flood subsides. Some 10 000 people are currently engaged in the fishing industry.

In the past the area used to support about 1 500 000 cattle and 1 000 000 sheep and goats, but the recent dry years have greatly reduced this number. It has been estimated that 27% of the cattle died in 1984 (Drijver & Marchand, 1985).

The majority of the floodplain residents are engaged in the traditional system of agriculture known as walo. Cultivation begins immediately after the floods subside. Millet, beans and water melons are the most important crops on the deeply inundated parts of the plain, but the shallow sandy fringes are used to produce maize, tomatoes and potatoes as well, and these latter areas produce by far the heavier yields. Some 40 000 - 180 000 ha is cultivated this way each year. A further 30 000 ha is now under irrigation, 25% of which is devoted to sugar production. Small irrigation schemes are encouraged, whereby a group of villagers can cultivate 14-20 ha. Numerous dykes and channels have been built on the floodplain to facilitate irrigation culture.

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Hunting is no longer very important on the floodplain, most of the big game having already been hunted to extinction. Only *Phacochoerus aethiopicus* survives in substantial numbers and this is still hunted.

In 1972 the *Organisation pour la Mise en Valeur du Fleuve Senegal* (OMVS) was created by Mali, Mauritania and Senegal to develop water management policies and projects. Among the proposals of OMVS were that the Bafing River should be dammed at Manatali in Mali, 1200 km upstream, and that the Senegal River should be dammed at Diama, 27 km upstream from Saint Louis. This lower dam (closed late 1986) is designed to prevent salt water intrusion, and it is intended that control of water levels by the two dams will permit year round navigation between Saint Louis in Senegal and Kayes in Mali. It has been proposed that a dyke should be cut alongside the right bank of the river through the delta, to prevent river water flooding a large part of the delta. However, the wisdom of this is now questioned by a number of authorities and the dyke may indeed not be built. It is proposed that a deep water port should be built at Saint Louis and that a canal should provide a navigable passage through the delta to the river in order to permit floodplain produce to be shipped overseas. The dams will provide hydroelectric power and provide for irrigation on the periphery of the floodplain.

There can be little doubt that the full implementation of these schemes will result in the loss of most of the floodplain and of a great deal of riverine and levée forest, and that they will precipitate socio-economic upheaval for the half million people who live on and depend upon the floodplain. Nevertheless, the controlled availability of water at certain points will provide the potential to rehabilitate wetland areas which have lost their water supply as a result of previous developments. Drijver & Marchand (1985) comment upon the potential problems in some detail.

Conservation Status: Unprotected.

2. The Senegal River Delta Complex

Location: 15°44'-16°29'N/15°35'-16°29'W
Area: 320 000 ha (c. 200 000 ha in Senegal)
Altitude: 0-4m asl
Nearest Towns: Saint Louis (on delta); Dakar (200 km SW)

General: The delta comprises large areas of low lying seasonally flooded land, some small areas of dry land, areas of semi-permanently wet sand, river channels, islands, and numerous lakes, some of which are 5 km long and 2-3 km wide. The main channel of the Senegal River constitutes the border with Mauritania through the delta. The Langue de Barbarie, where the river reaches the sea south of Saint Louis, is an area of sand-bars, tidal lagoons and saline mudflats fringed with mangroves.

A parallel series of SW-NE trending sand dunes occurs in northwest Senegal and the Senegal River crosses the north end of this system before swinging southwestwards to reach the sea by flowing along the Atlantic side of the outer line of dunes. The dune system is 125 km wide from east to west, and some 45 km long from north to south, with a total area of more than 575 000 ha. Drainage from the Vallée du Ferlo crosses several of the eastern dune ridges perpendicularly, but is then diverted northeastwards between dune ridges where it expands to form a series of little lakes, culminating in Lake Guiers,

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after which it enters the head of the Senegal River Delta at Richard Toll. Lake Guiers is the only large freshwater lake in the country and measures 35 km in length with a maximum width of 7.5 km. At high water the open water surface is close to 17 000 ha. Apart from the Lake Guiers system, many of the dune swales are permanently moist or marshy.

Hydrology: The seasonal flood at the delta rises in August and persists through November. Maximum flood depths are 1.5 m over the lowest lying areas. There is little influx to Lake Guiers from the Vallée du Ferlo in most years and the principal water supply is from the Senegal River at Richard Toll. Here, water is diverted into the lake through valves in the dyke.

Flora & Fauna: Floodplain grasses occur on the delta, and permanent reed swamps fringe the lakes and the river channels. Some stunted trees occur on the high land and levées, but the area is saline due to the regular intrusion of sea water and has a harsh Sahelian climate with a severe dry season. For much of the year only the vegetation fringing watercourses and waterbodies is noticeably green. At the river mouth stable sand-bars are colonised by littoral species such as *Alternanthera maritima, Ipomoea pescaprae, Sesuvium portulacastrum* and *Sporobolus* spp. Lake Guiers is fringed by reeds and sedges and has a typical submerged and floating flora.

Lake Guiers is an important site for the rich and prolific avifauna of the district, especially when the other delta wetlands dry up. It harbours a small population of manatees, and almost the full spectrum of small aquatic mammals is present, as detailed in the regional introduction. The other lakes of the delta are similar to Lake Guiers in terms of their fauna, although only the Djoudj National Park is known to contain resident manatees. Sand-bars at the river mouth are nesting sites for the marine turtles *Chelonia mydas*, and *Dermochelys coriacea. Felis caracal, Herpestes ichneumon* and *Varanus niloticus*, all of which may prey upon young birds and their eggs, are known from the delta. The two latter species are present in large numbers. *Python sebae* is also common. The area has a rich avifauna, typical of the West African coast, but among notable species are *Pandion haliaetus*, which overwinters, together with *Alopochen aegyptica, Anas acuta, A. angustirostris, A. clypeata, A. querquedula, Nettapus auritus, Plectropterus gambensis* and *Sarkidiornis melanota*. Species which nest here include *Anhinga rufa, Ardeola ralloides, Bubulcus ibis, Casmerodius albus, Egretta garzetta, E. intermedia, Ibis ibis, Nycticorax nycticorax, Platalea alba*, and *Threskiornis aethiopicus*. Dupuy (1971a,b,c; 1972) and Roux (1973a,b) give some account of the mammal and bird faunas of the delta.

Human Impact & Utilisation: Proposals to alter the flooding regime of the delta are recorded in section 3.13.1. Many dyke systems have been constructed in the delta to influence flooding patterns, and these have been detrimental to wildlife in the complex. The various programmes to control the hydrological regime will all result in a reduction of flooding and a loss of wetland habitat. Lake Guiers serves as a reservoir for several towns including Dakar. The flooding of Lake Guiers is contrived artificially and its water is used for the sugar refinery at Richard Toll as well as for domestic consumption.

Conservation Status: Important wetland sites are protected in the Djoudj and Langue de Barbarie National Parks. The Djoudj Park is situated in the northern part of the delta (16°30'N/16°10'W) and was created in 1971. It lies between the main river channel and the Djoudj and Ooram Bayous and comprises 16 000 ha of low-lying saline flats. It

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retains floodwater longer than most other parts of the delta. It is in close proximity to the Ndiael Bird Reserve of 46 500 ha, and will be contiguous with a proposed National Park in Mauritania. The Langue de Barbarie Park at the Senegal River mouth was established in 1976 and enlarged in 1977 to an area of 2000 ha. It is estimated that more than 3 million migrant birds pass through the parks each year including large numbers of *Anas acuta, A. clypeata, A. querquedula, Limosa limosa* and *Philomachus pugnax*. The Djoudj Park is a nesting site for large numbers of *Pelecanus onocrotalus* and several species of ducks, geese, cormorants and herons.

3. The Saloum River & Delta

Location: 13°34'-14°10'N/15°48'-16°48'W
Area: 150 000 ha
Altitude: 0-5 m asl
Nearest Towns: Kaolack (at head of delta); Dakar (125 km NW)

General: The Saloum is a small river, formed by the confluence of numerous intermittent headwater streams, the longest of which rises 105 km east of Kaolack (14°09'N/16°08'W). The river reaches the sea in a drowned but shallow valley and it is the marine transgression which, on a map, gives the Saloum the appearance of a major river. At the coast the river has a substantial delta which shelters behind the southward pointing spit of Sangomar. The main river channel reaches the sea at the end of this spit, Point Sangomar, and the major part of the delta lies below this on the south bank of the river.

The delta stretches along the coast for a linear distance of 72.5 km and reaches 35 km inland, while mangrove swamps extend almost 70 km upstream to Kaolack. South of the main river channel the delta comprises a network of anastomosing streams weaving between mangrove covered mud islands, with only small areas above high tide level. In this section several other seasonal streams enter the complex from the landward side. To the north of the main channel the delta is more sandy. Some islets on this side support mangroves, but others are subject to infrequent tidal flooding and support herb fields, or are more or less devoid of vegetation, while areas on the fringes experience seasonal rather than tidal inundation and support typical floodplain grasses. There are also large areas of permanently wet but sparsely vegetated saline sand. In total the delta wetlands cover 150 000 ha, some 70% of which is mangrove forest.

Mangroves extend upstream for 25 km between the delta and Kaolack in a belt 5 km wide, but thereafter the river meanders on a wet sandy plain, through Kaolack, for a further 35 km. It finally peters out in a patch of little lakes into which the intermittent headwater tributaries flow. In dry cycles, saline influence extends this far inland.

Hydrology: Subject to seasonal high water flooding, but principally under marine influence.

Flora & Fauna: As described in the regional introduction. Principally a mangrove system. Manatees and marine turtles are present in the delta and mona and colobus monkeys are present in the forest trees. The avifauna is typical of the West African coast, but among the more interesting species breeding here are *Egretta gularis, Hydroprogne tchegrava, Larus cirrocephalus, L. genei, Sterna hirundo and S. maxima. Pandion*

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haliaetus overwinters here, as does *Numenius phaeopus*. *Phoenicopterus ruber* sometimes breeds in the salt flats upstream, above Kaolack.

Human Impact & Utilisation: The mangrove forest has traditionally been exploited, and this continues outside the park, while the creeks are fished, and shellfish and crabs are also taken from them. There are plans for industrial and agricultural (rice) expansion in the area and these pose potential threats.

Conservation Status: The Siné-Saloum National Park occupies a large part of the delta, covering 72 000 ha, and is itself situated within the larger Biosphere Reserve of 180 000 ha. The Biosphere reserve includes 23 000 ha of seasonally flooded lands, 72 000 ha of land under marine influence, i.e. tidal swamps, sand-bars, lagoons etc., and 85 000 ha of dry land. It is planned that the park shall become part of an international park with a new section to be added in the south, across the Gambian border to include the mangroves at the mouth of Karenti Bolon.

4. The Gambia River Floodplains

General: The estuary of the Gambia River is almost entirely situated in Gambia, but affluent channels on the north bank carry mangrove and other halophytic vegetation across the border into Senegal. The most seaward of these watercourses is the Mini Minium Bolon which branches over the border. The longer branch, the Koular Bolon, is tidal for a linear distance of 12 km and supports mangroves (13°38'N/16°06'W) 8 km across the border. There are 4000 ha of wetland in Senegal on this system. Farther east (15°45'W) the Bao Bolon is flanked by a belt of saline sand flats for 33 km across the border. The flats are 5 km wide at the downstream end and are subject to a combination of tidal and seasonal inundation over an area of 9000 ha.

East of Gambia, seasonal floodplains extend along the Gambia River in Senegal for a distance of 70 km, finally reaching an altitude of 20 m asl. Another floodplain extends for 105 km. up a tributary, the Koulountou River, crossing Senegal and reaching the Guinean border at an altitude of 25 m asl. The floodplains vary from 1.5-5 km wide, and there are about 53 000 ha of wetland in the system.

Hydrology: The Mini Minium and Bao Bolons are tidal. The flood on the upper Gambia River and the Koulountou River rises between July-November and subsides before the end of January, covering some land to a depth of 5 m.

Flora & Fauna: Typical floodplain grasses and Soudanian gallery forest types accompany the rivers, as described in the regional introduction. *Cola laurifolia, Cynometra vogelii* and *Diospyros elliotii* occur in swampy riverine sites, with *Acacia nilotica, Baissea multiflora, Borassus aethiopum, Crateva religiosa, Dalbergia saxatilis, Diospyros mespiliformis, Erythrophleum guineense, Landolphia dulcis, Raphia sudanica, Syzygium guineense* and *Ziziphus mucronata* on levees and islands. Sedges fringe the rivers, notably *Cyperus baikiei*, together with aquatics such as *Rotula aquatica* (Ehretiaceae) and *Hygrophila odora*. Permanent swamps occur in sections of abandoned river bed. Here *Phragmites* and *Typha* are present, together with some swamp forest trees.

The fauna is typical of a partly forested Soudanian river floodplain, but big game have been hunted to extinction in all but the protected areas. *Crocodylus cataphractus*,

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C. niloticus, *Hippopotamus amphibius*, *Loxodonta africana*, *Osteolaemus tetraspis*, *Panthera pardus* and *Syncerus caffer* survive in the wetland section protected in the Niokolo-Koba National Park. The park is the last refuge of the elephant in Senegal. Vervet monkeys are abundant in the gallery forest.

Human Impact & Utilisation: Traditionally, crops are cultivated on the floodplains immediately after the flood recedes each year, and cattle, sheep and goats are grazed there. The floodplains are also fished intensively. The Gambia River is navigable for over 100 km above the Gambian border.

Conservation Status: A small area of the wetlands on the upper Gambia and Koulountou Rivers is situated in the Niokolo-Koba National Park. Otherwise unprotected.

5. The Casamance Estuary

Location: 12°21'-13°00'N/15°25'-16°50'W
Area: 360 000 ha (includes open water).
Altitude: sea level
Nearest Towns: Ziguinchor (on estuary); Dakar (235 km NNW)

General: The Casamance Estuary is another drowned valley at the mouth of which recent alluvium has formed a delta. It is situated close to the southern border in the wettest part of Senegal, where, although highly seasonal, mean annual rainfall exceeds 1550 mm/yr and the dry season is only 7 months long. The inlet is tidal for a linear distance of 165 km inland, and considerably more than this if measured along the centre of the main channel. In addition, tides penetrate far up several affluent valleys, notably those of the Tinkili, Baila and Soungrougrou streams, all on the north side. The main channel is 2.5 km wide at the mouth, then widens to 5 km and thereafter varies in width from 1-5 km for over 100 km. The delta area is almost entirely covered by mangrove forest, of which there is some 250 000 ha. Upstream of the mangroves there are palm-pandan and reed swamps, and areas of swamp forest subject to brackish/freshwater inundation depending upon the season. While these latter wetland types extend up estuary for over 165 km, the vast bulk of the wetland in the system is found within 60 km of the mouth.

On many small affluents on the north side, above tidal influence, and not continuous with the estuarine wetlands, there are narrow strips of seasonally inundated land. These are generally between 50-500 m wide, but extend in total length for hundreds of kilometres. They support floodplain grasses and gallery forests.

Hydrology: Principally marine and tidal, but with freshwater backup occurring in the rainy season and transmitting tidal influence extra far inland. Purely seasonal inundation occurs in the upstream sections of the minor affluents. The road at Dianah Malari, which crosses the head of the estuary 165 km inland, is 6 m asl.

Flora & Fauna: This is a mangrove estuary with areas of palm-pandan swamp, freshwater swamp forest, gallery forest, reed swamp, grass floodplain and some permanent ponds in the upstream sections. The flora is as described in the regional introduction. Cercopithecus mona and Hippopotamus amphibius occur here, the former often abundant in the mangrove trees. Up to 6000 pairs of *Pelecanus onocrotalus* breed on

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Kalissaye Island. Notable species in the mangroves are *Ardea goliath* and *Platalea alba*. Upstream, in the vicinity of Ziguinchor, *Ibis ibis* and *Pelecanus rufescens* nest in riverine trees.

Human Impact & Utilisation: A number of centres of population are situated on the periphery of the wetland area, e.g. Oussouye, Nyassia, Ziguinchor, Naiguisse, Diattacounda, Sédhiou, Tanaff, Djindé, Marassoum, Tanghory, Sindian, Bignona, Tendouck and Diouloulou. There is an estuarine fishery and an offshore fishery based in the estuary, which supply these towns. Mangrove timber is used locally for fuel and construction as virtually no real forest remains elsewhere in the district.

Conservation Status: Mostly unprotected, but the National Park de Basse Casamance, of 5000 ha, includes some of the wetland a few kilometres from the sea. The park contains mangrove areas, and bare saline mudflats, as well as terrestrial forest with Guinean species, and some wooded savanna. *Trichechus senegalensis* is present in the park. Dupuy (1971d) gives an account of the park. 16 ha at Kalissaye Point are protected in a bird sanctuary.

6. Minor Coastal Wetlands

Location: 14°44'-15°39'N/16°35'-17°25'W
Area: 4000 ha (total at low water)
Altitude: 1-4 m asl
Nearest Towns: Dakar (15 km SW); Saint Louis (100 km NE)

General: A series of small coastal lakes occurs to the north of Dakar in the Périmètre de Reboisement des Niayes. The coast, from Cape Vert northeastwards, is an open sandy coast, subject to strong wave action and longshore drift. Behind the sand beach however, along the 'Périmètre' the string of lakes extends for 120 km. The southernmost lakes are the largest, and they include Nhiarhol Pool, and Lakes Mbao, Mbeubeussé, Retba and Ourouaye. Lake Retba, which is the largest, has an open water surface 5 km long and 1.7 km wide at low water. The northern lakes are not named. The southern lakes are enclosed by vegetated zones subject to seasonal inundation, and at high water they may increase their areas fivefold. They all have a rich avifauna and harbour most of the small aquatic mammals associated with the region.

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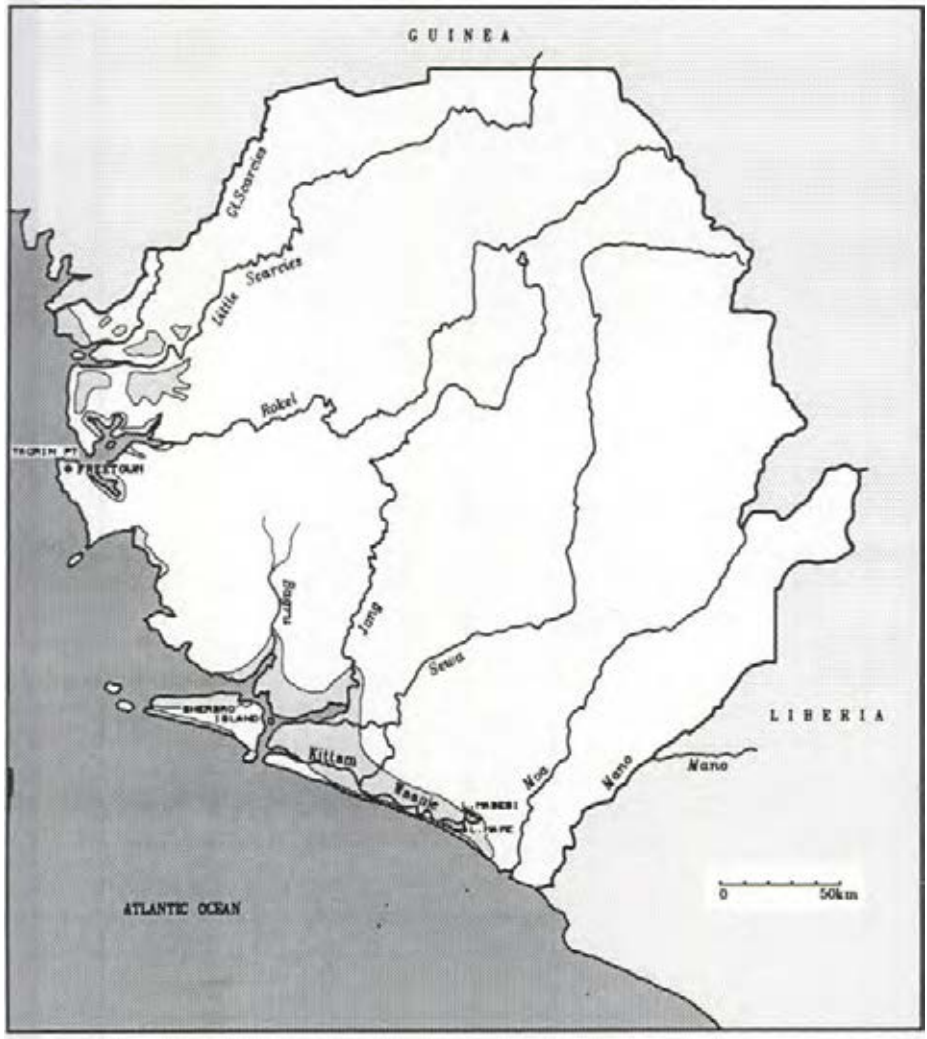

Map of Sierra Leone

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3.14 SIERRA LEONE

Introduction

Sierra Leone is situated on the Atlantic Coast of West Africa, bounded by Guinea on the north and east and by Liberia in the south. It has an area of 72 325 km^2, a population of 3 627 000 (1982), and thus a mean population density of 50.8 persons/km^2. The mainland extends approximately 352 km from N-S between latitudes 6°55'N and 10°00'N, and 323 km from E-W between longitudes 10°14'W and 13°17'W, while the highly indented coast measures some 825 km, excluding offshore islands. The coastal half of the country lies below the 200 m contour, while the interior half is mostly above 500 m. The coastal lowlands are 50 km wide in the south and 125 km wide in the north, but are interrupted by a mountainous block near Freetown (8°30'N/13°17'W), which rises steeply from the sea to the summit of Picket Hill (888 m asl). In passing inland the coastal plain is sandy, swampy and often flooded for the first 30-50 km. Thereafter, the land rises to a gently undulating plateau which continues inland to the foothills of the Guinean Dorsale crossing the interior from NW-SE. Bintimani Peak (9°13'N/11°08'W) at 1948 m asl in the Loma Mountains, and Sankanbiriwa Peak (8°57'N/10°44'W) at 1853 m asl in the Tingi Mountains, are the highest points in the country. Both are situated a few kilometres distant from the Guinean border.

Drainage is directly to the sea by a series of rivers which rise on the dorsal. From north to south these are the Kolente or Great Scarcies River, which forms the border with Guinea for 52 km in its middle reaches, followed by the Little Scarcies, Rokel, Jong, Sewa, Moa and Mano Rivers. The latter forms the border with Liberia. Other streams rise in the lowlands, and the most important of these are the Ribi, Kukuli, Gbangbaia and Waanje Rivers. In the south, the Gbangbaia, Jong, Sewa and Waanje Rivers discharge into a long coastal lagoon system.

Climate

Mean annual rainfall varies between 3000-5000 mm at the coast, decreasing inland to 2000-2500 mm on the eastern border. There is a long wet season, but the dry season is severe with virtually no rain and hot desiccating winds. On the coast, e.g. at Freetown, where mean annual precipitation is 3639 mm, January and February are dry and December is moderately dry. The situation is similar at Bo (7°58'N/11°45'W) on the lowland plateau, but rainfall is lower, c. 2900 mm, and at Kabala (9°40'N/11°36'W) in the mountains of the north it persists for 4 months, from December-March inclusive.

Vegetation

Both the coastal lowlands and mountain slopes were once entirely covered by high Guinean forests, with grasslands on northern parts of the interior lowland plateau and wooded Guineo-Soudanian transitional savanna on other parts in the south. However, the primary rain forest has almost disappeared, the only surviving pockets being in forest reserves. Over 97% of the primary forest in the country has been destroyed. Some has been replaced by secondary forest, and some by herbaceous associations.

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Wetlands

Mangrove swamps used to occlude most of the coast, but there have been great clearances for rice cultivation which began in the late 1940s. Freshwater swamp forests and *Raphia* swamps back the mangroves in the lowlands, and an extensive lagoon system stretches along the southern coast. Inland pockets of swamp forest dot some river valleys and there are large areas of swamp grassland, much of which is secondary. Other grasslands occur in the north, on the lowland plateau below the mountains. They are flat featureless areas which are flooded during the rains, but which dry into hard cracking soils in the dry season. Forests subject to seasonal inundation form narrow strips on some of the montane rivers.

List of Wetlands Described

1. Coastal Wetlands
2. Riverine Wetlands
3. Lake Confon or Sonfon
4. Artificial Impoundments

1. Coastal Wetlands

General: Much of the northern coast is deltaic, and was at one time entirely cloaked by mangrove forests, which extended far up rivers and distributaries, and then gave way to *Pandanus* and *Raphia* swamps, and these in turn to freshwater swamp forests along the river sides. Much of this forest has been cleared or is heavily disturbed, and much has been replaced by secondary herb swamps. The deltaic coast is interrupted by the Freetown Peninsula, but continues again to the south end of Sherbro Island, from which point the nature of the coast changes and it becomes sandy, with swamps between old beach ridges and along the courses of streams which have been deflected alongshore.

Littoral Swamps: From the northern border mangrove forest extends 17.5 km along the coast to the mouth of the Great Scarcies River. It reaches 8-10 km inland and 15 km up Sasiyek Creek. Yellibuya and Kortimaw Islands are entirely covered by mangrove forest. There are 14 800 ha of mangrove forest here, with trees reaching 25 m in height locally, and to landward there are 9 isolated patches of swamp forest covering about 1900 ha in total.

There are few mangroves on the estuaries of the two Scarcies Rivers, and between their mouths (8°24'N/13°11'W) and Tagrin Point (8°01'N/13°09'W) the coast is sandy/rocky and exposed, and comprises open beaches. However, small areas of swamp forest and large areas of grass swamp land occurs between the two Scarcies rivers and along the south bank of the Little Scarcies. Between the rivers there are 7000 ha of grass swamp, and a further 30 000 ha on the south bank of the Little Scarcies River in a discontinuous strip 42 km long and 10 km deep.

Mangroves are again well developed at the mouths of the Rokel River, behind Tagrin Point, and several islands in the estuary, e.g. Yema and Tasso Islands are mangrove covered. The mangrove belt extends southwards to the Bunce River and along the

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landward side of the mountainous Freetown Peninsula. The mangrove swamps are 0.5-3 km wide and are broken by numerous creeks, up which, behind the mangroves, there are strips of freshwater swamp forest. To the south of Freetown, mangroves fringe Yawri Bay almost completely, in a strip 37 km long and 1-5 km deep. Three small rivers reach the sea here, the Ribi, Kukuli and Kagboro. Mangroves extend up these for 20km, 10km and 17 km respectively, in all cases giving way to freshwater swamps which then ascend the rivers for a further 20-22 km. A strip of sandy coast then continues south from Shenge Point, at the mouth of the Kagboro, for 20 km to the Sherbro River mouth.

Here Sherbro Island shelters a broad waterway 60 km long and 3-7.5 km wide, known as the Sherbro River, into which the Bagru, Jong and Kittam Rivers discharge, together with a number of minor streams. Both banks of this waterway are cloaked by mangroves up to 10 km deep, and in total there are about 39 000 ha of tidal forest in this locality.

Sherbro Island is at the end of a long sandspit, Turner's Peninsula, which has been built up by the powerful northwestward flowing longshore drift. The island exists because the waters of the Jong and Kittam Rivers have breached the spit, cutting off the tip as an island. The sandspit is 112 km long, reaching southeast to the mouth of the Moa River (6°58'N/11°35'W), and behind it, the Sewa and Waanje Rivers unite to form the Kittam River which has been diverted northwestwards alongshore. This river is separated from the sea by dune ridges, in the swales of which, towards Sherbro Island, swamp grasslands and swampy forests occur, the latter rich in *Pandanus* and *Raphia* spp. Inland, the entire area between the Jong and Sewa Rivers is swampy, with great patches of herb, palm or tree swamps covering a total of 71 000 ha in a mosaic with dry land. Southeast of the Sewa River, behind the sandspit, mangrove swamps, palm swamps, grass swamps, lagoons and dry land are interspersed in a belt 60 km long and 25 km deep, as far as the right bank of the Moa River. Wetlands occupy most of the 150 000 ha tract of low lying sandy land. The mangroves are situated in the southeast on Keree Creek (7°01'N/11°38'W), on the shores of Lake Mape (7°10'N/11°49'W), and around Masa Island in the Waanje River (7°13'N/11°58'W).

There are a number of lakes and lagoons in the littoral belt, e.g. Lakes Kenema (7°19'N/12°17'W), Kwako (7°18'N/11°59'W), Kamason (7°19'N/11°58'W), Baiama (7°17'N/11°57'W), Masatoi (7°12'N/11°50'W), Mape (7°06'-7°11'N/11°42'-11°51'W) and Mabesi (7°10'-7°13'N/11°41'-11°45'W). Other littoral lakes occur immediately behind the coastal barrier spit on Sherbro Island, centred on a point 7°30'N/12°05'W. These lakes vary between 1-6 m asl and are more saline and alkaline than the riverine lakes described in the next section, having pH values approaching 8.5.

Flora & Fauna: In their pristine state these lakes were fringed by pandans, *Raphia* palms, swamp forest trees, and by sedges, reeds and littoral grasses such as *Anadelphia*, *Paspalum*, *Phragmites* and *Sporobolus* spp., which can tolerate salinity and varying degrees of inundation. On Lakes Masatoi, Mape and Mabesi there are trees typical of mangrove forest, e.g. *Avicennia africana*, *Laguncularia racemosa* and *Rhizophora* spp., even although these lakes are not normally tidal. The mangrove, palm and freshwater swamp forest floras are as described in the regional introduction. The area provides a wider range of habitats than is apparent in the littoral zones of neighbouring countries and the avifauna is particularly rich, with virtually all the coastal West African species,

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and most of the inland aquatic species, present within 10 km of the coast. Mona monkeys are common in the mangroves.

Human Impact & Utilisation: A great deal of mangrove and freshwater swamp forest has been cleared for agriculture, particularly rice culture. The mangroves have otherwise been used quite extensively for fuel wood and building timber, and for materials for making fish traps. The mangroves yield crabs, prawns, oysters and fish, and the mangrove creeks are fished intensively. Many are overfished.

Conservation Status: Unprotected.

2. Riverine Wetlands

General: Because of the marked seasonality of rainfall the rivers become very swollen in the wet season and may flood extensive areas. However, water levels fall by as much as 8 m in the dry season when the rivers may be reduced to shallow streams, meandering in broad watercourses. All the riparian trees tend to be inundated during the rainy season. In the mountains the flooded strips are narrow, but become broader and less deeply inundated towards the coast.

In the lowlands of the Moa Valley, in the southeast, there are more than 140 discrete swamps, most of which are forested or partly forested. They are situated at altitudes below 200 m between the Kambui Hills and Gola Hills, while another 120 swamps lie between the Kambui Hills and the Sewa River. Most of these swamps are on affluents of the principal rivers, but some are in shallow depressions which are filled each year by the rains, and which overflow at the surface only at times of high water.

In the central northwestern districts there are extensive areas of seasonally inundated grassland on the lowland plateau. No less than 150 such areas occur in a belt 30 km wide and 190 km long, oriented NNW-SSE, from the Great Scarcies River in the NW corner of the country (9°45'N/12°45'W) to the town of Mano (8°00'N/12°05'N). Some of these treeless grasslands are small, c. 100 ha, but others cover 4000 ha. Again some are associated with minor streams, but others are in depressions which are essentially endorheic.

In the coastal lowlands, lagoons and ponds are common on riversides, and innumerable swampy patches occur in depressions on the floodplains, often quite far distant from the rivers. Many of the lakes are in continuity with the river during the floods but are isolated during the dry seasons. Small ponds are too numerous to discuss in detail, but Lakes Fula (7°33'N/11°58'W), Gambia (7°31'N/11°58'W), Kpoli (7°30'N/12°05'W), Poepi (7°28'N/12°00'W) and Tibi (7°25'N/11°58'W) along the Sewa River are good examples. They are all situated about 30-40 m asl, and are shallow water bodies, probably not exceeding 2 m in depth at any place.

The largest of these lakes, Lake Poepi, is 2.5 km long, up to 1.3 km wide and has an open water surface of 285 ha. It is 1.7 km distant from the banks of the Sewa River at its nearest point. All the riverine lakes exhibit pH values close to that of river water, acid in reaction, c. 5.2. Although Lake Poepi is entirely isolated from tidal ebb and flow (at least for the greater part of the year), there are stands of *Rhizophora* at the southeastern and southwestern extremities, while the rest of the lake is enclosed by tree, palm, pandan and *Typha* swamps, and such swamps cover the land between the lake and the river. All the

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other lowland riverine lakes are fringed by similar swamp associations, and have beds of floating and submerged aquatic macrophytes. Their fish faunas are similar to those of the rivers with which they are associated, but they are otherwise faunistically similar to the littoral wetlands already discussed.

Flora & Fauna: The aquatic vegetation is typical of West African riverine lakes as described in the regional introduction. The 'mangroves' on these lakes are situated well above tidal influence and grow in freshwater. All the small obligate aquatic species are present, but crocodiles, terrapins and turtles are scarce having been hunted intensively for decades. Due to the secondary nature of most of the surrounding vegetation, and the loss of a great deal of the natural swamp forest, large mammals normally associated with these habitats are also uncommon. However, *Hippopotamus amphibius* and *Syncerus caffer nanus* occur locally and *Cercocebus torquatus*, *Cercopithecus aethiops*, *C. mona*, *C. petaurista* and *Colobus badius* are widespread in the trees. The avifauna of the coastal lowland section is rich, with most of the West African aquatic species being present.

Human Impact & Utilisation: Population density is high in the lowlands, as high as it is anywhere else in West Africa except for parts of Nigeria. As a consequence the rivers and lakes are fished intensively, and indeed are overfished in most places. There have been extensive clearances of riverine vegetation throughout the country, both for agriculture and for other developments.

Conservation Status: No wetland system is protected in the coastal lowlands. Areas of seasonally inundated grassland are protected in the Outamba-Kilimi National Park in the northwest, and another substantial swamp area is likely to be protected in the Mamunta-Mayoso Swamp Nature Reserve (8°40'N/11°55'W) near Makeni. This latter reserve has not yet been ratified by central government, but was given protection by the local tribal chiefs in 1981.

3. Lake Confon or Sonfon

Location: 9°15'N/11°30'W
Area: 820 ha
Altitude: 549 m asl
Nearest Town: Freetown (205 km SW)

General: Lake Confon is the only permanent lake on the interior plateau of Sierra Leone and is situated in the Sula Mountains. It appears to have been formed by the collapse of the land surface after deep weathering of lower layers. The maximum depth recorded is 8 m. The lake is exorheic, receiving water from 7 small streams and draining from the southern end. Studies of the lake are reported in Gerrath & Denny (1979), Green (1979) and Gerrath & Denny (1980a,b).

Flora & Fauna: The entire lake is covered by emergent vegetation during the dry season, with *Colocasia* sp., *Eleocharis dulcis*, *Polygonum senegalense* and *Thalia welwitchii* the dominant species. *Nymphaea lotus* and *Utricularia* spp. are prominent in the areas of open water. Among the fish *Aphyosemion guineense*, a small *Barbus* sp., *Epiplatys fasciolatus* and a species of *Kribia* have been identified. The avifauna appears typical of well vegetated permanent West African lakes, with *Acrophilornis africana*, *Anhinga*

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rufa, *Bubalcus ibis*, *Casmerodius albus*, *Ceryle rudis* and *Plectropterus gambensis* in evidence, among many others.

Human Impact & Utilisation: The lake is isolated and rarely visited, although hunters may operate around its shores sporadically. It is not utilised.

Conservation Status: Unprotected.

4. Artificial Impoundments

General: There are several small dams, e.g. at Sefadu (8°39'N/10°58'W), but they are not important as wetlands.

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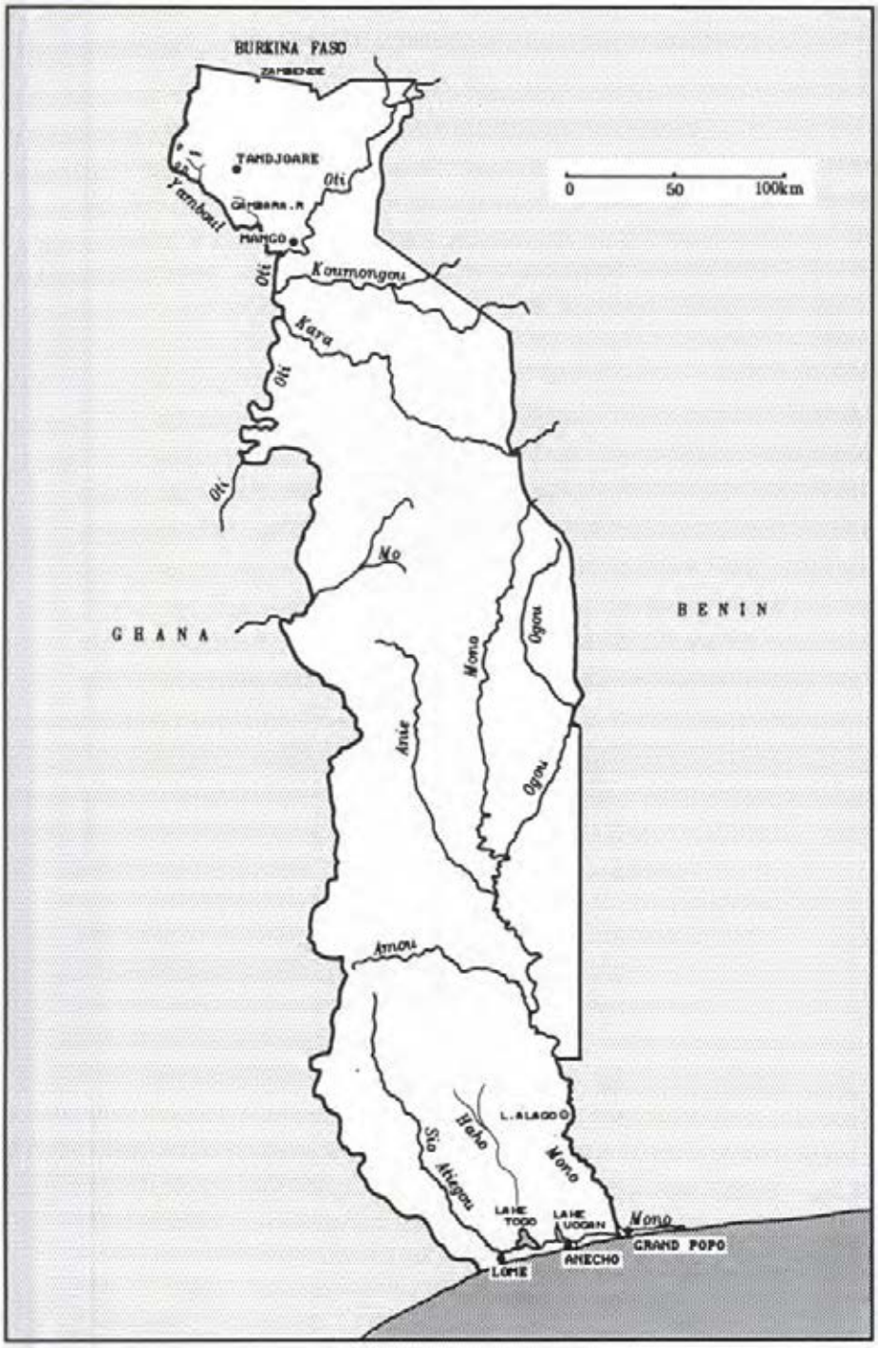

Map of Togo

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3.15 TOGO

Introduction

Togo has an area of 56 785 km^2, a population of 2 963 000, and a mean population density of 52 persons/km^2. It lies on the Gulf of Guinea and is bounded by Ghana in the west, Burkina Faso in the north and Benin in the east. It is 551 km long, some 100 km wide and is roughly rectangular, reaching inland along its long axis from the Gulf of Guinea. The coast is just 75 km long, and behind the continuous dune barrier there is a lagoonal system which has only tenuous connection with the sea and is essentially a freshwater system. The water bodies are situated in a littoral depression which was inundated at the time of the last marine transgression, but are now semi-permanently isolated from the sea. The coast is thus one of submergence, but it is sandy, with pronounced longshore drift to the east. The coastal plain, of some 5400 km^2, is also sandy and rises gently to the 100 m contour some 40 km inland. The undulating slope then continues northwards, over an equivalent area, until the 200 m contour is reached some 100 km inland, where a chain of mountains (Chaîne du Togo) enters the country from the west and crosses the interior obliquely, being oriented SSW-NNE. The mountain range extends for 350 km up and across the centre of the country. This comprises a string of isolated peaks, rising to a maximum altitude of 1000 m asl (7°20'N/0°42'E), although Baumann Peak (6°52'N/0°46'E) at 986 m asl is often cited as the highest point. The southern and central mountainous sector is drained by the Mono River and its tributaries, the Mono reaching the sea in swamp land on the Togo Coast where it forms the border with Benin. The north of the country is traversed by the broad valley of the Oti (Pendjari) River, a tributary of the Volta, which crosses the country from Burkina Faso to Ghana. The valley floor is flat and the river meanders so that its course across Togo, a straight line distance of 80 km, is almost doubled. In this valley the Oti receives several tributaries draining the northern part of the Togo Mountains, and other tributaries from the high plateau which intrudes into the extreme northwest of Togo from Burkina Faso.

Climate

Togo lies between the two per-humid rainforest blocks of the Guinean region and has two wet and two dry seasons at the coast, but a single wet and single dry season inland. At Lomé (6°10'N/1°21'E) on the coast, the principal wet season is from March-July, with a short dry period during August and September. This is followed by a brief rainy period in October before the major dry season sets in from November-February inclusive. Some 100 km inland, in the mountains, Kpalimé (6°55'N/0°44'E) is wet for 10 months of the year, and only December and January are dry. From here the climate becomes progressively drier in passing north as the dry season extends, reaching 5 months at Sokodé (8°59'N/1°11'E) in the central highlands and 6 months, November-April, at Mango (10°23'N/0°35'E) in the valley of the Oti River. At the coast, insolation varies from maxima close to 220 hrs/month in October to minima close to 90 hrs/month in June. A regular sea breeze blows from the SW during the day, with wind speeds of 3-4 km/hour, and from June-September there is a permanent haze. In the north, the dry Harmattan wind begins to blow during November and persists until March.

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At the coast mean annual precipitation is 850 mm/yr, but this has varied between extremes of 600 mm in a dry year and 1200 mm in a wet year. Over the mountains mean annual precipitation ranges from 1300-1500 mm/yr, with wet and dry cycle maxima and minima of 1750 mm and 1000 mm. Here maximum falls are in June and minimum falls in January. Over a decade mean coastal temperatures varied from 24°C in July to 29°C in March. Rainfall is sufficient to support tree savanna, which includes baobabs along the littoral.

Wetlands

The coast is sandy and exposed and there are no mangrove stands of significance. The coastal lagoons are enclosed by reed swamps and seasonally inundated lands. Lakes Togo and Vogan are the only major lakes and they are not normally tidal. Floodplains occur on most rivers because of the highly seasonal nature of the rainfall. In the mountainous central part of the country, the floodplains are narrow, often mere strips 25-50 m wide, but in the north, the floodplains are much better developed and occur in wide valleys at low altitudes. Isolated dambos are found in the highlands of the savanna zone in the north. There are some 70 small agricultural impoundments and a large dam is being built at Nangbato on the Mono River.

List of Wetlands Described

1. Lakes Togo & Vogan & the Coastal Lagoons
2. Riverine Wetlands
   (a) Wetlands of the Mono River
   (b) Wetlands of the Oti River
3. Minor Wetlands

1. Lakes Togo & Vogan & the Coastal Lagoons

Location: 6°15'-6°33'N/1°17'-1°47'E
Area: 6400 ha (open water) + 38 000 ha inundated land
Altitude: 0-99 m asl
Nearest Towns: Lomé (15 km W); Vogan (10 km E)

General: The system comprises Lake Togo, some 15 km long and up to 6 km wide, the smaller Lake Vogan, and a lagoonal system behind the coastal dunes, which links them, and continues eastwards to the Mono River on the Togo/Benin border. This lagoonal system opens to the sea at Anécho.

Lake Togo receives water from several streams. The Sio or Aziegou River enters at the southwestern extremity. This stream has a broad floodplain for many kilometres upstream of the lake, and some 10 km west of it, it divides to form two distributaries which enter the lake through a marshy delta. Several small lakes are situated on the lower floodplain. Some minor streams enter Lake Togo along its western flank, and at the northern extremity, having traversed an extensive floodplain, the Haho River enters, again through a lakehead swamp. Other short coastal streams enter the lake along its

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eastern border. At its southern extremity it comes within 1 km of the sea and abuts the coastal sand-bar, thereafter turning due east and continuing as a narrow lagoon or canal to a point north of Anécho where it receives the effluent from Lake Vogan.

The main body of Lake Vogan is 7 km long and 1.5 km wide, oriented SW-NE, with an open water surface of 1600 ha. It has several deep arms extending northwards, into which affluent streams discharge, the most important of which is the Boko River. A narrow canal carries water from the southern extremity to the lagoonal system along the coast, and some 2.5 km east of this junction the lagoon/canal branches. One branch extends 3 km to the sea at Anécho, the other, the Ghaga Canal, continues east to Grand Popo on the Mono River in Benin, and over this stretch it is navigable. The mouth at Anécho frequently closes due to the development of a sand-bar in the dry season, and is unblocked artificially every 2-3 years.

The lagoonal sediments are mainly very fine, and quicksands occur near the banks, but there are outcrops of beach rock near the sand-bar. The catchments of the affluent streams are the Haho, 3400 km^2; the Sio, 2800 km^2; and the Boko, 1000 km^2.

Wetlands stretch back up the tributary rivers, above Lake Togo. Periodically inundated land occupies 19 800 ha on the Sio, reaching 60 km upstream, and 12 000 ha up the Haho, reaching 40 km upstream. The swamps on the Sio ascend to an altitude of 99 m, while those on the Haho reach 50 m. Smaller swamps occur on the Elio and Boko Rivers which enter Lake Vogan. Other swamps accompany the canal along the landward side of the coastal dunes to the mouth of the Mono River. Small areas of high swamp forest occur on the Sio and Haho Rivers, but most of the wetland is occupied by grassy floodplain with isolated trees, and some small isolated herb swamps.

Hydrology & Water Quality: Spring tidal range is 3.05 m and salt-water penetration occurs when the bar is breached, however, the lake is predominantly a freshwater body. The mean annual discharge from the Sio River, which is perennial, has ranged from 3.9 to 26.3 m^3/sec. We have no information regarding volumetric discharge for the other streams, but flow in the Haho River is intermittent. The lagoon is oligomictic and there is usually a difference of about 1.5°C between the surface and bottom water. The lowest recorded surface water temperature was 23°C during the flood season in July 1982, and the highest was 34.8°C at low water in March 1982. The lowest transparencies are reached during the floods, when Secchi depths are about 25 cm, and the highest values, up to 1.2 m, are obtained at the height of the dry season. The pH varies from 8.21 downstream at low water, to 6.75 in the affluent streams at high water. Sodium ion concentrations have been recorded as varying between 14 mg/l upstream during floods, to 6000 mg/l in the lagoon at low water. There is a diurnal variation in dissolved oxygen when the lagoon is calm with a saturation range of 76-91% at the surface and 78-93% at depth.

Flora & Fauna: Peripheral areas of the lake, subject to inundation, are occupied by swards of *Acrostichum aureum* and *Paspalum distichum*. There are no mangroves because the lagoon is not normally tidal. Freshwater macrophytes, e.g. *Pistia stratiotes*, appear in the lagoon at times of high flood. Swamp forest, containing both Guinean and Soudanian species occurs on the rivers, while the floodplains are covered by the typical spectrum of floodplain grasses. Some *Phragmites* and *Typha* occur in permanent water in depressions. The fish fauna includes both marine and riverine species, but is dominated

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by the genera *Chrysichthys* and *Tilapia*. Invertebrate populations are dominated by the molluscs *Pachymelania* sp. and *Tympanotonus* sp., and the crustaceans *Callinectes latimanus* and *Penaeus duorarum*.

Human Impact & Utilisation: A main international road passes along the Togo beach front, to seaward of the Lake Togo System, connecting in Togo, the towns of Lomé and Anécho, while other main roads ring the lake between Lomé, Tsévié, Tabligbo, Vogan and Anécho. Population density around Lake Togo is not great, but the coastal lowlands are possibly the most populous part of the country. Scattered villages around the lake combine extensive agriculture with fishing, and fish are sold in the nearby towns. Seine nets are principally used, but there are to date, no collective fishing enterprises. Coconuts are grown on the sand-bar to seaward of the lagoonal swamps, especially in the west, and other plantations, of coconut and oil palm, have been established on the floodplain of the Sio River just above Lake Togo. There is little tourism in the area.

Conservation Status: Unprotected.

2. Riverine Wetlands

(A) WETLANDS OF THE MONO RIVER

General: A swampy floodplain occurs over the lower reaches of the Mono River, between the rapids section (6°48'-6°56'N/1°37'E), where there are 6 separate rapids, and the coast. The wetland extends from Lake Alago (6°44'N) to the dune barrier, but it is at first discontinuous. The lower continuous section measures 30 km in length and 6 km in width and covers some 18 000 ha. A larger area of contiguous wetland, perhaps amounting to 26 000 ha, lies across the border in Benin. The area comprises permanent herb swamp, patches of swampy forest, and areas of grassy floodplain.

Flora & Fauna: *Phragmites* and *Typha* are present, together with lower growing sedges and grasses, and a spectrum of Guineo-Soudanian swamp forest trees. The area has a rich wildlife, typical of a West African tropical coastal wetland. Most of the truly dependent wetland species cited in the regional introduction are present. Manatees, crocodiles and *Hippopotamus amphibius* occur in the river. The avifauna is both rich and prolific.

Human Impact & Utilisation: The area is fished, but not intensively, small scale agriculture occurs on the margins of the floodplain, and cattle are grazed on the floodplain margins.

Conservation Status: Unprotected. However, an area of flooded gallery forest and some 20 km of river frontage is protected above the rapids on the Mono River in the Togodo National Reserve.

(B) WETLANDS OF THE OTI RIVER

General: The Oti (Pendjari) crosses Togo in the north, in a savanna covered valley, some 40-50 km in width, situated between the co-ordinates 10°00'-11°00'N/0°27'-0°55'E. The river banks are cloaked by strips of gallery forest and substantial areas of this are subject to periodic inundation. A floodplain accompanies the river and its tributaries for over 80 km from the northern border to the town of Mango, reaching 10 km in width across the main river. There are in total some 48 000 ha of wetland in this

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locality. In the south of this valley the Oti receives a tributary, the Koumongou River, which flows west from the Chaîne du Togo to join the Oti on the Togo/Ghana border. A floodplain occurs along the lower reaches of the Koumongou in a belt 25 km long and 4 km wide, occupying 9500 ha, and covered by ox-bows and meanders. This plain floods to depths of 5 m in the wet season. Both Oti and Koumongou Floodplains are parched during the dry season, except for some ponds and lakes which persist in depressions. Water levels on the Koumongou Floodplain respond very quickly to rain in the hills during the May-October period. Upstream, on the Koumongou, gallery forests, characterised by a mixture of Soudanian and Guinean species and subject to periodic inundation, extend for 70 km along the river in a strip some 300-500 m wide.

Farther downstream the Oti receives two other tributaries which also have small floodplains above their confluences. These are the Kara River, with a floodplain of 1500 ha immediately above the confluence (10°01'N/0°25'E) and strips of swamp forest upstream, and the Mô River, with a discontinuous and rather narrow floodplain between the co-ordinates 8°52'-9°05'N/0°31'-0°54'E. Both of these streams drain the central highlands of the Chaîne du Togo, and their floodplains are floristically and faunistically similar to those of the Oti and Koumongou Rivers.

Flora & Fauna: These floodplains are all situated in Soudanian savanna country and are dominated by typical floodplain grasses. Most of the trees cited as occurring in Guineo-Soudanian transitional swamp forests, and in Soudanian swamp forests, occur along the rivers, and there is a levée forest community.

Human Impact & Utilisation: Cattle graze the floodplains in the dry season, and are often to be found in the Kéran National Park. There is some settled agriculture and much hunting on these floodplains.

Conservation Status: Much of the floodplain of the Koumongou River is protected in the Kéran National Park, and a 30 km section of the upper Mô River, with a narrow floodplain, is included in the Fazao-Malfakassa National Park. Poaching is a problem in the Kéran National Park, as is the presence of domestic cattle which compete with wildlife. The Oti Floodplain is unprotected.

3. Minor Wetlands

General: A small strip of floodplain and inundated forest, occupying about 150 ha, occurs on an un-named ephemeral stream on the far northern border near to the small town of Zambéndé, situated almost due north of Dapaong (10°58'N/0°07'E).

Semi-permanently inundated depressions occur in the high savanna zone on the north-eastern border, west and south of the town of Tandjoaré. These depressions are centred on a point 10°44'N/0°05'E, and are mostly associated with minor watercourses. They are peaty, dominated by grasses, but support swamp forest trees along the watercourses. In this area there are perhaps 2400 ha of these depressions.

4800 ha of periodically inundated land occur on the Yamboul River, just inside Togo and 20 km WNW of Mango (10°23'N/0°35'E), and other small areas occur on the Gambara River, an affluent of the Yamboul River.

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REGION 4

CENTRAL AFRICA

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Introduction

This region has a total area of 4 083 600 km^2 and comprises the six countries which drain in major part to the Zaire River. It extends over more than 26° of latitude, from 13°25'S in SE Zaire to 13°08'N at Lake Chad, and over nearly 23° of longitude, from 8°29'E on the Cameroon/Nigeria border, to a point 31°18'E in Lake Albert on the Zaire/Uganda border. It is bounded in the east by the Western Rift Valley, along the western rim of which many mountains rise to heights of over 3000 m, while the highest point in the region is reached on the eastern side of the rift at 5110 m asl in the Ruwenzori Mountains. The southern boundary follows the watershed between the Zambezi and Zaire Rivers for much of its length, and in this section reaches maximum altitudes of 1000-1600 m asl. The highest point in the north is Mt. Cameroon (4095 m asl) on a SW-NE trending volcanic ridge which extends along the Cameroon/Nigeria border. The frontage to the Atlantic Ocean is deeply indented in places and measures 2160 km. Only the Central African Republic is landlocked. A coastal plain is continuous from Congo to Cameroon, reaching 100 km wide in the north where it is densely forested. Towards the south it is narrower, 20-40 km wide, and is covered by savanna and littoral forest. In the central sector it is very swampy.

Drainage patterns within the region are controlled by three major watersheds, in the south, east and north; the Zaire/Zambezi watershed, the Zaire/Nile watershed and the Zaire/Chad Basin watershed respectively. In addition there is a series of coastal watersheds in the west from which streams flow either eastwards to the Zaire Basin or westwards to the sea. In the northwest, in central Cameroon, a quadruple watershed occurs in the Massif de l'Adoumaoua which separates the extremities of the Chad, Niger, and Zaire Basins from a coastal basin.

However, the drainage and physiography of the region is dominated by the Zaire River Basin which is the second largest drainage basin in the world exceeding 3 700 000 km^2. It extends well outside the region, spanning more than 32° of latitude and almost 21° of longitude. The southernmost tributaries, the Mulembo and Muniengashi Rivers, rise in Zambia, at a latitude of 13°13'S, while the northernmost tributary, the Kotto, rises near Mt. Dj Ngaya in the Central African Republic, 9°15' north of the equator. The easternmost tributary, feeding Lake Tanganyika, rises in Tanzania on the longitude 33°18'E, while far to the south in Zambia, a source of the Chambeshi, feeding Lake Bangweulu, lies on the longitude 33°E. Other tributaries rise in Angola, Burundi, Rwanda, Gabon and Cameroon. At its mouth the mean

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annual volumetric discharge of the Zaire River is 43 000 m^3/sec, second only to that of the Amazon, and over its middle course in the central depression, together with its two principal tributaries the Kasai and Oubangui, it provides 3150 km of slow flowing open water surface covering some 2 000 000 ha.

The eastward flowing rivers draining the watershed along the eastern rim of the Zaire Basin discharge to the rift valley lakes. Of these, the two southern lakes, Lakes Kivu and Tanganyika, drain to the Zaire River, while the northern ones, Lakes Edward and Albert, drain to the Nile. Many rivers reach the Atlantic Ocean from the western watersheds, but from south to north, the most important are the Kouilou, Nyanga, Ogooué, Mbini, Nyong and Sanaga Rivers.

Climate

In the upper and middle atmosphere a dry easterly air flux persists over the region for much of the year, sandwiched between the semi-permanent high pressure regions over the tropics to north and south. However, in the lower atmosphere, below 2000 m asl, a mass of moist oceanic air floods across the region from the west, and this is also confined by the high pressure zones to north and south. The meeting of the moist Atlantic air mass with the dry anticyclonic masses gives rise to distinct southern and northern inter-tropical convergence zones. The position of the moist westerly air mass varies, moving north and south with the seasons, as the anticyclones over the tropics alternately strengthen and weaken. During the northern summer the moist Atlantic air mass extends between 20°N and 9°S, while during the southern summer it extends from about 20°S to 5°N. The precise limits vary from year to year, as does the maximum easterly extension. The eastern limit of the air mass, known as the Monsoon Front, is opposed by a low level easterly stream blowing off the Indian Ocean and coming up over East Africa. The easterly extension of the Atlantic air mass over the continent is greatest during the northern summer, and in June-July the Monsoon Front may have crossed the entire region to reach 35°E. During the southern summer it withdraws westwards to 29-30°E, being just confined within the region at a time when the SE Trade Winds across the Indian Ocean are strongest.

The equatorial rain belt oscillates from north to south across the equator in the course of a year. The equator is always wet, but dry seasons of increasing duration occur in moving to higher latitudes. At intermediate distances from the equator there are two wet and two dry seasons. As one approaches the tropics the minor wet season becomes reduced in duration until at high latitudes, the two dry seasons merge. The dry seasons are thus most pronounced at the northern and southern extremities of the region where they persist for 6 months during the periods when the moist equatorial air mass is displaced from them.

The patterns of precipitation are however, rather more complex than this suggests, especially towards the Atlantic coast and the eastern boundary, where they are strongly influenced by topography. The wettest part of the region is in the northwest at Fernando Póo and the Cameroon coast. Here rain falls all the year and mean annual precipitation ranges from 3500-5500 mm on the coasts, while on the south-western slopes of the Gran Caldera Range of Fernando Póo annual falls over 11 400 mm have been recorded, and the mean annual figure for the southwestern slopes of

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Mt. Cameroon reaches 9960 mm at one station. These coastal mountains, at the head of the Bight of Biafra, intercept the SW Monsoon winds as they swing inland during the northern summer, bringing peak falls of 700-800 mm during the month of August.

The second, and by far the largest perhumid zone, lies along the equator across the central depression of the Zaire River Basin. Here mean annual rainfall is lower, just 1800 2200 mm, but it is quite evenly distributed and there is no marked dry season. It increases in the east to over 3000 mm on the high mountains of the Western Rift Valley.

Precipitation decreases rapidly in passing southwards down the coast, from 4001 mm at Douala to 3000 mm at Campo, but with a wet pocket, c. 4500 mm on the Rio Muni Estuary, then declining to 2645 mm at Libreville, 1768 mm at Mayumba, 1512 mm at Pointe Noire and 800 mm at the mouth of the Zaire River. However, while rainfall decreases towards the interior, away from the wet Cameroon coast, in the south of the region it increases towards the interior, and 100 km inland, in the hills of Congo and Cabinda it reaches or exceeds 1800 mm.

The equatorial region, including most of the central depression of the Zaire River Basin, is frequently cloudy and overcast, with about 2000 hours of sunshine/yr, increasing to over 3000 hours on the northern and southern boundaries of the region. The central depression is constantly warm, and daily temperature ranges are small, revealing little fluctuation from month to month. Mean annual temperatures are 24-25°C with mean daily maxima close to 30°C and mean daily minima near 20°C. At the boundaries of the region, temperatures are subject to wide variations, with mean daily maxima approaching 40°C in the far north during the warmest months, and mean daily minima falling to 15°C in the coolest months. A permanent snowfield exists above 4500 m in the Ruwenzori Mountains, and all along the eastern boundary frosts occur in the high mountains. Mean daily minima of 12°C are not uncommon in the populated highlands. Coastal temperatures become more variable from north to south. The temperature regime at Douala is not greatly different from that of the central Zaire depression, with a mean annual temperature of 26°C, a mean monthly maximum of 31°C in the warmest month and a mean monthly minimum of 21°C in the coolest month. By contrast the mean figure at the Zaire River mouth is 23°C with a much wider range.

Vegetation

The vast central depression of the Zaire Basin is covered by tall evergreen forest. In moving out of the depression, up the slopes of the plateaux to south and north, one traverses semi-deciduous forests, then broad leaved savannas, then *Acacia* savannas, and finally, in the north, scrub bushlands on the fringes of the Sahara. Evergreen forests extend out of the central depression into the plateau regions along river valleys, giving way to narrow galleries of evergreen and then semi-deciduous forest along rivers in the savanna zones.

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Wetlands

Tidal (mangrove) forests are well developed in the northwest, in Cameroon, where high rainfall throughout the year on the coastal mountains has led to the production of bounteous alluvium and a deltaic coastline. This is so well supplied by fresh water that at high tide, river water backs up and inundates much low lying land, so that in consequence the tidal forests are saline at the seaward face but flooded by fresh water on the landward margins. Mangroves occur at all river mouths in the region, but south of Douala, extensive tidal forests are confined to major estuaries and lagoons. They are well developed in the Gabon and Ogooué Estuaries, where again fresh water tidal forests occur, and there are extensive stands in some of the major Gabonese lagoons and at the mouth of the Zaire River.

Because of the highly seasonal precipitation patterns around the periphery of the region, many rivers in the savanna zones have floodplains. Some of these are very extensive, covering millions of hectares in the north of the region. These are covered by typical floodplain grasses, but often with galleries of swampy forests, or ribbons of levée forest along the principal watercourses.

In the central depression of the Zaire River Basin, rainfall is more or less aseasonal and the rivers are mostly brim full in their channels. However, since the major rivers are fed by tributaries rising in the surrounding savanna zones, they flood whenever their tributaries are in spate. The Zaire River, having tributaries rising far to the north and south of the equator, tends to flood for prolonged periods twice a year. Because the land is very flat in the central depression, which was once the floor of a Pliocene lake, the floods spread far from the river channels and the major blocks of swamp forest in the central depression cover more than 14 000 000 ha.

Virtually every stream entering the central depression, en route to a confluence with the Oubangui, Zaire or Kasai Rivers, floods some land along the floor of its valley. Downstream these floodplains may reach 10 km in width, while upstream they may be only a few metres wide. Throughout the central depression, and up the lower valleys of the tributaries, these floodplains are forested. However, along some rivers of the central depression, where flooding is semi-permanent, e.g. the Likouala aux Herbes in Congo, the river channels are fringed by vast meadows of floating grasses, in belts up to 5 km wide on either side of the river. These in turn are backed by swamp forests, on less deeply inundated ground. Shallow depressions in the basin are covered by permanent swamp forest, while the areas which drain and are inundated less permanently are covered by other types of forest. North of the central depression other swamp forests occur in Gabon and Cameroon, in the second per-humid area.

On the high plateaux surrounding the central depression, some large permanent swamp systems occur where rivers meander across unusually flat stretches, or flood shallow depressions, e.g. in the Shaba Province of SE Zaire. All permanent swamps at high latitudes are dominated by tall reed grasses or papyrus. However, some western plateaux, closer to the equator and the coast, in steppe zones, support extensive swamps dominated by lower growing grasses and sedges, and some tall grass swamps and montane bogs occur in the eastern highlands of Zaire.

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Permanent swamps also occur on the floodplains of the rivers flowing roughly N-S along the floor of the Western Rift Valley between lakes. In the south these are covered by herbaceous vegetation, but in the north, there are swamp forests and flooded gallery forests as well as reed and papyrus swamps. The lakes of the Western Rift Valley lie along the boundary of this region. Lake Tanganyika is the second deepest lake in the world and is among the largest of the African Lakes. There are several shallow swamp fringed lakes on the southern plateau, in the Shaba Province of Zaire, several more in the central part of the Zaire Basin, numerous others on the coastal plain, and crater lakes, some fed by thermal waters, in the mountains of Gabon, Cameroon and the Western Rift Valley.

Wetland Flora & Fauna

There is a greater diversity of wetland habitats in this region than in the others. This region includes the wettest parts of Africa as well as some of the hottest and driest, and extends from sea level to altitudes in excess of 5000 m asl in the Ruwenzori Mountains. It includes fully maritime islands in the Gulf of Guinea, part of the Sahara Desert, tropical rain forest in the Cuvette Congolaise, the deep lakes of the Western Rift Valley, shallow unstable endorheic lakes like Lake Chad, and swamps and seasonal wetlands in temperate, tropical and equatorial zones. It also possesses a greater diversity of plant and animal life than the other regions and its wetland flora and fauna both exhibit marked geographical variations; they are therefore dealt with on a national rather than a regional basis.

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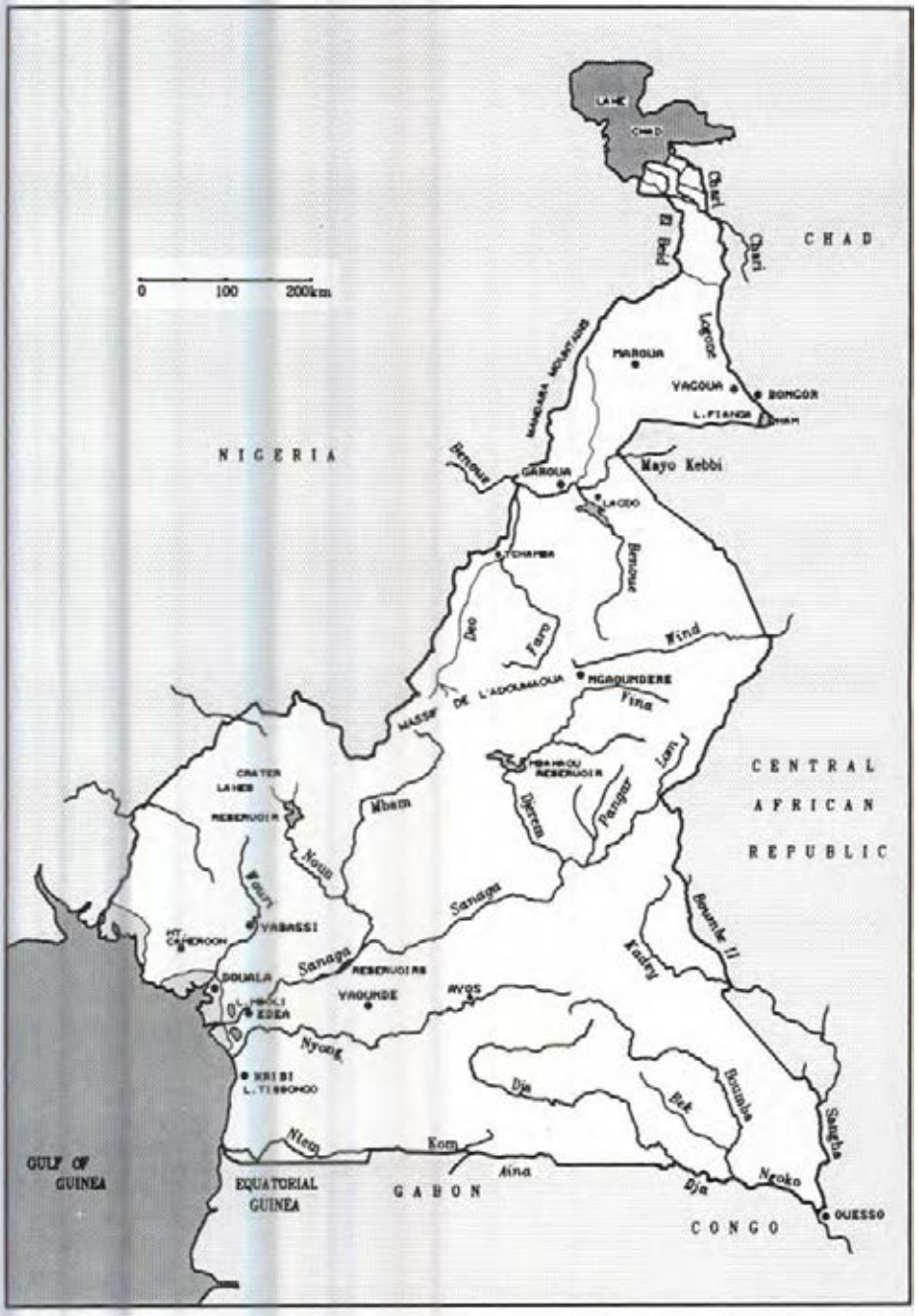

Map of Cameroon

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4.1 CAMEROON

Introduction

Cameroon extends over 10° of latitude, from 1°38'N, where the Ngoko and Sangha Rivers meet on the Congolese border, to a point 13°08'N in Lake Chad. In longitude the country extends from 8°29'E at the mouth of the Cross River in the Bight of Biafra, to 16°07'E, in a bend of the Sangha River where the borders of Cameroon, The Central African Republic and Congo meet. It has an area of 475 500 km^2, a population of 9 160 000 (1983), and a mean population density of 19.3 persons/km^2. The population is however very localised. Cameroon is bounded by Equatorial Guinea, Gabon and Congo in the south, The Central African Republic and Chad in the east, Nigeria in the northwest and the Atlantic Ocean in the west. The coastline is highly indented in the north and measures 590 km in length, behind which the coastal plain decreases in width from 100 km in the north to 30 km in the south. Hills rise abruptly from this plain, to a vast plateau block between 500-1000 m asl. This occupies some 70% of the country, from the southern border to the parallel 9°N. A mountain ridge oriented SW-NE continues inland from the Oceanic Volcanic Ridge, on which the islands of Annobón and Fernando Póo are situated. It extends up the northwestern side of the interior plateau, along the Nigerian border, in a strip of land over 1500 m high and 500 km long, before swinging east across the country in the Massif de l'Adoumaoua. The highest point of the ridge, and also the highest point in Cameroon, is Mt. Cameroon (4095 m asl), situated (4°12'N/9°10'E) on the coast 60 km WNW of Douala. The Mandara Mountains are an isolated massif, rising to over 1200 m asl, between 10-11°N, astride the northwestern border.

Drainage is complex as there are 9 major river basins. Much of the northern extremity drains into Lake Chad, and the northern borders are delineated by two rivers which enter that Lake. On the northwestern side, the El Beid River rises at about 11°N, in the north of the Mandara Mountains, and flows for 250 km along the Nigerian border to Lake Chad, draining a small part of northern Cameroon en route. Run-off from the southeastern slopes of the Mandara Mountains collects in several streams which enter the Kebbi River (Mayo Kebi), an affluent of the Bénoué River, the largest tributary of the Niger. To the south, the Massif de l'Adoumaoua is an important triple watershed. On the eastern side, the Logone River rises near Ngaoundéré (7°20'N/13°35'E), and drains the eastern end of this highland block. It flows east into Chad, but then turns northwest and forms the border between Chad and Cameroon for 325 km until its confluence with the Chari River, which in its turn also forms the border for a further 135 km to Lake Chad. Run-off from the northern slopes of the Massif de l'Adoumaoua also enters the Bénoué River, while its southern slopes drain into the Djérem and Lom Rivers which enter the Sanaga River. This latter is the largest river in Cameroon, draining much of the central highland region, before reaching the sea at a delta on the Bight of Biafra. Several other rivers reach the sea on the Cameroon coast. North of the Sanaga, the most important is the Wouri, which rises in the coastal mountains of the great SW-NE ridge and reaches the coast at Douala. South of the Sanaga, the principal streams are the Nyong, Lokoundjé and Ntem Rivers, which all drain the western edge of the interior plateau and the coastal slopes. The southeastern and south central parts of the plateau drain to the Zaire River system. The southeastern part of the plateau is drained by the Kadey (Kadei) River and its two

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tributaries the Boumbé II and Doumé Rivers, while the central southern portion is drained by the Dja and its tributaries the Boumba and Bek Rivers. Both the Dja and Kadey flow into the Ngoko River, which has a confluence on the Congolese border with the Sangha, a tributary of the Zaire River.

Climate

Precipitation is highest in the north of the coastal sector and on the coastal mountains. More than 5500 mm of rain falls on the outer delta of the Wouri River each year, and over 9500 mm on the mountains just inland to the north. Mean annual rainfall decreases rapidly in passing southwards down the coast and is 4500 mm at the Sanaga Delta, 3500 mm at the mouth of the Nyong River, and about 3000 mm at the Campo Estuary on the southern border. Rainfall also decreases steadily in passing inland. It is about 2600 mm/yr 60 km inland and has declined to 1800 mm/yr 150 km inland. Although the mountain ranges along the Nigerian border receive 2500-3000 mm/yr far inland, stations in central Cameroon record mean totals of 1500-1700 mm, falls generally being higher in the northwest than in the southeast. The mean annual figure for Yaoundé (3°51'N/11°32'E) is 1570 mm and that for Maloundou (2°03'N/15°13'E) is 1477 mm. By contrast Tibati (6°25'N/12°33'E), much farther inland, receives 1717 mm and Ngaoundéré 1592 mm. The northern tip of the country is much drier, mean annual rainfall having decreased to 1000 mm at 9°N; to 800 mm at 10°N; to 600 mm at 12°N; and to less than 400 mm at the southern end of Lake Chad.

In the mountains along the western border there are two distinct dry seasons. The most important one is short at the coast and increases in severity in passing inland, where it may last for 4 months from November-February, e.g. at Mamfe (5°46'N/9°18'E) and Bamenda (5°55'N/10°09'E), where these months are virtually rainless. At Tiko (4°02'N/9°19'E) on the coast, this dry season is much shorter, lasting just two months, December-January. The second dry season is much shorter and is far less severe, but is seen in a sharp diminution of rainfall during June-July, when the monthly totals are in the region of 90-150 mm at all three stations. By contrast, moving towards the central axis of the country, at Douala, there is no mid-year diminution of rainfall and July is the wettest month. Rainfall is nevertheless still strongly seasonal, with reduced falls in December-January. The mean monthly total for January is 70 mm, but this increases to a figure of 725 mm in July, and then declines again to a mere 50 mm in December, the driest month. This temporal pattern of precipitation is followed at centres along the central axis of the country, right to the north. At Maroua (10°35'N/14°19'E), for example, August is the wettest month with a mean figure of 267 mm, but the dry season lasts from October-April and these 7 months are virtually rainless. In the south and along the eastern border the mid-year diminution in rainfall again becomes apparent. At Maloundou, for example, April and October are the wettest months while January, July and December are the driest months. However, here the driest month (December) has 65 mm and the wettest month (October) 217 mm. Thus the dry periods are far less harsh than those of the north.

Mean temperature is 26°C in the coastal region around Douala, but decreases to 21°C in the mountains of the western border and to 23°C over the centre of the interior plateau. From here mean temperature rises to the southeast, being 25°C at Maloundou, and to the

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north reaching 28°C at Maroua. The mean monthly maximum at Douala is 31°C in January while the monthly minimum is 21°C in July. Corresponding data for Mamfe in the western mountains are 34°C in May and 21°C in June; for Ngaoundéré 32°C in February and 13°C in December; for Maloundou 31°C in April and 19°C in December; and for Maroua 40°C in April and 19°C in December.

Vegetation

Few countries in Africa have such a rich vegetation and such a range of vegetational types as Cameroon. Many factors conspire to this end, among them topography and climate, which are both very variable, and the geographic situation of the country between three major floristic regions. It is perhaps worth emphasizing that the altitudinal range is from sea level to 4095 m asl, and that mean annual rainfall varies from 300 mm at Lake Chad to 9500 mm on the seaward slopes of Mt. Cameroon. The coast enjoys a per-humid equatorial climate, the far north a semi-desert climate.

Wetlands

Tidal forests are well developed on the coast between the Cross River and the Wouri Estuary, but are rather poorly developed to the south of this. Elsewhere on the coastal plain areas of freshwater swamp forest occur on several rivers, and there are some shallow lakes and swampy depressions on the alluvial flats between the mouths of the Sanaga and Lokoundjé Rivers.

There are several deep crater lakes in the hills of the southwest, west and northwestern provinces. Some of these contain endemic species of fish, and some, such as Lake Barombi Koko, are important bird sanctuaries. Lake Barombi Mbo is the best studied of the crater lakes, but there are several others including Lakes Bangem, Beme, Debundscha, Oku and Soden. In the far north, there are several small shallow semi-permanent lakes in the floodplain areas, and part of Lake Chad is situated in Cameroon.

However, the most extensive wetlands are seasonal and are associated with river systems in the interior. In the far north, virtually the entire area between the Logone/Chari Rivers and the El Beid River is flooded seasonally, and several permanent channels connect these rivers. Other extensive floodplains occur on the Faro, Bénoué and Kebbi Rivers, north of the Massif de l'Adoumaoua, while to the south of this massif there are forested floodplains on the Djérem, Lom, Pangar and upper Sanaga Rivers in the headwater basin of the Sanaga. Permanent swamp forests and permanent and seasonally inundated grass swamps occur along the upper Nyong River, and in the southeast there are seasonally flooded forests and galleries on the Dja, Kadey and Boumba Rivers.

Wetland Flora

Tidal Wetlands: These are dominated by *Rhizophora racemosa* which is generally the seaward pioneer, and which forms the frontal forest. *Rhizophora harrisonii* grows to landward of this, and *R. mangle* is common in upstream sites. On the landward side of the swamp, especially up creeks, the last two species are often involved in transitions to a brackish or freshwater tidal forest co-dominated by *Pandanus candelabrum* and *Raphia*

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spp. *Raphia vinifera* is the commonest species in the west towards the Niger delta, but *Raphia palma-pinus* and *R. regalis* are more common farther south, e.g. in the Wouri Estuary. Other arborescent species found in the tidally inundated zones in SW Cameroon include *Anthocleista vogelii, Avicennia africana, Callophyllum inophyllum* (naturalised), *Carapa procera, Chrysobalanus orbicularis, Conocarpus erecta, Crudia klainei, Cynometra mannii, Hibiscus tiliaceus, Manilkara obovata, Nypa fruticans* (naturalised), *Ozystigma mannii, Phoenix reclinata* (= *P. spinosa* of older authors) and *Podococcus barteri*. Bushy species and climbers include *Baphia nitida, Caesalpinia bonduc, Dalbergia ecastaphyllum, Drepanocarpus lunatus, Ormocarpum verrucosum*, while herbs include *Acrostichum aureum, Bacopa decumbens* (parasite), *Crinum natans, Echinochloa stagnina, Eleocharis geniculata, Fimbristylis ferruginea, Paspalum distichum* (= *P. vaginatum*), *Utricularia* sp. and *Xyris anceps*. Common epiphytes include *Bulbophyllum falcipetalum, Cyrtorchis aschersonii, Phymatodes scolopendria, Phragmitera incana* (parasite), *Platycerium stemaria, Polystachya* sp., *Rhipsalis cassytha, Tapinanthus belvissi* (parasite) and *Tridactyle anthomaniaca*.

Raphia Swamps: In addition to their occurrence on the landward sides of mangrove swamps, *Raphia* associations cover many swampy valley floors and line forest rivers and streams in riparian strips. Forest streams, just a few metres wide, may support a *Raphia* belt a dozen trees wide on either bank, especially in areas subject to periodic inundation. The swamp forest and riparian associations are floristically distinct. *Raphia humilis* dominates montane valley floors in the southwest, while *Raphia laurentii* (= *R. monbuttorum*) covers swampy valley floors, often in belts 3 km across, and is the most widespread species in southern Cameroon. *Raphia hookeri* is more common in riparian forests but is rather localised in Cameroon. It is common in the Boumba, Doumé, upper Dja and Nyong Valleys and tends to occupy the types of sites in which *Raphia sese* is dominant in the central Zaire Basin. However, several species of *Raphia* exhibit rather wide ecological amplitudes in West Africa. Trees are comparatively uncommon in valley floor *Raphia laurentii* swamps, becoming important only in the fringes, in transitions to other forest types. Species widespread in floodplain and permanent swamp forest are the most common.

There is usually a dense understorey of tall herbs, above which the *Raphia* palms are emergent, and the most common species in this situation are *Aframomum limbatum, Ataenidia conferta, Costus dinklagei, Cyrtosperma senegalense, Haplopegia azurea, Hypselodelphys scandens, Marantochloa purpurea, Palisota hirsuta, P. megalophylla, Piper umbellatum, Renealmia macroclea, Rhynchospora corymbosa, Sarcophrynium brachystachyum, Scleria verrucosa, Thalia welwitschii* and *Trachyphrynium braunianum*. Tall or climbing pteridophytes include *Cyathea camerooniana, C. manniana, Cyclosorus striatus, Diplazium proliferum, Lastreopsis efulensis, Lonchitis curroris, L. gracilis, Marattia fraxinea* and *Tectaria magnifica*. Lower growing herbs include *Acanthus montanus, Aneilema beniniense, Boehmeria platyphylla, Desmodium adscendens, D. salicifolium, Elytraria marginata, Fleurya ovalifolia, Gymnosiphon bekensis, Hibiscus* sp., *Impatiens hians, I. irvingii, I. niamniamensis, Melanthera scandens, Melochia melissifolia, Parapentas setigera, Platostoma africanum, Stanfieldlo imperforata* and *Urera repens*, together with numerous pteridophytes. Among the latter *Bolbitis auriculata, Ctenitis lanigera, Cyclosorus afer, C. dentatus, Diplazium sammatii, Pteris burtoni, P. communata, P. prolifera*, and *Tectaria angelicifolia* are widespread.

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Valley floor *Raphia* swamps contain numerous climbers, some woody but most herbaceous, and these often show prolific development. The most widespread species are *Adenia cissampeloides, Basella alba, Calamus deeratus, Dalbergia hostilis, Haumania danckelmaniana, Paullinia pinnata, Psophocarpus palustris, Urera cameroonensis* and *Vitex thyrsiflora*, together with species of *Cissus, Dewevrea, Dioscorea, Popowia* and *Tetracera*. Epiphytes are common and include *Arthropteris palisoti, Asplenium africanum, Culcasia* sp., *Lomariopsis guineensis, Lygodium smithianum, Microsorium punctatum, Nephrolepis biserrata, N. undulata, Phymatodes scolapendria, Platycerium angolense, Rhektophyllum mirabile, Selaginella* spp. and *Stenochlaena mildbraedii*.

In riparian raphiales, characterised by the presence of *Raphia hookeri*, the commonest large trees are typical riverside trees, many of which are associated with gallery and floodplain forests, described later. Climbers are abundant and include *Agelaea pseudobliqua, Artabotrys auranticus, Calamus deeratus, Connarus griffonianus, Entada gigas, Eremospatha cuspidata, Hippocratea myriantha, Landolphia owariensis, Loeseneriella africana, Manniophyton fulvum, Melanthera scandens, Mikania cordata, Paullinia pinnata, Physostigma venenosum, Stephania dinklagei, Strychnos boonei, S. tschibangensis, Tetracera alnifolia, Turraea vogelii, Urera camerooniensis* and *U. gabonensis*. Epiphytes are also abundant in riparian raphiales, at least locally, and include *Agelanthus platyphyllus, Angraecum distichum, Asplenium africanum, Begonia polygonoides, Bulbophyllum schinzianum, Calyptrochilum emarginatum, Culcasia scandens, Drynaria laurentii, Ficus asperifolia, F. lingua, F. pseudomangifera, Loxogramme latifolia, Microgramma owariensis, Microsorum punctatum, Momordica gilgiana, Nephrolepis biserrata, Oleandra distenta, Phragmanthera capitata, Phymatodes scolapendria, Raphidora africana, Rhipsalis boccifera, Schefflera barteri* and *Stenochlaena mildbraedii*.

River Bank Vegetation: Ground cover which may be dense along the banks of wide rivers includes *Adiantum vogelii, Afromomum pseudostipulare, Boehmeria platyphylla, Cyperus fertilis, Dracaena ovata, Hypolytrum heteromorphum, Palisota megalaphylla, Scleria verrucosa, Stipularia africana* and *Trachyphrynium braunianum*.

In the water along the river banks *Adenostemma perrottetii, Cyclosorus striatus, Commelina* sp., *Floscopa confusa, Hibiscus* sp., *Impatiens irvingii, Isachne buettneri, Leersia hexandra, Pistia stratiotes, Plotostoma africanum, Polygonum limbatum, P. strigosum, Pycreus smithianus, Rhynchospora corymbosa* and *Thalia welwitschii* are common. *Nymphaea caerulea* and *N. lotus* are common on open water at the edges of lakes, with submerged species of *Ceratophyllum, Myriophyllum, Najas, Potamogeton* and *Utricularia*. Shady forest pools are covered by *Azolla* and *Lemna*. Vast floating grass swamps are extensive along the courses of some rivers, e.g. the Nyong and its principal affluents below Ayos. Here *Echinochloa pyramidalis* is dominant, but with numerous sedges and *Azolla africana, Ceratophyllum demersum, Hydrocharis chevalieri, Impatiens irvingii, Ludwigia repens, Nymphaea lotus, N. maculata, Pistia stratiotes, Polygonum* spp. and *Utricularia foliosa* as typical associates.

Swamp Forests: In south Cameroon, floodplain forests are characterised by a high proportion of *Uapaca paludosa*, or in semi-deciduous zones of *Uapaca guineensis*. However, in moving north through the savanna zone *Uapoca guineensis* is progressively replaced by *Uapaca togoensis*. In the south there is an undergrowth which contains an abundance of *Adiantum vogelii, Afrumomum pseudostipulare* and *Trachyphrynium*

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braunianum. The following are less common associates in this type of forest; *Afrolicania elaeosperma, Alstonia boonei, Anthonotha macrophylla, Berlinia confusa, Bombax buonopozense, Brazzeia congoensis, Cassipourea congoensis, Ceiba pentandra, Cephalis mannii, Cercestis congoensis, Cleistopholis patens, Elaeophorbia drupifera, Ficus vogelii, Gaertnera longevaginalis, Garcinia ovalifolia, Irvingia smithii, Lasiodiscus marmoratus, Macaranga schweinfurthii, M. staudtii, Mammea africana, Manilkara argentea, M. pellegriniana, Mitragyna ciliata, M. stipulosa, Nauclea pobeguinii, Pachypodanthium barteri, P. staudtii, Pachystela brevipes, Rhynchospora corymbosa, Sarcophrynium brachystachyum, Scleria verrucosa, Sorindeia grandifolia, Spondianthus preussii, Synsepalum dulcificum, Syzygium guineense, Xylopia porviflora* and *X. rubescens*.

Riparian fringe forests differ from floodplain forests. Characteristically they contain a high proportion of *Uapaca heudelotii* and *Cathormion altissimum*, with *Trichilia retusa* becoming important in semi-deciduous zones and being locally co-dominant with *Tetracera alnifolia* in the northern savanna zone. The more widespread associates, including riverside shrubs, are *Alchornea floribunda, Anthocleista liebrechtsiana, Anthonotha isopetala, A. macrophylla, Antidesma venosum, Beilschmiedia piya, Bersama abyssinica, Calpocalyx dinklagei, Cercestis congoensis, Diospyros gilletii, Dracaena ovata, Ficus anganophila, F. asperifolia, F. natalensis, F. pseudomangifera* (sometimes an epiphyte), *F. rederi, F. vogelii, Gaertnera longevaginalis, Gardenia imperialis, Grewia* sp., *Hymenocardia heudelotii, Ixora guineensis, Lecaniodiscus cupanioides, Leptaulus daphnoides, Memecylon fosteri, Mimusops andongensis, Morelia senegalensis, Neobautonia velutina, Neostenanthera myristicifolia, Oleandra distenta, Oubanguia africana, Pavetta calothyrsa, Psychotria vogeliana, Rauvolfia macrophylla, Securinega virosa, Synsepalum dulcificum, S. letouzeyi, Treculia africana, Vismia guineensis* and *Vitex ferruginea*.

In the southeast, in the valleys of the Bek, Dja, Boumba, Ngoko and Sangha Rivers, there is, along the rivers, a type of inundated (floodplain) forest which is similar in composition to the riparian forest described above, but characterised by a high proportion of *Guibourtia demeusei*. After this species the most common trees are *Cathormion altissimum, Cynometra mannii, Irvingia smithii, Trichilia retusa, Uapaca heudelotii* and *Xylopia parviflora*.

Permanent swamp forests are dominated by *Sterculia ambacensis* (= *S. subviolacea*) which forms a broken canopy, providing 50% cover about 30 m high. The trees have sinuous, spreading buttresses which reach 5-6 m in height, above which the boles are up to 1.8 m in diameter. Below the canopy there is an inferior tree stratum, 20-25 m high, comprising mainly *Englerophytum oubanguiense, Macaranga staudtii, Pauridiantha pyramidata, Spondianthus preussii, Xylopia aethiopica, X. rubescens, X. talbotii* and *X. staudtii*. There is a bushy layer, poorly differentiated from the herb layer, which is comparatively rich in species. Here there are numerous Euphorbiaceae (e.g. *Alchornea laxiflora, Antidesma* sp., *Crotonogyne giorgii, Macaranga schweinfurthii* and *Mallotus oppositifolius*) and Rubiaceae (e.g. *Cephaëlis mannii*, and *Psychotria djumaensis*), together with an abundance of *Ouratea flava* and *O. reticulata*. There are however, very few lianes. The spectrum of epiphytes is similar to that found in other types of swamp forest. In the Nyong Basin this type of forest covers some 100 000 ha, but is strictly

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confined to the high valleys above Ayos. It also occurs elsewhere, particularly in the southeast, e.g. in patches in the Sangha Valley.

Throughout the southern part of Cameroon, the physiognomy and floristic composition of flooded forests varies with the degree and duration of inundation they receive, and with edaphic conditions. Thus these distinct types of swamp forest are not recognisable everywhere and they frequently grade into each other, e.g. *Sterculia ambacensis* forest occurs in depressions in galleries in several southeastern valleys, and this type of forest may also be transitional to *Raphia* swamps. There are also transitions between floodplain and riparian forest. In the savanna zones of central Cameroon, degraded swamp forest ribbons tend to be replaced by isolated raphiales, accompanied by *Dichaetanthera calodendron, Pandanus candelabrum, Phaenix reclinata*, and *Voacanga africana*, and thickets dominated by *Alchornea cordifolia*.

Herbaceous Swamps: In the transitional zones between forest and savanna, both permanently and periodically inundated valley floors may be covered by herbaceous vegetation. Periodically inundated (floodplain) herb swamps are found on the Boumba River near Médoum, on the Bek near Ngato, on the Dja near Mintom and in the north, along the Kadey River, and near the confluences of the Pangar, Lom, Djérem and Sanaga Rivers in the upper Sanaga Basin. Here the dominant species is generally *Leersia hexandra*, with *Cyclosorus striatus, Rhynchospora corymbosa* and *Scleria* sp. as the most abundant associates, and *Axonopus flexuosus, Cyperus difformis, Fimbristylis* sp., *Indigofera spicata, Lipocarpha chinensis, Melochia melissifolia, Oldenlandia lancifolia, Pycreus smithianus, Sporobolus pyramidalis, Thalia welwitschii* and *Torenia thouarsii* as less important associates. *Pandanus candelabrum* and *Phoenix reclinata* often fringe these swamps, in dense belts, and some bushy species intrude into them, often forming little clumps. Among these, *Antidesma venosum, Mimosa pigra, Sida* sp., *Stipularia africana* and *Triumfetta* sp. are most common.

Permanent herb swamps have restricted distributions, being limited by topography to shallow depressions on the plateau in transitional areas between evergreen forests and savannas. They are, however, common between Yokadouma (3°25'N/15°05'E) and Batouri (4°26'N/14°27'E), on the flat watershed between the Doumé and Boumba Rivers, and along the line of the shallow valleys of some affluents. The vegetation is typified by pure stands of *Cyclosorus striatus*, covering perhaps 55% of the swamp, with *Mariscus pseudopilosus* making 35% and *Stipularia africana* 10%. The rootstocks, rhizomes and bases of the aerial parts form a dense elastic mattress, from which the stems rise 1-2 m, and over which it is possible to walk in the dry season. In the wet season, although extremely spongy and difficult to negotiate, the surface is rarely submerged. Associate species include *Adenia gracilis, Cissus diffusiflora, Desmodium salicifolium, Dioidia scandens, Dioscorea bulbifera, Hibiscus rostellatus, Impatiens irvingii, Lygodium microphyllum, Melochia melissifolia, Neohyptis paniculata, Polygonum limbatum, Sacosperma paniculatum, Tristemma hirtum* and *Tylophora* sp. Small clumps of stunted woody species occur in these swamps, the most abundant of which is *Voacanga thouarsii* followed by *Pyschotria djumaensis*, and thereafter by *Allophyllus zenkeri, Bridelia ndellensis, Macaranga staudtii, Spondianthus preussii* and *Xylopia rubescens*. In places these herb swamps are contiguous with *Raphia* swamps, and *Cyrtosperma senegalense, Marantochloa purpurea, Nephrolepis biserrata* (terrestrial), *Palisota megalophylla,*

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Phoenix reclinata, Thalia welwitschii and *Urera cameroonensis* are transitional species, which enter the swamps at these sites. In some sites *Cyperus nossibeensis, Ficus asperifolius, Hyptis lanceolata, Jussiaea linifolia, Ludwigia prostrata* and *Oldenlandia lancifolia* have been reported in these swamps.

Alluvial banks occur at the meander bends of some rivers between latitudes 5°-7°N (e.g. the Kadey, Doumé, Lom, Pangar, Mékié, Djérem, Sanaga, Ndjéké, Djim, Kim, Mbam and Noun Rivers) where they traverse savanna zones. The alluvial banks vary from 30-200 m wide and are flooded at high water, but are dry and often burned during the dry season. On relatively well drained soils the graminaceous cover is mainly provided by *Hyparrhenia* spp. with tufts of *Clappertonia ficifolia*. On soils which are wet for a substantial part of the year one finds grassland composed of *Hypogynium spathiflorum, Loudetia phragmitoides* and *Setaria anceps*, while on soils which are more or less permanently swampy, sedges are dominant, principally *Bulbostylis filamentosa, B. laniceps, Cyperus tenuicaulis, Kyllingia polyphylla* and *Rhynchospora candida*. Characteristic associates of these areas are *Eulophia horsfallii, E. latilabris, E. lindleyana, Liparis rufina, Lycopodium affine, Oldenlandia corymbosa, Otomeria elatior, Sauvagesia erecta* and *Schizziella tetragona*.

Herbaceous Floodplains: In the zones of deep and prolonged inundation to the south of Lake Chad, where water depths may exceed 2 m, typical floodplain grasses predominate. *Oryza barthii* dominates the most deeply flooded zones, giving way to *Echinochloa pyramidalis* in the middle zone and this in turn to *Hyparrhenia rufa* and *Vetiveria nigritana* on the margins. Other species apparent on the shallow margins during the rainy season, from August to October, are *Acroceras amplectens, Andropogon gayanus, Brachiaria deflexa, B. mutica, Chloris lamproparia, C. pilosa, Cyperus iria, C. longus, C. microlepis, C. pustulatus, C. tenuispica, Digitaria acuminatissima, D. marginata, Dinebra retroflexa, Echinochloa colona, E. obtusiflora, E. stagnina, Eleocharis atropurpurea, Eragrostis atrovirens, Hyparrhenia dissoluta, Ischaemum brachyatherum, Oryza breviligulata, Panicum anabaptismum, P. laetum, P. subalbidum, Paspalidium geminatum, Pennisetum ramosum, Pycreus albomarginatus, Scirpus articulatus, S. praelongatus, Setaria anceps, Sorghum arundinaceum, S. bipennatum, Sporobolus marginatus, S. pyramidalis, Thelepogon elegans, Urochloa lata* and *Vossia cuspidata*.

In the drainage channels, which attain depths of a metre or more, and in the lakes and pools, one finds an ephemeral aquatic flora comprising such species as *Aeschynomene crassicaulis, Apanogeton subconjugatus, Burnatia enneandra, Centrostachys aquatica, Ceratopteris cornuta, Eichhornia crassipes* (among the most abundant), *Eriocaulon bifistulosum, Heteranthera callifolia, Ipomoea aquatica, Limnophyton obtusifolium, Lophotocarpus guayanensis, Marsilea crenulata, Nymphaea lotus, N. rufescens* (among the most abundant), *Nymphoides indica, Ottelia ulvifolia* and *Scholleropsis lutea* (naturalised). Among the rooted submerged species *Ammania auriculata, Limnophila barteri, Rotala mexicana, R. tenella* and *R. welwitschii* are most common. Free-floating submerged species include *Chara zeylanica, Najas graminea, N. pectinata, Nitella acuminata*, and on the surface *Utricularia benjaminiana, U. gibba* var. *exolata* and *U. inflexa* var. *stellaris*.

In the more superficially flooded areas, a mosaic vegetation develops in the rainy season, with patches of different composition, some containing only one gregarious species,

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others being heterogeneous. Representative species include *Acalypha crenata, Aeschynomene nilotica, A. uniflora, Alternanthera sessilis, Ammania auriculata, Aspilia helianthoides, Borreria radiata, Burnatia enneandra, Caperonia palustris, Cassia mimosoides, Celosia argentea, Cleome hirta, Commelina diffusa, C. erecta, Crinum pauciflorum, C. yuccaeflorum, Cucumis melo, Cyanotis cucullata, Dichondra repens, Evolvulus alsinoides, Glinus oppositifolius, Hibiscus articulatus, H. cannabinus, H. esculentus, H. panduriformis, Hygrophila auriculata, Ilysanthes parviflora, Luffa echinata, Melochia corchorifolia, Phyllanthus maderaspatensis, Sesbania leptocarpa, S. pachycarpa, S. sesban, Sonchus exauriculatus, Sphenoclea zeylanica, Stachytarpheta angustifolia, Thalia welwitschii, Withania somnifera* and *Zornia glochidiata*. *Acacia seyal* is the only tree on the floodplain proper.

The southern shores of Lake Chad are fringed by great stands of *Cyperus papyrus* and *Phragmites mauritianus* with much *Vossia cuspidata* in the water, while on the northern shores these species are replaced by *Phragmites australis* and *Typha latifolia* var. *australis*.

Levée Forest: On the leveés of the Chari, Logone and El Beid Rivers and their affluents, on the elevated banks of lakes in abandoned sections of channel, and on sundry other high spots, woody vegetation develops in groves dominated by *Mitragyna inermis*. This is associated with certain other species, among which *Acacia nilotica, A. polyacantha, A. sieberana, Allophyllus africanus, Anogeissus leiocarpus, Antidesma venosum, Balanites aegyptiaca, Bauhinia rufescens, Borassus aethiopum, Celtis integrifolia, Crateva religiosa, Dalbergia melanoxylon, Diospyros mespiliformis, Ficus gnaphalocarpa, Morelia senegalensis* and *Phyllanthus muellerianus* are found.

Various local accounts of the phytogeography of Cameroon have appeared. However, the most comprehensive, which refers to numerous earlier and more regional accounts, is that of Letouzey (1968).

Wetland Fauna

Fishes: The fish faunas reflect affinities with the major drainage basins adjacent to the region, the Niger, Chad and Zaire Basins. Those of the SE rivers are typical of the Zaire Basin, while that of the Bénoué/Kebbi system has affinites with that of the Niger. Lake Chad is within the Soudanian ichthyogeographical region. There are 179 species in the Lake Chad Basin, of which 106 (59%) are common to the Niger Basin; 85 (47%) are common to the Nile Basin and 47 (26%) are common to the Zaire Basin. Of the 179 species in the Lake Chad Basin, only 84 occur in the lake, and of 25 endemic species in the basin, only *Alestes dageti* is found in the lake. *Alestes baremose, A. dentex, Citharinus citharus, Clarias lazera, Heterotis niloticus, Hydrocynus forskali, Lates niloticus, Malapterus electricus, Oreochromis galilaeus, O. niloticus, Polypterus senegalus, Synodontis schali* and *Tilapia zillii* are common to Lake Chad and the Volta, Niger and Nile Basins, including Lakes Albert and Turkana. Other common species are *Alestes macrolepidotus, Bagrus bayad, Chrysichthys auratus, Distichodus rostratus, Eutropius niloticus, Heteropisus bebe, Hydrocynus brevis, Labeo senegalensis, Micralestes acutidens, Mormyrus rume, Pollimyrus bane, P. isidori, Schilbe mystus, Synodontis batensoda, S. clarias, S. frontosus, S. membranaceus* and *Tetraodon fahaka*. Many fish

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move up the Logone/Chari Rivers to spawn as the floods rise, and some cross the floodplain to move back to the lake via the El Beid River.

Over 100 species of fish have been identified in the upper Bénoué and Kebbi Rivers, some representatives of which are *Arius gigas, Brienomyrus niger, Hyperopisus occidentalis, Labeo coubie, Mormyrops deliciosus, Mormyrus rume, Petrocephalus sinus, Pollimyrus isidori* and *Synodontis ocellifer*. A number of species is shared with the Logone/Chari Rivers, e.g. *Citharinus citharus, C. distichodoides* and *C. latus*. A sole, *Dagetichthys* sp. and a sting-ray, *Potamotrygon garouensis*, occur in the Bénoué far from the sea. Details of the fish fauna of the Niger system are given in section 3.12 Nigeria.

The Sanaga and Nyong Rivers have fish faunas related to both the Niger and Zaire Basins, and indeed the forest structure of the upper Nyong also shows strong affinities with that of the Zaire Basin, suggesting periods of headwater communication.

Amphibia: Abundant, but poorly known.

Reptiles: Both *Crocodylus cataphractus* and *C. niloticus* occur in Cameroon. While both species are persecuted, the latter at least is by no means uncommon in certain localities, and some human deaths have been caused by crocodiles in the mangrove creeks of the SW in recent years. *Varanus niloticus* is common, as are terrapins and tortoises. Aquatic or semi-aquatic snakes include *Bothrophthalmus lineatus, Boulengerina annulata, Grayia smythii, Naja melanoleuca, Natrix anoscopus, Philothamnus* sp., *Psammophis sibilans* and *Python sebae*, while *Boiga blandingii, Dasypeltis fasciata, D. scabra, Dendroaspis jamesoni, Philothamnus semivariegata, Thelotornis kirtlandii* and *Thrasops occidentalis* are arboreal species found in swamp and gallery forests.

Birds: The avifauna is rich and varied because of the range of wetland habitats, from closed swamp forest to open graminaceous floodplains. The birds of the northern floodplains have many species in common with equivalent floodplains south of the equator. Here *Balearica pavonica, Coracias abyssinica, Ephippiorhynchus senegalensis, Haliaeetus vocifer, Leptoptilos crumeniferus, Merops bullocki* and *M. nubicus* occur, together with herons, egrets, weavers, warblers, ducks and geese. *Ploceus batesi*, a forest weaver, is an endemic species in the south. Owls, eagles, skimmers, darters, cormorants, kingfishers and herons are piscivorous species throughout the country, and other birds of prey take squirrels, monkeys and dassies from the the swamp forest.

Mammals: Among mammals, *Trichechus senegalensis* occurs in all the river systems, but is now an endangered species. Its range extends to the Bénoué and Kebbi Rivers and thence into the Lake Chad Basin, also to the Sanaga and Nyong Rivers, and to the Kadey and other headwater streams of the Sangha River. *Hippopotamus amphibius* was once far more common and widespread, but it survives in many places, including the floodplain of the Logone/Chari Rivers in the far north. Other large mammals resident in, or otherwise dependent upon, the wetlands, including the periodically flooded areas, are *Cephalophus maxwelli, C. monticola, C. ogilbyi, C. sylvicultor, Felis aurata* (S only), *Kobus ellipsiprymnus, K. kob, Loxodonta africana, Manis gigantea, Panthera pardus, Phacochoerus aethiopicus, Potamochoerus porcus, Redunca redunca* (north), *Sylvicapra grimmia, Syncerus caffer, Tragelaphus euryceros, T. scriptus* and *T. spekei*. Small mammals include *Aonyx capensis, Atilax paludinosus, Herpestes ichneumon, H. sanguineus, Lutra maculicollis, Thryonomys gregorianus* and *T. swinderianus*. Arboreal

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species include *Anomalurus beecrofti, A. derbianus, A. pusillus, Cercocebus albigena, C. torquatus* (S only), *Cercopithicus aethiops, C. cephus, C. l'hoesti preussi* (SW only), *C. mona mona* (S only), *C. neglectus* (SE only), *C. pogonias* (S only), *Colobus badius preussii* (SW only), *C. polykomos satanas* (S only), *Dendrohyrax dorsalis, Funisciurus lemniscatus, F. leucogenys, F. pyrrhopus, Galago senegalensis, Heliosciurus rufobrachium, Idiurus macrotis* (S only), *I. zenkeri* (S only), *Miopithecus talapoin* (S only), *Myosciurus pumilio* (S only), *Nandinia binotata* (S only), *Paraxerus poensis* and *Protoxerus stangeri.*

In addition to most of the foregoing, mammals which visit the galleries and floodplains in the north include *Acinonyx jubatus, Aepyceros melampus, Cephalaphus rufilatus, Cercopithecus nictitans, Crocuta crocuta, Damaliscus lunatus, Felis lybica, Hippotragus equinus, Hyaena hyaena, Ichneumia albicauda, Leptoilurus serval, Panthera leo,* and *Taurotragus derbianus,* while smaller species include *Felis caracal, Genetta tigrina, Mungos mungo, Viverra civetta* and *Vulpes pallida.*

List of Wetlands Described

1. Tidal Swamps
2. Wetlands of the Coastal Plain
3. Floodplains of the North
   (a) The Logone/Chari/El Beid System
   (b) The Faro/Bénoué/Kebbi System
4. Floodplains of the Central Districts
   (a) The Upper Sangha System
   (b) The Upper Sanaga System
   (c) The Nyong River System
5. Natural Lakes
   (a) The Crater Lakes
   (b) Lake Chad
   (c) Lake Fianga
   (d) The Coastal Lakes
6. Artificial Impoundments

1. Tidal Swamps

General: At the coast the border with Nigeria is defined by the course of the small Akpa Yafé River, which reaches the sea through a mangrove swamp 35.5 km deep between landward and seaward faces. This forest block, intersected by the the Rio del Rey, Ngosso and Andoka Estuaries, stretches 57 km along the coast until it is interrupted by the slopes of Mt. Cameroon which descend steeply into the sea. This great mangrove block, covering 145 000 ha, has developed on the deltaic coast created by hundreds of small streams draining the very wet slopes of Mt. Cameroon and the Roupi Mountains immediately to the NE. The canopy of the mature *Rhizophora* forest reaches 45 m in

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height, and freshwater tidal swamps occur at the back of the mangroves in places, e.g. 70 km upstream on the Moko River which discharges via the Andokat Estuary.

On the south side of Mt. Cameroon another large mangrove block occurs on the Cameroon or Wouri Estuary. Mangroves are 20 km deep on the north shore and extend 35 km up-estuary, dissected by Moukouchou and Bodeaka Bays, essentially wide waterways in the swamp. These mangroves are backed by banana plantations on the slopes of Mt. Cameroon and by extensive freshwater tidal swamps, 5 km deep, to the NE. A single block of freshwater swamp forest in this vicinity covers 7500 ha (4°07'-4°16'N/9°29'-9°34'E) between Muyuka and Dibombari. The Wouri is tidal for 45 km above Douala and freshwater tidal swamp forests occur in blocks for this distance upstream, to within 15 km of Yabassi (4°26'N/9°58'E). On the south shore of the estuary, mangroves extend from Douala down to Point Souelaba at the head of a long northwestward facing spit. They are broken by the courses of the Dibamba River and Manoka Bay and Island, and they end behind the spit which has been built northwards from the mouth of the Sanaga River by longshore currents. In total there are some 118 000 ha of mangrove forests on the Wouri Estuary.

Spring tidal range at the mouth of the Wouri Estuary is 2.8 m and rainfall exceeds 5000 mm/yr, but this decreases upstream to 4000 mm at Douala. Salinities in the estuary vary seasonally as does the riverine discharge rate, but median annual salinities of the surface waters are very low. The highest salinities, at high tide during the driest part of the year, November-January, seldom exceed 20‰ in mid estuary 15 km below Douala. During the monsoon, salinities below 10‰ are recorded at the estuary mouth at high tide, while at Douala, at low tide they are below 0.8‰. Surface salinities below 4‰ are common in the vicinity of Douala throughout the year.

The southern section of coast, from the Sanaga River mouth to the Campo Estuary supports only small and scattered mangrove stands. The mouths of both the Sanaga and Nyong are sandy and contain several elevated islands, the fringes of which are clad with mangroves, but Lake Tissongo (3°35'N/9°53'E), which occupies 3125 ha with its surrounding swamps south of the Sanaga River, is connected to the estuary by a tidal channel. Farther south, mangroves occur in the estuary of the Lokoundjé River and are backed by small areas of freshwater swamp. From this point south the coast is of high relief and mangroves occur only in sheltered spots at the mouths of small coastal streams. The mangrove forests of the Campo Estuary on the southern border are situated in Equatorial Guinea. The most comprehensive account of mangrove ecology in Cameroon is for the Wouri Estuary (Boyé *et al.*, 1975). There are about 300 000 ha of tidal forest in Cameroon.

Human Impact & Utilisation: The Cameroon Government's records for the offshore fishing catch gave a figure of 20 500 tonnes for 1980-81 and estimated that this would grow at an annual rate of 20% during the period 1981-86. It also noted that as much as 35 000-40 000 tonnes was not recorded. Much of this is caught in mangrove creeks in the north, by Nigerian fishermen, and is clandestinely exported to Nigeria. The government report suggests a maximum sustainable yield of no more than 50 000 tonnes.

Conservation Status: Although there are faunal reserves which include tidal areas, there is little effective protection of animals in them. Thus *Trichechus senegalensis* is threatened throughout the mangrove area, even in the supposed sanctuaries of Lakes Ossa and

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Tissongo, and in the Nyong, Sanaga and Dibamba Rivers. About 15 000 ha of mangrove forest on the Wouri Estuary are situated in the Mouanko Reserve, extending from the south shore of the estuary to the Sanaga River mouth.

2. Wetlands of the Coastal Plain

General: Lake Mboli or Ossa (3°43'N/9°58'E) of approximately 500 ha, to the north of the Sanaga River, drains by a small stream into the Sanaga Estuary, but is not tidal. It is fringed by freshwater swamps. Between the Sanaga and Lokoundjé Rivers there is a large flat area of recent alluvium, on which there are numerous swampy depressions. Two of the largest of these, each covering about 2700 ha, are situated at 3°33'N/9°48'E and 3°28'N/10°02'E on these flats. Several of these depressions are brackish, but none is tidal. Some patches of permanent swamp forest still occur on the Dibamba (e.g. 4°03'N/9°52'E) and Wouri Rivers (e.g. 4°15'N/9°49'E), and on a tributary, the Dibombé River, although many others have been cleared and drained for oil palm plantations.

Human Impact & Utilisation: The coastal lakes and rivers are fished intensively and both crocodiles and manatees are hunted in the north, between Douala and the Nigerian border, where they are offered no protection. Both *Crocodylus niloticus* and *Trichechus senegalensis* are considered to be endangered in inhabited regions, and crocodiles are actively persecuted outside of reserves. Nevertheless, *Crocodylus niloticus* still survives in the mangrove creeks in the north, and man-eating crocodiles are still a problem in the south west province.

Conservation Status: Wetland systems on the coastal plain are afforded some protection, at least theoretical, in the Faunal Reserves of Douala-Edea and Lake Ossa. The Mangombé Forestry Reserve includes the impoundment on the Sanaga River at Edea and includes both banks of the river for many kilometres upstream.

3. Floodplains of the North

(A) THE LOGONE/CHARI/EL BEID SYSTEM

Co-ordinates of Region: 10°00'-13°00'N/14°38'-15°36'E (in Cameroon)
Area: 1 450 000 ha (c. 1 300 000 subject to inundation)
Altitude: c. 300 m asl
Nearest Towns: Maroua (70 km E); Ngaoundéré (400 km SW)

General: The sources of the Logone are in the Massif de l'Adoumaoua, where the Wind River rises (7°23'N/13°22'E) near Ngaoundéré. This stream is ephemeral in its upper course and flows east between Mts. Ganga and Péné, crossing the border into Chad at its confluence with the Mbéré River near Baïbokoum (7°46'N/15°44'E), then becoming known as the Logone. The Mbéré rises even farther south (6°43'N/14°12'E), on the wetter side of the same massif, and is a perennial stream throughout. Small swamps occur in its upper reaches and those of its affluents, e.g. an 8000 ha swamp is situated on the Sing River, west of Mabang (7°10'N/14°28'E). From the confluence of the Mbéré and Logone Rivers, the Logone flows NE into Chad, receiving several more tributaries from

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Cameroon on its west bank, and another river, also called the Logone, from The Central African Republic on its east bank. From this last confluence it turns NW and re-enters Cameroon at Ham (10°00'N/15°36'E) in the Mayo Kebbi Swamps. The Logone forms the Cameroon/Chad border from Ham to its confluence with the Chari River, after which it forms the border to the point where it discharges into Lake Chad, a total straight line distance of 350 km.

For 50 km downstream of Ham, the Logone forms one side of a triangle of permanent swamp in Cameroon covering 78 750 ha. The western border of this swamp is Fianga Lake and at the height of a wet season, water flows from the Logone through several effluents across the swamp to Fianga Lake, and thence via the Kebbi to the Bénoué River, a tributary of the Niger. At this point the Lake Chad and Niger Basins are connected and the watershed between them is indistinct.

Below Bongor (10°16'N/15°21'E), at the downstream end of the Fianga Swamp, a floodplain extends from the west bank of the Logone into Cameroon for 300 km to Lake Chad. In places this floodplain is more than 45 km wide, and in the north it merges with the east bank floodplain of the El Beid River which forms the Cameroon/Nigeria border. At about 11°N the Logone breaks up into three parallel streams, the Logomatya, Lorome Mazra and Logone, which persist for a distance of 55 km before reuniting. Here the western stream, the Logomatya, receives several seasonal tributary rivers which drain the eastern slopes of the Mandara Mountains. At its northern end, before rejoining the Logone, the Logomatya sends an effluent, the Mayo Komarka, westwards to the El Beid River; thus north of this stream the entire area between the Logone and El Beid Rivers is subject to seasonal inundation. The total area flooded by these rivers in Cameroon in a wet year, between Ham and Lake Chad, exceeds 1 200 000 ha.

The area is mostly covered by Quarternary fluvio-lacustrine deposits which have given rise to black hydromorphic clays and vertisols. Sunshine averages 8.6 hours/day, i.e. 3142 hours/yr at Ndjamena (12°10'N/14°59'E), with a mean monthly total of 310 hours in December and a mean monthly minimum of 182 hours in August, the wettest month. Evaporation from an open water surface is estimated as 1750 mm at Ndjamena. The hot dry Harmattan wind blows across the floodplains during the dry season, November-April, but during the wet season winds are predominantly from the SE.

Hydrology & Water Quality: The pattern of flooding and the depth of the flood varies from year to year. In a normal year local rains, between May and September, saturate the soil, fill the lagoons and flood shallow depressions. A flood comes down the El Beid River and the seasonal tributaries from the Mandara Mountains in August. This is joined by a much bigger flood from the Logone/Chari which rises in September and persists until December. A large area of the plain is flooded to a depth of 1 m, with maximum depths of 3 m at the far north of the plain. It is estimated that when the flow of the Logone at Bongor exceeds 1200 m^3/sec the river begins to flood the plain, but that its waters will not reach the El Beid unless the flow exceeds 1500 m^3/sec. The mean annual contributions to the flood on the plain have been calculated as 3.3 billion m^3 from the Logone, 8.5 billion m^3 from direct precipitation, and 1.15 billion m^3 from the El Beid, while evapo-transpiration is considered to account for a loss of 10.55 billion m^3. Thus some 2.4 billion m^3 enter Lake Chad from the flood plain. Accounts of the hydrology of Lake

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Chad are given by Carmouze (1971) and Bénech & Quensière (1982; 1983a,b), while Barber (1965) describes the hydrology of the lands to the SW of the lake.

The transparency of the flood water varies from place to place but generally reaches a maximum in October when it has been as high as 2.1 m in the north but as low as 40 cm in the Logone River. Water temperatures rise to 32°C in the Logomatya between September and October, whereas the waters of the El Beid vary from 17-27°C, with a mean figure of 22°C at this time of year. It has been estimated that the mean annual deposition of silt over the floodplain is 850 000 tonnes. A series of droughts in recent years has led to minimal flooding and the drying of many waterholes.

Human Impact & Utilisation: The area is comparatively densely populated and some development has taken place along the Logone. Traditionally the floodplain was fished intensively, cattle were grazed on the margins, and crops, principally a type of sorghum, were planted on the floodplain margins as the water receded each year. However, in the south, immediately below Yagoua (10°21'N/15°14'E), there are two irrigation projects producing rice, over an empoldered area of 12 000 ha, with an artificial lake of 39 000 ha which has been created as a reservoir. This is Lake Maga. A consequence of this development is that an additional area of 59 000 ha is no longer flooded each year because it lies behind the dyke which has been constructed along the left bank of the Logone from Yagoua to Tékélé, which encompasses the irrigation projects. The flood regime has also been affected over a further 100 000 ha outside the dyke, in an area that includes the seasonally flooded part of Waza National Park, although in this latter area the changes are not serious at present. The two schemes produce a mean annual harvest of 70 000 tonnes of rice representing 70% of the total national consumption. Some 100 000 people are involved in the different aspects of this development.

The few high points on the plain are occupied by villages of fishermen and cattle herders, and these are completely surrounded by water when the floods rise. Close to the villages, elevated areas are used for rainfed cultivation of sorghum, and on the higher parts of the floodplain the villages cultivate a type of floating rice. At present between 200 000-300 000 domestic cattle and at least 50 000 wild ungulates depend upon the floodplain. Many cattle are driven onto the floodplain in large herds from Nigeria and Chad when the flood begins to recede. A certain amount of hunting takes place on the floodplain, and poaching in the National Parks is a problem. The larger centres of population are situated on the leveés of the Logone River.

Fishing is carried out by almost every conceivable means, using lines, nets and a variety of traps, and is most intense as the flood recedes and fish are caught returning to the channels, or are trapped in pools after reproduction. Thus many juveniles are caught, in places comprising as much as 95% of the catch. The total catch from the flooded lands of the Lake Chad Basin (amounting to some 9 000 000 ha, only a fraction of which are in Cameroon) is estimated as 60 000-80 000 tonnes/yr (Lowe-McConnell, 1975), but declines dramatically in dry periods. The total annual catch for the north Cameroon floodplain is difficult to assess but has been placed as low as 2000 tonnes (Drijver & Marchand, 1985). The potential production of the Maga Reservoir has been placed at 2000 tonnes/yr, but when actual production reached 800 - 1000 tonnes in 1985, it declined due to overfishing.

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The only tree species on the floodplain proper is *Acacia seyal* and this and several levée species have traditionally provided fuel for the indigenous population. However, the large number of people employed in rice cultivation has placed a serious burden on the tree resources of the region, and small afforestation schemes, using various species, but principally eucalypts, have been undertaken with limited success on areas of higher ground. It is estimated that the local population will consume 156 000 m^3 firewood/yr by 1990, and the way in which this demand may be met is discussed by Drijver & Marchand (1985) who give an account of the floodplain, and the effects of commercial rice production, including the impoundment at Maga, on the ecology of the area. These authors also cite and evaluate some earlier studies of the area.

Conservation Status: Two National Parks and a Forestry Reserve are situated in the area. The Kalfou Forestry Reserve lies to the west of the Fianga Swamp and Lake on unflooded land. It is proposed to utilise the resources of the reserve in an attempt to provide adequate fuel wood for the population engaged on rice production in the Yagoua district; thus, depending upon patterns of utilisation employed, its value as a reserve may be lost. Waza National Park & Biosphere Reserve is situated (11°05'-11°30'N/14°27'-14°52'E) midway along the floodplain in the west, and approximately 85 000 ha in its eastern half is flooded in a normal year. This is probably the best known national park in Cameroon and certainly among the most important in terms of the wildlife it protects. Lions, panthers and cheetahs have been recorded on the floodplain during the dry season. Kalamaloue National Park is situated on the eastern side of the floodplain, on the main road from Nigeria to Chad, immediately west of the confluence of the Chari and Logone Rivers. It covers just 4500 ha. The ground is bare in the dry season, but during the wet season is either covered by shallow lily ponds and grassland, or becomes a swamp subject to superficial inundation. There are waterholes along the northern boundary which persist in most dry years. Poaching is a problem and animals are frequently killed on the international road which crosses the park. Large herds of elephants from outside often invade the park with detrimental effects upon its ecology. *Hippopotamus amphibius* survives in the park and there is a tourist camp and many tracks. Tourist potential is increased by the proximity of an international airport a few kilometres distant at Ndjamena.

(B) THE FARO/BENOUE/KEBBI SYSTEM

Co-ordinates of Region: 7°40'-10°18'N/12°12'-15°11'E (in Cameroon)
Area: 162 500 ha wetland (in Cameroon)
Altitude: 161-1000 m asl
Nearest Towns: Garoua (on Bénoué River); Ngaoundéré (160 km SE)

General: Floodplains occur on the Faro and Kebbi tributaries of the Bénoué River and on the Bénoué itself. The Faro has sources 650-1100 m asl in the northwest of the Massif de l'Adoumaoua which give rise to its principal affluent, the Deo River. These descend steeply to a region of confluence, from where the Deo flows through a small patch of swamp forest (1000 ha) before swinging north and flowing down beneath the steep scarp of the Monts Atlantiks in Nigeria (which rise to 1889 m asl). The Faro proper rises as an ephemeral stream near Tignère (7°25'N/12°33'E) and is joined by the Deo at Tchamba (8°35'N/12°48'E). Upstream from this point it supports about 18 000 ha of seasonal and

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semi-permanent wetlands, while below the confluence a floodplain extends to the Bénoué. In the upper part of its course the Faro has a narrow, forested, seasonally inundated floodplain, but in its lower course it breaks into several streams and here a broad floodplain extends back from the Bénoué, in places 7 km wide, for a distance of 40 km, covering some 25 500 ha. The floodplain extends from 8°20'-9°20'N on the Deo/Faro. Another 20 000 ha of semi-permanent swampland occupy the triangular region between the two rivers immediately above their confluence, which, at 161 m asl, is the lowest point in northern Cameroon.

The Kebbi flows west through a long depression in Chad, in its upper reaches draining Fianga Lake and the swamps on the Logone near Ham, mentioned in the preceding account. It enters Cameroon at a point 7°37'N/14°00'E, and thereafter receives several tributaries flowing SE from the Mandara Mountains and reaches a confluence with the Bénoué 17 km east of Garoua (9°17'N/13°22'E). A floodplain extends back up the River Kebbi for 50 km from the confluence. This is 5 km broad over the lowest 15 km, but quickly dwindles to 1 km upstream, comprising 17 000 ha of wetland in Cameroon.

The Bénoué rises in the Mbang Mountains on the Massif de l'Adoumaoua close to the 1250 m contour and flows south to an impoundment at 9°04'N/13°44'E. The artificial lake, Lake Lagdo, 50 km long, and with a mean width of 10 km, now occupies the valleys of 4 streams which once entered the Bénoué at this place. Narrow floodplains extend back up the Bénoué and its tributaries above the lake, and another floodplain extends downstream from the dam to the Nigerian border, a distance of 102 km. The width of the floodplain varies from 3-7 km and comprises 96 000 ha of inundated land. A further tributary, the Mayo Tiel, rises in the Mandara Mountains and joins the Bénoué just below its confluence with the Faro. This stream also has a narrow floodplain and permanent swamp land along most of its length.

Hydrology: The floodplain of the Bénoué used to be inundated in most years, prior to the impoundment at Lagdo. Mean annual rainfall is 1000-1400 mm over the floodplain areas, and 88% of this falls between May and October. Peak flow rates of the Kebbi and Bénoué Rivers reach 2000 and 3000 m^3/sec respectively during August to September. In a wet year the flood used to rise in July and persist until December (c. 160 days), while in a dry year it was often delayed until late August and was gone by November (c. 90 days).

Human Impact & Utilisation: The area is sparsely populated with a mean density of 7 persons/km^2 in the Bénoué Valley and less in the Faro Valley. There are plans to develop the area and resettle people from the north where population density is much greater reaching 40-70 persons/km^2. The rivers and floodplain are fished and annual production is estimated as 2000 tonnes for the Bénoué/Kebbi. Cattle are herded along the Kebbi and the lower reaches of the Faro, Bénoué and Tiel Rivers, but the headwater regions of the Faro, Deo and Bénoué are infested with tsetse fly. Crops are grown on the floodplain, being planted as the waters recede, chiefly a form of sorghum, but cultivation presently occupies only about 3200 ha, just 2% of the total area inundated in the system.

Irrigation agriculture is planned, using the water of the new dam which has drowned 78 500 ha of valley land. The dam provides 300 GWh of electricity annually, sufficient to supply the town of Garoua until at least the year 2000. The irrigation projects will occupy about 24 000 ha of floodplain and about 1000 ha on the shores of the new lake.

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The principal sites for irrigation will be immediately below the dam (12 000 ha) and at the Faro/Bénoué confluence (7000 ha). However, in 1982, when the dam was being filled, the discharge of the Bénoué was reduced by 90% and flooding at Garoua lasted only for 3-15 days compared with the usual 93-160 days, and maximum water depth was only 1 m. The succeeding year was very dry, and outflow was still reduced by 65%. It is anticipated that by 1995 the floodplain will cease to be flooded, and this will no doubt be disastrous for the wildlife. The many lakes along the river now form important staging posts for migratory birds, cattle and wildlife. Clearly the fishery will collapse, but this will be replaced in part by a new fishery in Lake Lagdo. Also the recession culture of sorghum will no longer be possible. Development is proceeding apace with insufficient attention having been given to the full implications of the changes proposed; an account of the floodplain and an evaluation of proposals for its development are given by Drijver & Marchand (1985).

Conservation Status: Three national parks occur in the area and protect some of the wetlands. The most westerly park, the Faro National Park (330 000 ha), includes some of the upper Faro and Deo Rivers. The Bénoué National Park (180 000 ha) protects a 50 km section of the Bénoué River on its southern boundary, and headwater stretches of two of its upper tributaries in the northern section. To the east of this the Bouba-Ndjidah National Park (220 000 ha), on the Chad border, includes some 120 km of the Lidi River and its affluents, and some affluents of the Rei River, both of which enter the Bénoué in Lake Lagdo. However, the major floodplains are all outside the parks and are unprotected. Poaching is a problem in these parks, especially Bouba-Ndjidah, and although villages within them have mostly been relocated, people still enter to collect firewood, and areas are often burned. There is a small hotel in the Bouba-Ndjidah Park and an airstrip, and there are 500-600 visitors each year. The three national parks are linked by a game management area, in which hunting is controlled, and together these form the largest wildlife protection area in West and Central Africa (3 000 000 ha).

4. Floodplains of the Central Districts

(A) THE UPPER SANGHA SYSTEM

General: The Kadey with its affluents, the Doumé and Boumbé II Rivers, drains the southeastern borders of Cameroon, before forming the Sangha at a confluence with the Ekeia River in Central African Republic. The Sangha River also flows along the Cameroon border in the extreme southeast. In the central south of Cameroon, the Boumba and Bek Rivers join the Dja at Moloundou to form the Ngoko which then flows along the Cameroon/Congo border to a confluence with the Sangha at Ouesso (1°37'N/16°02'E). The Sangha then flows south through the Cuvette Congolaise to enter the Zaire River. The Dja River has one southern (2°43'N/12°05'E) and two northern sources (3°44'N/15°40'E and 3°34'N/13°34'E) and drains much of central southern Cameroon. Most maps show the last source to be on one side of a flat watershed across which watercourses are continuous with the source of the Voumo River, itself a tributary of the Boumba.

Permanent swamps and periodically inundated forests follow the courses of all these rivers in strips ranging from a few metres in width in the upstream sections, to 7 km wide

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on the Sangha. Raphiales flank the rivers in their upper courses, over 500 m asl, while below this altitude in the extreme southeast of the country, riparian raphiales are flanked by broad belts of periodically inundated forest. Perusal of aerial photographs and maps suggest that there are 225 000 ha of wetland along these rivers, within Cameroon, at a conservative estimate. The area has not been thoroughly explored from a biological point of view.

Human Impact & Utilisation: Forest clearances in the upper Nyong, originally carried out for health reasons, have led to the development of ribbons of permanent grass swamps along the central river courses, with herbaceous floodplains on the borders. In other river systems, lumbering operations have led to the expansion of valley floor *Raphia* swamps at the expense of swamp forest in several river valleys.

Conservation Status: Some 500 000 ha of forested land is protected in the Dja Forestry and Faunal Biosphere Reserve (2°49'-3°23'N/12°25'-13°35'E) which lies in a great bend of the Dja River. The river forms the southern border of the reserve, and receives several tributaries within it. However, the permanent swamps and periodically inundated areas along the river are very narrow here, in places only a few metres wide, and some tributaries, in the SE of the reserve, are deeply entrenched. Lake Lobeke, in the extreme SE, is situated within the Lake Lobeke Faunal Reserve (43 000 ha).

(B) THE UPPER SANAGA SYSTEM

General: The Sanaga drains most of the wet central part of Cameroon. Among its major affluents the Djérem River rises on the southern side of the Massif de l'Adoumaoua, while the Mbam River drains the mountains of the southwest. The source of the Mbam is at 1790 m asl (7°20'N/11°49'E) on the Nigerian border, and from here the river flows south collecting numerous tributaries, mainly from the mountains to the west. Wetlands occur on all of these, e.g. the Mapé, Ngouh, Mabu, Manyé, Mfi, Kwi, Ngam and Noun Rivers, wherever they traverse flat land. For example, semi-permanent swamps and floodplains, about 1 kilometre wide, used to accompany the Mapé River for 60 km as it meandered across the Mbaw Plain between Bamenda (5°55'N/10°10'E) and Foumbot (5°43'N/10°50'E), but much of this area is now submerged behind a recent impoundment. Swamps also occur along the Mbam River, e.g. for 130 km where it descends from 740 m asl to about 700 m asl flowing from east to west between longitudes 12°00' and 11°20'E. This wetland stretch, 2-3 km wide, accompanied by numerous lagoons, ox-bows and other sections of abandoned channel, covers over 30 000 ha.

The Djérem has several important tributaries. The Vina River rises at 7°01'N/13°58'E in the Massif de l'Adoumaoua and meanders northwest to Ngaoundéré, then southwest and south to join the Djérem River. A swamp of some 15 000 ha is situated on the Vina, SE of Ngaoundéré. The Djérem River proper rises at 6°47'N/14°10'E near Babongo and flows west, with several small strips subject to periodic inundation along its banks, e.g. near Mboula (6°40'N/13°55'E) and then almost continuously between longitudes 13°40'-13°00'E. Below this the river is impounded, at a point 6°16'N/12°45'E, to form the M'Bakaou Reservoir with an open water surface of some 45 000 ha. The Meng and several minor tributary streams now enter this reservoir. The Meng rises in the Hosséré Ngabo at 892 m asl in a region of small permanent pools, and flows for 80 km to the impoundment. Over most of this distance it is liable to overflow its banks. Below the

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impoundment the Djérem flows SE to the Sanaga, meandering in places and with a narrow floodplain. Towards the confluence its bed becomes wide and it contains many islands.

The Sanaga is formed some 40 km above the entry of the Djérem, by the confluence of the Lom and Pangar Rivers, which rise, with their several affluents on the Massif de l'Adoumaoua north of latitude 6°N. All these headwater streams inundate forested galleries in savanna country, on floodplains which vary in width from a few hundred metres to several kilometres. Studies of maps and aerial photographs suggest that there are at least 200 000 ha of wetland in the upper Sanaga system.

Human Impact & Utilisation: The most important changes in the system in recent years have been the construction of the two impoundments, on the Noun and Djérem Rivers. Both have significantly reduced the extent of flooding below the dams. The middle Sanaga Valley, and the Pangar Valley, are traversed by the railway from Douala to Ngaoundéré, and the Sanaga Valley by a main road. There are several centres of population and the forests have been extensively exploited in these regions, but the upper valleys, of the Djérem and Lom, are far less disturbed. Where the population is high the rivers are fished intensively.

Conservation Status: The large (480 000 ha) Pangar-Djérem Game Reserve is bounded by the Pangar River in the east, the Com River in the south, and the Djérem River in the west, and includes many minor affluents of these streams. It protects large areas of inundated gallery forest and is situated in the zone transitional between closed forest and savanna, including closed evergreen forest, semi-deciduous forest, broad leaf savanna and *Acacia* savanna.

(C) THE NYONG RIVER SYSTEM

General: The Nyong has two sources (4°02'N/13°35'E and 4°25'N/13°08'E) on the southern central plateau, and in this region, above Ayos (3°57'N/12°33'E), some 100 000 ha of *Sterculia ambacensis* permanent swamp occurs along the river and its affluents. The forest occupies a belt about 4 km wide on the Nyong, and lesser widths on the affluents, at altitudes above 650 m asl. Below Ayos the forest is replaced by a ribbon of permanently inundated floating grassland along the river, with broad belts of periodically inundated floodplain on either side of this.

Human Impact & Utilisation: The forests of the upper Nyong are relatively undisturbed, but the grasslands below Ayos have developed where the forest has been cleared in an attempt to reduce the incidence of sleeping sickness.

Conservation Status: Unprotected.

5. Natural Lakes

(A) THE CRATER LAKES

General: Lake Barombi Mbo (4°39'N/9°24'E) has an open water area of 453 ha. The lake surface used to be at an altitude of 301 m asl, but this has been raised artificially. The lake now has a maximum depth of 111 m and a mean depth of 69 m, and contains

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11 endemic species and 1 endemic subspecies of fish. Lake Barombi Koto is situated 25 km SW (4°28'N/9°16'E) and covers 330 ha at 110 m asl. It is an important sanctuary for birds and contains one endemic species, and also one endemic subspecies of fish. Lake Soden (4°43'N/9°17'E), c. 360 ha, is 15 km NW of Lake Barombi Mbo. Lakes Alangani (6°05'N/10°21'E) and Oku (6°11'N/10°28'E) are situated farther north in the high mountains. They both have areas of about 315 ha and are 2002 and 2019 m asl respectively. Mt. Oku close by rises to an altitude of 3011 m asl. Lake Nyi (6°25'N/ 10°13'E) farther north is smaller. Information on the fish faunas and ecology of the lakes and associated rivers is given by Trewavas (1962; 1974), Trewavas *et al.* (1972) and Corbet *et al.* (1973).

Human Impact & Utilisation: A dam has been constructed at the outlet of Lake Barombi Mbo, which has raised the level of the lake surface and has had a deleterious effect upon the formerly extensive growth of sponges on the rocks, perhaps however, only temporarily. Much forest on the crater rim has been felled in recent years and the land given over to agriculture, and there is concern that concentrations of pesticides may build up in the lake with detrimental effects upon the resident fauna.

Conservation Status: Lake Barombi Mbo is now situated in a Forestry Reserve. The other lakes are unprotected.

(6) LAKE CHAD

Location: 12°29'-14°29'N/13°02'-15°21'E
Area: 2 500 000 ha at high water (c. 107 000 ha in Cameroon)
Altitude: 282 m asl (when lake surface covers 2 000 000 ha)
Nearest Towns: Maroua (250 km S); Douala (1100 km SW)

General: A detailed description of Lake Chad is given in Section 3.3 Chad. Published accounts of the area of the lake vary between 1 379 200 ha (5325 square miles - Welcomme, 1972) and 2 500 000 ha (Beadle, 1981). Beadle states that the open water area has fluctuated between 1 000 000 ha and 2 500 000 ha this century, but in 1908 and 1975 it was reduced to 250 000 ha. Only a small southern portion of the lake and its peripheral marshes and floodplain is situated in Cameroon and no part is protected in Cameroon. The lake is endorheic and occupies part of a great inland basin of more than 2 500 000 km^2. The basin and lake are shallow, which is why the surface area of the lake is so variable. Rainfall presently averages about 300 mm/yr over the basin, which nowhere nearly balances evaporation which is estimated as 2000 mm/yr (Dussart, quoted by Beadle 1981). Of the total riverine inflow 95% comes from the Logone/Chari system, the catchments of which, in the humid highlands of Cameroon, Chad and the Central African Republic, represent about 25% of the total basin. The contribution of the El Beid River is minimal, possibly 2.5% of the total inflow, while the remainder is contributed by the Yobe, Yedseram and other intermittent streams. The lake water is well mixed and well oxygenated, and has a salinity of less than 1‰. The lake is fished from villages in Cameroon and is unprotected. A brief account of the hydrology, geomorphology and history of the lake is given by Beadle (1981), who refers to more detailed studies.

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(C) LAKE FIANGA

Location: 9°46'-10°10'N/15°11'E
Area: 11 900 ha (4760 ha in Cameroon)
Altitude: 320 m asl (low water); 323 m asl (high water)
Nearest Towns: Maroua (115 km NW); Ngaoundéré (340 km SW)

General: Lake Fianga spans the border with Chad and is situated in permanent swamps of the Kebbi Depression. A channel connects the northern end of the lake with the Logone River and another connects the southern end with the River Kebbi. Water flow in the northern channel is reversible and thus the lake effectively lies on a watershed between the Lake Chad and Niger Basins, as the Logone flows down to Lake Chad and the Kebbi flows to the Bénoué, a tributary of the Niger. The swamps, which lie to the east of the lake, receive most of their flood water from the Logone and drain into Fianga Lake, the level of which varies by about 3 m in the course of a normal year. Fianga is a shallow lake, with a maximum depth of 4 m during low water (June-July), but the mean low water level varies by as much as 2 m from year to year.

Human Impact & Utilisation: The lake is fished quite intensively, and manatees, which are now extremely scarce in the Kebbi, have been hunted to virtual extinction.

Conservation Status: Unprotected.

(D) THE COASTAL LAKES

General: The main basin of Lake Ossa (3°44'-3°53'N/9°58'-10°04'E) is shallow, 15 km long and 7.5 km wide, and contains several islands. It is connected to a subsidiary eastern basin, 6 km long and 1.5 km wide, by a narrow channel nearly 5 km long. This lake, together with another small lake near its southern end, drains to the Sanaga river via a short stream. Both basins of Lake Ossa and the small southern lake are included in the Lake Ossa Faunal Reserve. Another small lake on the north bank of the Sanaga, Lake Mbali (3°42'N/9°57'E), drains to the river via the Mbali stream and is unprotected. To the south, Lake Tissongo (3°34'N/9°53'E), is really a lagoon, being connected to the south bank of the Sanaga River by a tidal channel 5 km long, which extends past the main lake for another 3 km to a very small subsidiary basin. Lake Tissongo is included within the Douala-Edea Faunal Reserve, but ineffective enforcement means that animals in the reserves are afforded little real protection, and poaching is rife.

6. Artificial Impoundments

General: The largest artificial impoundment is at Lagdo on the Bénoué River and has an open water surface of 78 750 ha (8°44'-9°07'N/13°41'-14°05'E). M'Bakaou Reservoir (6°22'N/12°41'E) on the Djérem River near Tibati is over 500 m asl, and in the mountains of the SW the large reservoir (5°50'N/10°33'E) on the Noun River near Bamenda is over 1000 m asl. Both these latter reservoirs are on tributaries of the Sanaga River. There are two other small impoundments on the Sanaga River system, at Edea and Song-Loulou. That at Edea has produced a widening of the river 19.5 km long and up to 3 km wide, in which there are many islands. There are 7 small impoundments in the Mandara Mountains.

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Human Impact & Utilisation: The effect of the Lagdo impoundment on the flooding of the Bénoué Floodplain has so far proved near disastrous, and with increased use of its water for irrigation it does not seem that the situation will improve. It is possible that no effective flooding will occur after 1995. This matter is discussed in section 4.1.3b, and a detailed report is given by Drijver & Marchand (1985). The impoundments on the Djérem and Noun Rivers have also affected downstream flood regimes, but the effects are believed to be less drastic.

Conservation Status: The reservoirs are unprotected but they are managed.

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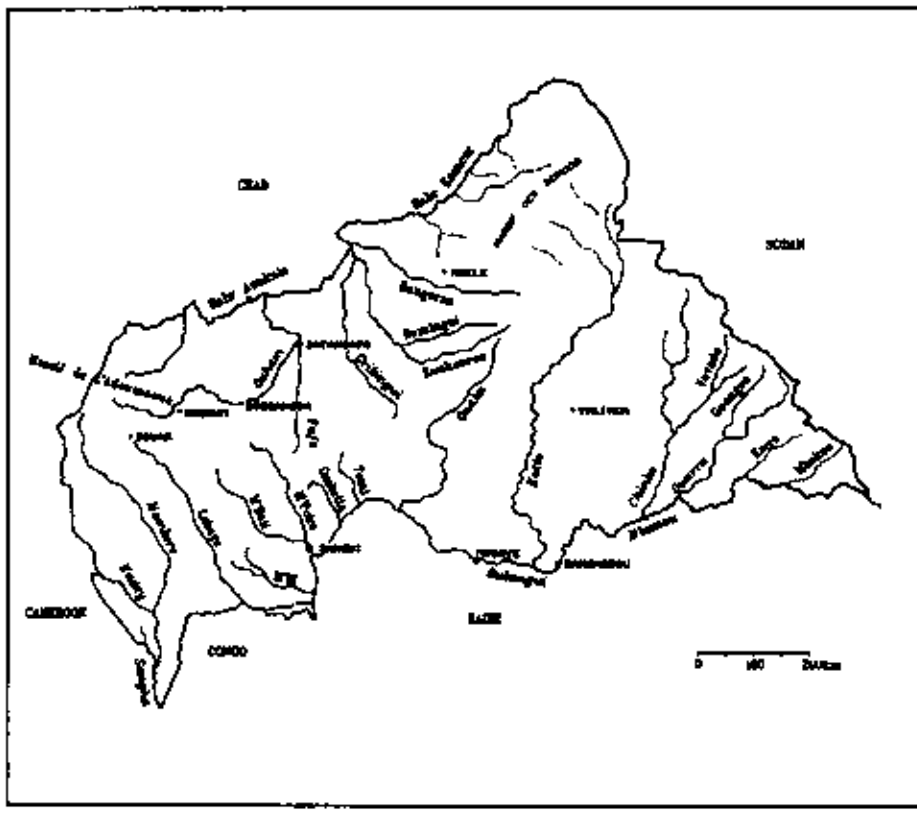

Map of Central African Republic

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4.2 CENTRAL AFRICAN REPUBLIC

Introduction

The Central African Republic is a landlocked country of 624 975 km^2. It is bounded by Zaire and Congo in the south, by Cameroon in the west, by Chad in the north and by Sudan in the east. With a population of 2 520 000 (1983) it has a low mean population density of only 4 persons/km^2. It extends 1445 km from east to west between longitudes 14°29' and 27°26'E, and 1050 km from south to north between latitudes 2°12' and 11°03'N.

Physiography is dominated by a rolling plateau, trending E-W, over 500 m asl, with two highland blocks exceeding 1000 m in altitude. These are situated at the far eastern and western ends of the country. A continuation of the Massif de l'Adoumaoua straddles the Cameroon border in the NW and the Massif des Bongos is close to the Sudan border in the NE. More than 90% of the land surface is above the 500 m contour. A watershed separating the Zaire and Chad Basins runs from west to east across the centre of the country and drainage is predominantly by streams flowing southwards to the Oubangui/ Mbomou River along the Zaire border, and by streams flowing north or northwest towards Lake Chad. Along the eastern border a triple watershed separates the Chad, Zaire and Nile Basins.

Climate

Mean annual precipitation is greatest in the southwest and southeast where it is in the region of 1750 mm. It decreases northwards, having declined to 1400 mm/yr on the parallel 8°N in the west, 6°N in the centre and 8°N in the east. Much of the northern region receives between 1000-1400 mm, while the extreme NE receives only 800-1000 mm/yr. Rainfall is seasonal, but more distinctly so in the north, rising to a sharp peak in August, with a 5 month dry season from November to March inclusive. Birao (10°11'N/ 22°49'E) in the northeast, 464 m asl, has a mean annual rainfall of 885 mm, with a mean monthly receipt of 210 mm in August. By contrast, Bangui (4°23'N/18°37'E) in the SW, 380 m asl, receives 1549 mm rain/yr, with a peak of 215 mm in August, and a dry season of 2 months, December and January. Bangassou (4°41'N/22°48'E) on the Mbomou River receives 1756 mm/yr, with 270 mm in August and a December-January dry season.

At Birao, May is the warmest month with a mean daily temperature of 30°C, and mean daily maxima and minima of 39°C and 19°C. January and December are the coolest months, with corresponding figures of 24, 35 and 13°C. At Bangui, March is the warmest month with a mean daily temperature of 28°C, and mean daily maxima and minima of 32 and 21.5°C. Here July is the coolest month with corresponding figures of 25, 30 and 20°C. The data for Bangassou are March 27, 24 and 20.5°C; September 25, 31 and 19.5°C. The northern regions receive about 2800-3000 hours sunshine/yr.

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Wetlands

The north of the country is subject to very seasonal rainfall, in a region where drainage is north or northwest to the Chad Basin. Here slopes are gentle, river valleys tend to be broad, and many rivers meander. Five months of the year are very dry, while 1300 mm may fall in the wet season with as much as 600-850 mm in the July-September period. The intensity of rainfall at this time leads to flooding on almost all streams, and many have broad floodplains, which in the case of the Bahr Aoukale is continuous for over 520 km. The northern rivers carry gallery forest which is inundated during the floods, and these tend to be backed by graminaceous floodplains, with sedges and occasional clumps of woody vegetation, especially on termite mounds.

There are some permanent lakes, swamps and pools on the central plateau along the watershed, and some patches of swamp forest and inundated gallery forest in the headwaters of the Yata River. The streams flowing south in the central region descend steeply over rapids and waterfalls to the Oubangui/Mbomou River. However, in the SW, drainage is to the Sangha River, which carries strips of periodically and semi-permanently inundated forest, and also *Raphia* swamps along its course into Congo. In the SE, rivers descend comparatively gentle slopes from the high land along the Sudan border, and then meander southwestwards over wide floodplains, e.g. the Mbokou River. In this region rainfall is higher, c. 1700 mm/yr, and the dry season lasts only from December-January. There are two seasonal rainfall peaks, and therefore two seasons of flooding. Here the floodplains are forested. The Oubangui River provides an extensive island studded open water surface, for 650 km along the southern border. This is slow flowing for most of the distance, but there are rapids almost midway at Kouimba.

Wetland Flora

The northern floodplain grasses include such species as *Acroceras* sp., *Echinochloa pyramidalis*, *E. stagnina*, *Eragrostis* sp., *Hyparrhenia rufa*, *Jardinea congoensis*, *Oryza barthii*, *Panicum* sp., *Paspalidium* sp., *Setaria anceps*, *S. sphacelata*, *Vetiveria negritana* and *Vossia cuspidata*, distributed according to depth and duration of inundation. *Acacia seyal* occurs on the floodplains, and a variety of trees occur in galleries along the levées, e.g. *Acacia albida*, *A. polyacantha* ssp. *campylacantha*, *A. sieberana*, *Allophyllus africanus*, *Anogeissus leiocarpus*, *Antidesma venosum*, *Balanites aegyptiaca*, *Bauhinia rufescens*, *Borassus aethiopum*, *Celtis integrifolia*, *Crateva religiosa*, *Dalbergia melanoxylon*, *Diospyros mespiliformis*, *Ficus gnaphalocarpa*, *Mitragyna inermis*, *Morelia senegalensis* and *Phyllanthus muellerianus*.

In the south, inundated riparian forests are characterised by the presence of *Uapaca heudelotii* and *Cathormion altissimum*, with some *Trichilia retusa*. The more widespread associates, including riverside shrubs, are *Alchornea floribunda*, *Anthocleista liebrechtsiana*, *Anthonotha isopetala*, *A. macrophylla*, *Antidesma venosum*, *Beilschmiedia piya*, *Bersama abyssinica*, *Calpocalyx dinklagei*, *Cercestis congoensis*, *Cynometra mannii*, *Diospyros gilletii*, *Dracaena ovata*, *Ficus anganophila*, *F. asperifolia*, *F. natalensis*, *F. pseudomangifera*, *F. rederi*, *F. vogelii*, *Gaertnera longevaginalis*, *Gardenia imperialis*, *Grewia* sp., *Hymenocardia heudelotii*, *Ixora guineensis*, *Lecaniodiscus cupanioides*, *Leptaulus daphnoides*, *Memecylon fosteri*, *Mimusops andongensis*, *Mitragyna stipulosa*,

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Morelia senegalensis, *Neoboutonia velutina*, *Neostenanthera myristicifolia*, *Oleandra distenta*, *Oubanguia africana*, *Pavetta calothyrsa*, *Psychotria vogeliana*, *Raphia laurentii*, *Rauvolfia macrophylla*, *Securinega virosa*, *Synsepalum dulcificum*, *Treculia africana*, *Vitex ferruginea* and *Xylopia parviflora*. In other places *Guibourtia demeusei* and *Irvingia smithii* are the commonest canopy species.

In some shallow basins, in the SW and SE, away from the rivers, where inundation is more or less permanent and the surface water is semi-stagnant, the forest is characterised by an abundance of *Sterculia ambacensis*. In these sites the soil surface is always muddy, and most arborescent species have either tall flanged buttresses or stilt roots. The buttresses of *Sterculia ambacensis* are narrow and plank-like, but sinuous, and 5-6 m tall at the bole. In this type of forest the most common associates are *Coelocaryon botryoides*, *Englerophytum oubanguiense*, *Lasiodiscus mannii*, *Macaranga staudtii*, *Mimusops warneckei*, *Pauridiantha pyramidata*, *Pseudagrostistachys ugandensis*, *Pseudospondias microcarpa*, *Spondiathus preussii*, *Symphonia globulifera*, *Treculia africana*, *Xylopia aethiopica*, *X. rubescens*, *X. talbotii* and *X. staudtii*.

In the south, the banks of tributaries to the Oubangui and Mbomou Rivers, which are subject to regular inundation, are colonised by *Alchornea cordifolia*, *Macaranga saccifera* and *Raphia* spp., all heliophilic species. This vegetation tends to be succeeded by *Mitragyna stipulosa* forest. Valley floor raphiales in the south tend to be dominated by *Raphia laurentii* (= *R. monbuttorum*). Riparian raphiales are characterised by the presence of *Raphia hookeri* and sometimes by *R. sese*, while the commonest large trees in the transition zones are typical of the various types of inundated forest.

Again in the south, on the slopes above the Oubangui River, where agriculture is comparatively intense, *Thalia welwitschii* swamps become established along rivers where the gallery forest has been destroyed. The existence of this vegetation depends upon a variable water level and a fairly swift current, at least in the wet season. *Thalia* is an obligate heliophyte, and these swamps, which contain few associates, deteriorate quickly if trees reappear. If the water levels are lower and less variable, and the water movement is sluggish, *Cyrtosperma senegalense* becomes established and is usually quickly succeeded by arborescent species.

In the higher country of the south, between 500-700 m asl, *Loudetia phragmitoides* swamps occur along the edges of gallery forests on poorly drained soils. These swamps include such other species as *Cyclosorus striatus*, *Cyperus halpan*, *Eulophia caricifolia*, *Ludwigia africana*, *Lycopodium cernuum*, *Sauvagesia erecta* and *Torenia parviflora*. The swamps develop where the water table is always high and flooding is periodic, whereas on better drained soils, which are often burned, *Imperata cylindrica* becomes dominant. These are both secondary associations.

In pools and quiet backwaters in the narrow parts of rivers shaded by gallery forest, a *Nymphaea lotus-Utricularia thonningii* community develops. By contrast, little depressions along the lowest central parts of valleys which are open to sunlight carry a much richer vegetation. Provided that water movement is minimal, water levels seem unimportant. Here *Nymphaea maculata* is dominant, while *Eleocharis acutangula*, *Fuirena stricta*, *Hydrocharis chevalieri* and *Sabicea africana* are the most common of a dozen or more associates.

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The pioneer species on sandy banks along, and in, the larger southern rivers is *Panicum repens*, which is soon joined by *Acroceras zizanoides*, *Cyperus erectus*, *C. maculatus* and *Hemarthria natans*, leading finally to a sward of *Cynodon dactylon* where inundation is infrequent. By contrast on mudbanks, the pioneers are *Basilicum polystachyon*, *Commelina diffusa*, *Eclipta prostrata*, *Ipomoea reptans* and *Ludwigia repens*. Meadows of aquatic grasses develop in deep water along the banks of backwaters, and here *Echinochloa pyramidalis*, *E. stagnina* and *Vossia cuspidata* are the most frequently encountered species, but in shallower places *Phragmites mauritianus* or *Cyperus papyrus* may cover extensive areas in monospecific stands. Little depressions on islands in the river are colonised by *Cyperus longibracteatus* and *Rhynchospora corymbosa* when they fill up, usually with some persistent *Echinochloa pyramidalis*. Open surfaces in quiet backwaters tend to be covered by *Lemna paucicostata*, *Nymphaea caerulea*, *N. lotus*, *Pistia stratiotes* and *Utricularia* spp., but comparatively recently *Eichhornia crassipes* has been introduced and tends to dominate this habitat, and also to invade the areas normally supporting floating grasses. It has become a serious threat to navigation in certain localities. Steep sandy river banks are covered, at water level, by plaques of *Marchantia chevalieri*, and above the water by a tracery of ferns dominated by *Dicranopteris linearis*. On any slips or shelves however, and on the tops of high banks, the forest vegetation quickly takes root, in particular *Anthocleista nobilis*, *Barteria nigritiana*, *Caloncoba welwitschii*, *Vernonia conferta* and occasionally *Alchornea cordifolia*.

As they become more elevated, islands in the Oubangui are colonised by woody species, first by single trees, or little clumps of *Alchornea cordifolia* with *Bridelia micrantha*, *Ficus mucuso*, and *Spondianthus preussii*, often with abundant *Mimosa pigra*. This pioneering woody vegetation is quickly entangled by creepers, and *Alchornea* is usually dominant in the early stages of the succession. However, a tall forest of *Lannea welwitschii*, with *Ceiba thonningii*, *Ficus mucuso*, *Oxystigma buchholzii*, *Pseudospondias microcarpa* and *Spondianthus preussii*, quickly replaces the *Alchornea* association. Occasionally *Elaeis guineensis* may be encountered in this vegetation, and the understorey is rather sparse, with *Leptonychia batangensis* the most characteristic species.

A description of the vegetation of the Central African Republic is given by Boulvert (1970).

Wetland Fauna

Fishes: The fish faunas of the southern rivers, all of which are ultimately tributary to the Oubangui River, are closely related to that of the middle Zaire River, which is briefly described in section 4.6, Zaire. The fish fauna of the Sangha River is virtually identical with that of the middle Zaire/Oubangui River. However, rivers like the Kotto, which are steep and have upper sections isolated by waterfalls, and which share watersheds with the Chad Basin, contain some species with Soudanian affinities.

The rivers draining northwards, via the Chari to the Chad Basin, have typical Chad Basin fish faunas, such as are described in section 1.2, Chad. Over 100 species are known from the upper reaches of the Chari/Bahr Aoukale/Bamangui System. Common species in the rivers of the north are *Alestes baremose*, *A. dentex*, *A. macrolepidotus*, *Chrysichthys auratus*, *Citharinus citharus*, *Clarias lazera*, *Distichodus rostratus*, *Eutropius niloticus*, *Heteropneustes bebe*, *Heterotis niloticus*, *Hydrocynus forskali*, *Labeo senegalensis*, *Lates*

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niloticus, *Malapterus electricus*, *Micralestes acutidens*, *Mormyrus rume*, *Pollimyrus bane*, *P. isidori*, *Oreochromis galilaeus*, *O. niloticus*, *Polypterus senegalus*, *Schilbe mystus*, *Synodontis batensoda*, *S. clarias*, *S. frontosus*, *S. membranaceus*, *S. schall*, *Tetraodon fahaka* and *Tilapia zillii*. Brief accounts of the Chad Basin fish fauna are given by Beadle (1981) and Lowe-McConnell (1975).

Reptiles: Those found in the rivers and lagoons, on the floodplains, and in the galleries and flooded forests, include *Bitis arietans*, *Crocodylus niloticus*, *Dasypeltis fasciata*, *D. scabra* (N only), *Dendroaspis jamesoni*, *Dispholidus typus* (N only), *Naja melanoleuca*, *N. nigricollis*, *Pelomedusa* sp., *Pelusios* spp., *Philothamnus irregularis*, *P. semivariegatus*, *Psammophis sibilans* (mainly N), *Python sebae* and *Varanus niloticus*.

Birds: The avifauna includes *Alopochen aegyptiacus*, *Anas* spp., *Anhinga rufa*, *Ardea goliath*, *A. purpurea*, *Balaeniceps rex*, *Bias musicus*, *Bubalornis albirostris*, *Bubulcus ibis*, *Chalcomitra senegalensis*, *Chloropeta natalensis*, *Ciconia ciconia*, *Cinnyris cupreus*, *Egretta garzetta*, *E. intermedia*, *Ephippiorhynchus senegalensis*, *Hagedashia hagedash*, *Haliaeetus vocifer*, *Hyliota flavigaster*, *Leptoptilas crumeniferus*, *Megaceryle maxima*, *Merops breweri*, *M. nubicus*, *Motacilla clara*, *Muscicapa caerulescens*, *Mycteria ibis*, *Nycticorax nycticorax*, *Pelecanus onocrotalus*, *Phalacrocorax africanus*, *P. carbo*, *Platalea alba*, *Plegadis falcinellus*, *Psittacus erithacus*, *Pteronetta hartlaubii*, *Rynchops flavirostris* (south only?) and *Threskiornis aethiopica*.

Mammals: The following list comprises mammals found on the floodplains, in the gallery forests, in swamp forests and *Raphia* swamps. *Acinonyx jubatus* (N only), *Alcelaphus buselaphus* (N only), *Aonyx capensis*, *Atilax paludinosus*, *Cephalophus monticola* (N only), *C. rufilatus* (N only), *C. sylvicultor*, *Cercocebus albigena* (S only), *Cercopithecus aethiops*, *C. mona denti* (SE only), *C. neglectus*, *C. nictitans*, *Colobus badius oustaleti* (S mostly), *Crocuta crocuta* (N only), *Damaliscus lunatus* (N only), *Felis aurata*, *F. lybica* (N only), *Funisciurus pyrrhopus* (S only), *Galago demidovii* (S only), *G. senegalensis* (N only), *Genetta tigrina*, *Heliosciurus rufobrachium* (S only), *Herpestes ichneumon*, *Hippopotamus amphibius*, *Hippotragus equinus* (N only), *Hyaena hyaena* (N only), *Hystrix cristata*, *Ichneumia albicauda* (N only), *Kobus ellipsiprymnus*, *K. kob* (N only), *Lemniscomys striatus* (N only), *Leptailurus serval*, *Loxodonta africana* (N only), *Loxodonta africana cyclotis* (S only), *Lutra maculicollis*, *Manis gigantea*, *Mungos mungo* (N only), *Nandinia binotata* (S only), *Panthera pardus*, *Papio anubis* (N only), *Phacochoerus aethiopicus*, *Potamochoerus porcus* (uncommon in N), *Potamogale velox*, *Praomys natalensis fumatus* (N only), *Redunca redunca* (N only), *Sylvicapra grimmia* (N only), *Syncerus caffer*, *Taurotragus derbianus* (N only), *Tragelaphus scriptus* (N only) and *Viverra civetta* (N only). Both *Ceratotherium simum* and *Diceros bicornis* are believed to occur in some of the northern reserves, e.g. Yata-Ngaya Faunal Reserve. The aquatic genet, *Osbornictis piscivora*, occurs in the wetlands of the southeast.

List of Wetlands Described

1. Wetlands of the Southern Region
2. Wetlands of the Northern Region

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1. Wetlands of the Southern Region

Co-ordinates of Region: 2°12'-9°30'N/16°00'-27°30'E
Area: c. 1 100 000 ha wetland
Altitude: 340-700 m asl
Nearest Towns: Bangui; Mobaye; Bangassou (on Oubangui/Mbomou River)

General: Flooded forests occur in the extreme SW, on the Sangha River and its headwater tributaries the Kadey and Ekeia Rivers. Forested floodplains extend for 400 km up the Sangha and Ekeia Rivers, between Bomassa (2°10'N/16°10'E) and Carnot (4°59'N/15°56'E), and above this in minor strips along the Mambéré and Nana Rivers. Other floodplains extend up the Kadey and its affluents the Boumbé I and II Rivers for a total of 280 km. In this sector there are, in total, at least 120 000 ha of periodically inundated forest and *Raphia* swamp.

Wetlands occur on almost all of the streams flowing south to the Zaire basin, but slopes on the southern side of the central massif are steeper than those on the northern side, and valleys tend to be less wide than they are in the north. Thus floodplains are less pronounced, and on most streams they are only a few metres to a few hundred metres wide. However, a forested floodplain is well developed along the north bank of the Oubangui, and on its tributaries, the Kouma, Tomi and Ombella Rivers, between 19-20°E, and also on the M'Poko, M'Bali, M'bi and Lobaye Rivers which enter the Oubangui below Bangui (4°23'N/18°37'E) at the head of the Cuvette Congolaise. Here the total area of inundated forest amounts to approximately 231 000 ha in major floodplain areas, and perhaps a further 100 000 ha in minor riparian strip swamps.

In passing eastwards up the Oubangui, the valley begins to narrow above the Kouimba Rapids (4°37'N/20°27'E) and the floodplain contracts. Several of the north bank tributaries descend very steep sections above their confluences; the Kotto, for example, descends no less than 5 waterfalls in the section immediately above its confluence with the Oubangui at Touté (4°13'N/22°02'E). However, the greatest development of riverine wetlands in the south of the country is in the far eastern part of the region, on tributaries of the Mbomou River between longitudes 23°45' and 27°00'E. These are, from west to east, the Chinko River and its affluent, the Vovado; the Ouarra and its affluent the Goangoa; and the Kerre (Kéré) and Mbokou Rivers. Floodplains are well developed for a total of 1320 km on these rivers, with widths of 2-10 km, and for a further 1000 km on minor streams in the region. The total area of periodically inundated land here exceeds 650 000 ha.

Human Impact & Utilisation: Several major centres of population including Bangui, Kouango, Mobaye, Bangassou and Zemio, and many minor centres, are situated along the north bank of the Oubangui/Mbomou River. Although there are major rapids at Kouimba, between Kouango and Mobaye, long stretches of the river are navigable and it is the major communication route along the southern central part of the country. East of Mobaye, a main road connects all the major centres along the border and crosses into Sudan. The river is fished intensively close to the towns, and in these regions the fringes of the floodplain are cultivated. The wetlands in the valley of the Sangha are sparsely populated and were undisturbed until 1970, but subsequently forestry leases were granted in this area and exploitation has begun. Timber is exported from Nola, a centre

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on the Sangha River. By contrast the wetlands in the SE are more densely populated, and there, locally, the floodplains are exploited for fish and for agriculture. Nevertheless, areas which are deeply and regularly flooded are still comparatively undisturbed.

Conservation Status: The small Basse Lobaye Biosphere Reserve on the Lobaye River (c. 3°40'N/17°50'E) covers 18 200 ha and includes an area of inundated forest. It is situated at the head of the Cuvette Congolaise in an evergreen forest area, where the canopy is 30-35 m high, with emergents exceeding 40 m in height. Mean annual rainfall is 1760 mm and there is a short dry season in December. The area is inhabited by pygmies and is relatively undisturbed, except near some villages in the north.

It has been proposed that the entire southwestern extremity of the country between Cameroon and Congo, south of 3°N, should become a sanctuary area, to be known as the Bongo Sanctuary. This will include a large area of inundated forest and *Raphia* swamp along the Sangha River.

In the far east the Zémongo Faunal Reserve, was first established in 1925 and was for a short time fully protected from hunting, e.g. in 1939. It was extended and redesignated in 1975, despite which it was still open to hunting in 1980-81. The reserve covers 1 010 000 ha and has the approximate co-ordinates 6°10'-7°28'N/24°40'-26°00'E. It includes about 172 000 ha of inundated forest. This is situated on the Vovado River system, principally on an affluent, the Bita, but also on the Goangoa River, a tributary of the Ouarra. A broad forested floodplain extends for 113 km up the Bita from its confluence with the Vovado.

In the northeast, the Yata-Ngaya Faunal Reserve protects the headwater basin of the Koto River, and this area includes several small wetlands on the southwestern slopes of Mt. Dj Ngaya.

2. Wetlands of the Northern Region

Co-ordinates of Region: within 5°45'-11°03'N/14°30'-23°30'E
Area: c. 2 050 000 ha wetland
Altitude: 350-520 m asl
Nearest Towns: Bouar; Bozoum; Bossangoa (in the western highlands)

General: Most of the northern rivers have broad floodplains. That on the Bahr Aoukale extends for 522 km from the Sudan border to the confluence with the Chari, and attains maximum widths of 40 km in the NE. About half of the floodplain (362 200 ha) is in the Central African Republic, together with a conservative estimate of a further 873 000 ha on its tributaries. For example, continuous floodplains extend for 320 km up the Kameur/Bahr Ouloou River, and then in turn along all of its affluents, e.g. for 180 km up the Ouandja. Floodplains also occur on the Gounda/Goro, Kounbala and Lélé tributaries. In places the floodplains on the tributaries are over 10 km wide, while their total length exceeds 1746 km. There are at least 1 238 200 ha of floodplain on the Bahr Aoukale system. On the Chari system in the west, into which the Bahr Aoukale flows, there are another 701 250 ha of major floodplains, and perhaps 100 000 ha of minor floodplains, less than 800 km wide, covering a distance of some 2000 km along minor rivers. There are numerous lakes and lagoons along the rivers.

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Human Impact & Utilisation: The river courses are mostly covered by gallery or semi-deciduous riverine forest, set in a Soudano-Guinean dry savanna landscape. In the north, the galleries are backed by grassy floodplains for long stretches. The rivers and open floodplains are fished, locally quite intensively, and sheep, goats and cattle are grazed on more open parts during the dry season. Some floodplain areas have been cleared, or semi-cleared, and are cultivated with crops sown as the floods recede, and shifting agriculture is widespread. Timber from the gallery forests is used for fuel, canoes and building. In some places cotton (which is also grown by traditional methods) is grown commercially. The run-off of pesticides has been very detrimental to river and floodplain life; the Bamingui River, for example, has been badly polluted.

Conservation Status: A great deal of floodplain is included in protected areas in the northern region. In the Nana Barya Faunal Reserve in the west, a floodplain extends along the national border for 82 km in the reserve on the Nana Barya River, and another extends 127 km up a tributary, the Bakassa River, of which the first 90 km are in the reserve.

Farther to the east, an area of 2 600 000 ha is protected in a complex of contiguous reserves, the most important of which are the Bamingui-Bangoran National Park and the Gribingui-Bamingui Faunal Reserve. In the latter, the right bank floodplain of the Gribingui River is protected for 116 km and the left bank floodplain of the Bamingui for 150 km. In the former, the left bank floodplain of the Bamingui is protected for 202 km, together with 105 km of floodplain on the Bangoran River, except for a 30 km section on the right bank immediately above its confluence with the Chari River. A floodplain, 52.5 km long, on another affluent of the Chari, is also included in the reserve. In the park centre, a strict nature reserve is bounded by the Vassoko and Bolo Rivers, both ephemeral streams. Lake Avakaba (50 ha) is a small permanent lake within the Avakaba Park (175 000 ha), also contiguous, which is used as a private hunting area under the control of the President.

Still farther east the Saint Floris National Park and the contiguous faunal reserves of Aouk-Aoukale and Ouandja-Vakaga protect further long stretches of floodplain. The left bank floodplain of the Bahr Aoukale is protected for 120 km in the Aouk-Aoukale Faunal Reserve, together with 135 km of the right bank floodplain of the Kameur/Bahr Ouloou River immediately above its confluence with the Bahr Aoukale. The left bank floodplain of the Kameur River is protected in the Saint Floris National Park for 82.5 km upstream of the confluence. In this park, 49.5 km of the lower right bank floodplain of the Goundja River is protected above its confluence with the Kameur River, together with 30 km of floodplain on the Ouandja River above its confluence with the Kameur. To the south, this floodplain forms the eastern and southern boundaries of the contiguous Ouandja-Vakaga Faunal Reserve, where the left bank floodplain is protected for a further 150 km. On the other, western side, the Vakaga River forms the boundary, and here, 102 km of its right bank floodplain is protected, while the interior of the reserve contains a further 150 km of floodplain on affluents of the Vakaga and Ouandja Rivers.

In the far east, 69 km of floodplain in the upper basin of the Yata River are protected in the Andre Felix National Park and the Yata-Ngaya Faunal Reserve.

Poaching and fires are serious problems in almost all of the reserves.

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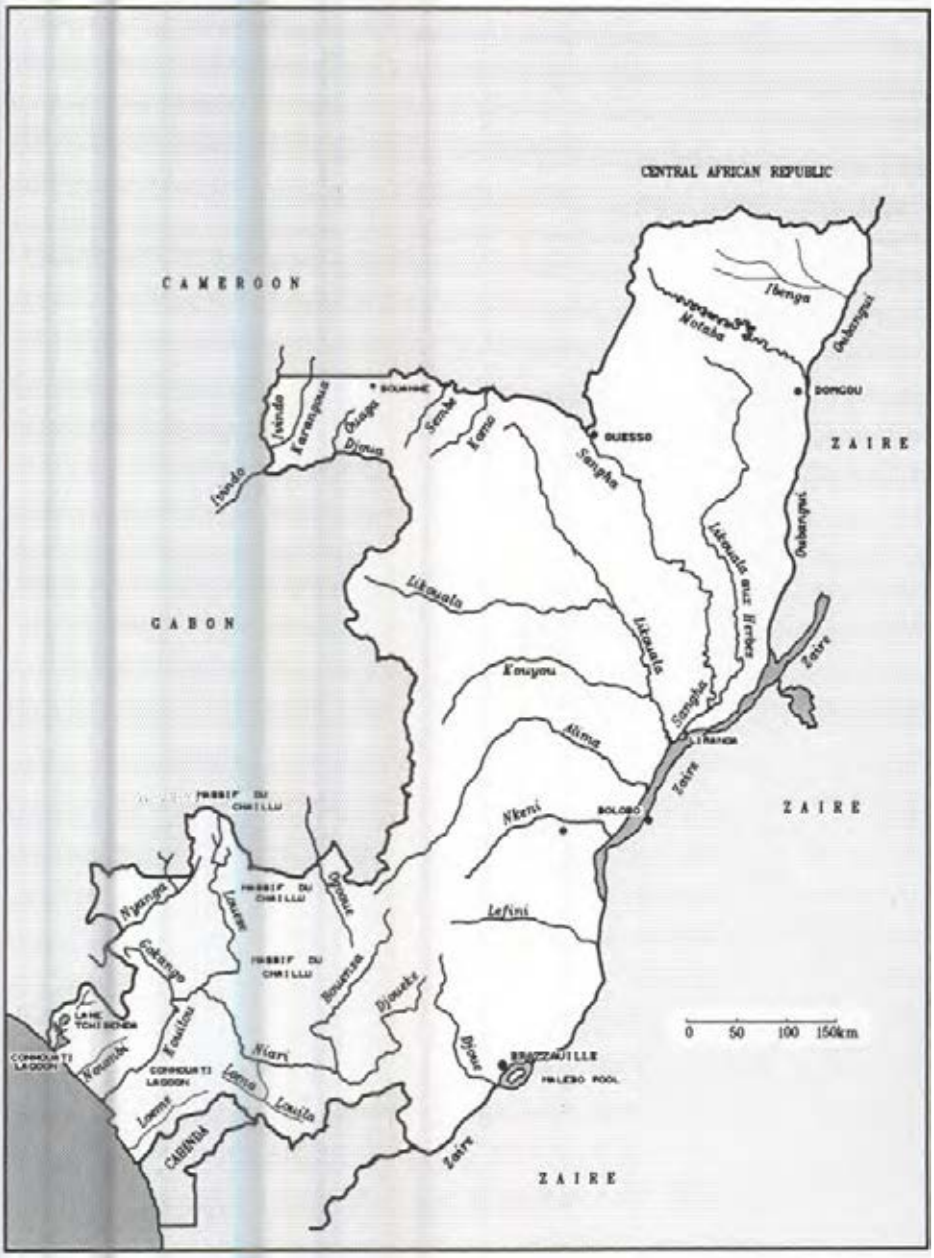

Map of Congo

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4.3 CONGO

Introduction

Congo covers 342 000 km^2, and with a population of 1 660 000 (1983) has a mean population density of 4.9 persons/km^2. It lies between 3°34'N and 5°00'S, and 11°11' and 18°35'E. The Atlantic coast is 190 km long, excluding the inlet of Conkouati Lagoon, which provides a further 55 km of tidal shoreline. A coastal plain, about 60 km wide, rises into low hills and then to the Chaîne du Mayombé, crossing the country from SE to NW with high points of 930 m asl at Mt. Foungouati and 800 m asl at Mt. Bamba. Between these mountains and the Massif du Chaillu, which also crosses the country from SE-NW farther inland, is the Plain of Dihésé. Beyond the Massif du Chaillu, even farther inland, a series of plateaux, between 500-650 m asl, covers almost all of Congo between latitudes 2-4°S, and thereafter extends northwards up the Gabonese border. In the east the border with Zaire is formed by the Congo (Zaire) and Oubangui Rivers. In this northern sector, between 2°S and 3°34'N, the land slopes from west to east, into the central depression of the Zaire Basin.

There are 7 drainage systems. The Oubangui/Congo River system is the largest and drains some 232 320 km^2, covering most of the eastern part of the country. Three minor systems drain the coastal plain, one of which comprises the Nyambi, Mousa, Ngongo and Louvanisi Rivers, and empties to the sea via Conkouati Lagoon. South of this is the Noumbi River, and south of Pointe Noire (4°46'S/11°43'E), the Loemé River system. Much of the southern central part of the country, including most of the Massif du Chaillu, the Plain of Dihésé and the Chaîne du Mayombé, is drained by the Kouilou River and its tributary, the Niari, which together have the second largest catchment in Congo, amounting to some 50 820 km^2. The Ogooué River, which reaches the sea in Gabon, drains 3 basins in Congo. It rises in Congo, as does one of its principal tributaries, the Ngounyé River, and these streams drain two separate parts of the Massif du Chaillu in Congo, while another tributary, the Ivindo River, drains the extreme northwest of Congo. The Nyanga River rises and reaches the sea in Gabon, but its upper course crosses a small corner of Congo in the southwest near Divénié (2°43'S/12°01'E).

Climate

There are 4 principal climatic zones in Congo. In the most northerly region, above 1°N, rainfall is in the vicinity of 1700 mm/yr (1718 mm at Impfondo), rising to 2000 mm in the hills along the western border. There is a short dry season in December-January and most rain falls during violent thunderstorms in the afternoon or night. Mean annual temperatures are 25-26°C, with diurnal ranges of the order of 9-14°C. The coolest month is August, at the height of the long wet season, but the lowest temperatures, c. 13°C, are recorded in January, and the highest, c. 40°C, in March. Humidity is generally high throughout the year, but plunges in the far north to 20% during the dry season.

The central region, between 1°N and 2°S, has a true equatorial climate with no dry season and little variation in temperature throughout the year. Mean annual precipitation is generally close to 1700 mm, but rises to 2000 mm in the west. Mean annual temperature

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is 25°C, with a mean monthly minimum of 23°C in June/July and a mean monthly maximum of 27°C in April.

The plateau region of SE Congo also has a mean annual rainfall of 1700 mm, rising to 2200 mm in the hills on the Gabonese border and falling to about 1300 mm along the southern border on the Congo River. It is for example, 1351 mm at Brazzaville. The region enjoys a distinct dry season from June-September, and a very wet one from October-May. Mean annual temperature is 24°C, but the range is 18-32°C.

The climate is more variable in the coastal region of the SW. Taken overall it is the driest part of the country, with two dry and two wet seasons. The main dry season is from June-September, and the short dry season from January-February. Mean annual rainfall is variable along the coast, averaging 1500 mm (1512 mm at Pointe Noire), but it increases inland to 1800 mm on the mountains of the Chaîne du Mayombé. In passing inland it falls again, to 1200 mm, over the Plain of Dihésé. March-April is the wettest period, and mists occur during May-September. Relative humidity however, remains at 82-84% throughout the year. Mean monthly temperatures range from 21-27°C, with absolute minima of 12-13°C and absolute maxima of 35°C.

Wetlands

By far the largest wetland in Congo covers the Cuvette Congolaise, the large low lying area between the Oubangui/Congo Rivers and the western hills. Here well over 6 500 000 ha are subject to permanent or seasonal inundation. Another important wetland system occurs in the headwater basin of the Ivindo/Djoua River in the northwest, between 470-600 m asl. In the southwest, wetlands occur on the tributaries of the Kouilou River leaving the Massif du Chaillu, and on the Plain of Dihésé. Other wetlands occur on all river systems of the coastal plain, and mangroves occur in Conkouati Lagoon and in the estuaries of the Ngounié, Kouilou and Loemé Rivers.

Wetland Flora

About 65% of Congo is covered by rain forest and 25% by savanna, with areas of short grassland, various types of herb swamp and gallery forest compriaing the remaining 10%. Much of the rain forest is swamp forest, and this covers some 25% of the total land surface. The savannas are almost entirely situated south of the equator.

Large areas of floating grassland occur in the swamp forest along river courses in permanently inundated situations in the Cuvette Congolaise and on M'Bamou Island in Malebo Pool. These are dominated by *Echinochloa pyramidalis*, *Leersia hexandra*, *Oryza barthii*, *Vossia cuspidata*, and some large sedges. These species all root in the mud, but generally emerge above the water surface. The vegetation is dense and often develops into free-floating rafts containing other hygrophilous plants, principally species of *Laurembergia*, *Ludwigia*, *Polygonum*, *Stipularia* and *Utricularia*, with *Cyclosorus striatus* and occasional plants of *Cyrtosperma senegalense*.

In the southern parts of the Cuvette Congolaise patches of peaty, boggy steppe form a mosaic with swamp forest; they generally contain some bushes or low trees, and patches of tall sedge, but the cover is principally a dense herb layer 30-50 cm high, and all plants are hygrophilic. The grasses *Hypogynium spathiflorum*, *Jardinea gabonensis*, *Panicum*

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parviflorum and *Rhytachne rottboellioides* are common, together with species of *Andropogon*, *Loudetia* and *Setaria*, and the sedges *Eleocharis nupeensis*, *Kyllinga pungens* and *Rhynchospora albida*. Other plants include Araceae, Commelinaceae, Eriocaulaceae, Melastomaceae, Onagraceae, Rubiaceae and Xyridaceae. The patches may become surface dry and be burned during the short dry season, but standing water is always retained in depressions.

On the fringes of the Cuvette, north of the Likouala River, a tall tufted grassland of *Andropogon schirensis*, with some *Hyparrhenia diplandra* and *Loudetia phragmitoides*, may occur on waterlogged soils where it forms a mosaic with seasonally inundated swamp forest.

Low grasslands dominated by *Loudetia simplex* occur in several places, but are particularly important on the Batéké Plateau, and some occur on waterlogged soils. Leached white sands on the plateaux, when they are frequently waterlogged, support *Loudetia simplex* with *Bulbostylis laniceps*, *Ctenium newtonii* and *Monocymbium ceresiforme* as associates. This grades into a richer association on soils with a higher organic content, where *Andropogon huillensis*, *Panicum parviflorum* and *Rhytachne rottboellioides* join the association, together with species of *Mesanthemum* and *Xyris*.

Papyrus swamps occur around the lakes and along the rivers of the Coastal Plain, and along some rivers on the Plain of Dihésé. They comprise dominant monospecific stands of *Cyperus papyrus*, with *Cyclosorus striatus*, *Cyrtosperma senegalense*, *Lygodium scandens* and *Vossia cuspidata* as lower growing associates, and occasionally, isolated trees or clumps of *Ficus congensis*. The papyrus swamps proper are fringed on their landward margins by a halo of herb swamp dominated by *Echinochloa pyramidalis* and *Leersia hexandra*, together with species of *Eleocharis*, *Nymphaea*, *Oryza*, *Polygonum*, *Utricularia* and *Xyris*. Outside this, in a transition to terrestrial vegetation, there is a zone which is partly bushy and partly herbaceous. This is rooted in peaty soil, which although always waterlogged, is flooded only temporarily. Here *Arundinella funanensis*, *Echinochloa pyramidalis*, *Ficus congensis*, *Honckenya ficifolia*, *Leersia hexandra*, *Ludwigia acuminata* and *Lygodium scandens* are common.

Swamp forests dominate the low lying Cuvette Congolaise, and are also well developed along rivers in the three headwater basins of the Ogooué system and also in the Kouilou/Niari system. Small pockets of swamp forest are found along minor streams throughout the country. The forests of the Cuvette are very similar to those of the central Zaire Depression. Much of the forest has a canopy between 25-30 m, but with regularly spaced emergents over 30 m tall. In the south of the Cuvette the canopy is lower, c. 20 m, but still with tall emergents. Floristically the forests are complex and include the following species: *Acioa lujae*, *Albizia laurentii*, *A. zygia*, *Alstonia congensis*, *Anopyxis klaineana*, *Anthocleista liebrechtsiana*, *Anthonotha pynaertii*, *Anubias affinis*, *Baikaea insignis*, *Berlinia brunellii*, *B. grandiflora*, *B. sapinii*, *Berteria laurentii*, *Brazzea congensis*, *Bridelia macrantha*, *B. ripicola*, *Ceiba thonningii*, *Chrysobalanus atacorensis*, *Coelocaryon botryoides*, *Coffea congensis*, *Crotonogyne giorgii*, *C. poggei*, *Dacryodes edulis*, *Dialium pachyphyllum*, *Dichaetanthera africana*, *D. strigosa*, *Dichostemma glaucescens*, *Elaeis guineensis*, *Entandrophragma palustre*, *Eriocoelum microspermum*, *Ficus mucoso*, *Garcinia smeathmannii*, *Gilbertiodendron dewevrei*, *Guibourtia demeusei*, *Hymenocardia heudelotii*, *Irvingia smithii*, *Lannea welwitschii*, *Lasiodiscus*

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mannii, *Mallotus oppositifolius*, *Mimusops warneckei*, *Mitragyna stipulosa*, *Monopetalanthus pteridophyllus*, *Nauclea diderrichii*, *N. pobeguinii*, *Oubangula africana*, *Paramacrolobium coeruleum*, *Parinari congensis*, *P. glabra*, *Pseudospondias microcarpa*, *Pycnanthus marchalianus*, *Raphia hookeri*, *R. laurentii*, *R. sese*, *Ricinodendron palustre*, *Sersalia palustre*, *Spondiathus preussii*, *Sterculia ambacensis*, *S. bequaertii*, *Symphonia globulifera*, *Syzygium gilletii*, *S. guineense*, *Treculia africana*, *Trichelia retusa*, *Uapoca guineensis*, *U. heudelotii*, *Uvaria laurentii*, *Uvariodendron mayumbense*, *Voacanga thouarsii*, *Xylopia aethiopica* and *X. rubescens*. Buttresses, stilt roots and pneumatophores are common. Understorey species are well developed only in clearings and along river banks and include *Cyrtosperma senegalense*, *Leptonychia batangensis*, *Marantochloa congensis*, *Sarcophrynium schweinfurthianum* and *Stipularia africana*, while the widespread climbers are *Artabotrys pynaertii*, *Calycolobus klaineanus*, species of *Memycylon*, *Popowia* and *Pouchetia*, and the lianoid palms *Ancistrophyllum*, *Calamus* and *Eremospatha*. Epiphytic ferns, orchids and Araceae are abundant. Palm swamps, dominated almost exclusively by *Raphia* spp., occur throughout Congo, and are common between papyrus swamps and swamp forests proper and also in fresh water areas at the back of the mangrove.

Temporarily inundated gallery forests in the southwest contain *Alchornea cordifolia*, *Caloncoba welwitschii*, *Carapa procera*, *Mitragyna stipulosa*, *Pycnanthus angolensis* and *Symphonia globulifera* among numerous other species. On some rivers, e.g. along parts of the Niari and around some of its associated lagoons, *Pandanus candelabrum* forms monospecific stands, and in the coastal plain swamp forests of *Anthostema aubryanum*, *Raphia hookeri*, *R. vinifera*, *Klainedoxa* sp., *Pandanus candelabrum*, *Phoenix reclinata* and *Symphonia globulifera* often lie behind, and grade into, tidal forests dominated by *Rhizophora racemosa*. Other mangrove species include *Avicennia africana*, *Chrysobalanus icaco*, *Conocarpus erecta*, *Dalbergia ecastaphyllum*, *Drepano- carpus lunatus*, *Rhizophora harrisonii* and *R. mangle*.

Wetland Fauna

Fishes: Over the 1190 km of the eastern and southern boundaries of Congo, the Oubangui/Congo River provides close to 535 000 ha of open water, and while the fish fauna of this stretch of water is known in broad terms, that of the other river systems in the country has not been investigated in any detail. The fishes of the Congo at Malebo Pool have been investigated (Poll, 1959), and studies have been carried out far upstream at Yangambi (0°47'N/24°24'E) in Zaire. Other studies have been made in Zaire at Lake Tumba opposite the confluence of the Oubangui and Congo Rivers and these, together with details of the hydrology of the river, are referred to in section 4.6. Many fish species move out of the rivers into the swamp forests of the Cuvette Congolaise during the two high water periods each year, and while the spectrum of these is likely to be similar to that at Yangambi, this has not been confirmed. Several species of *Clorias* have been identified in the Cuvette however, together with *Ctenopoma fasciolatum*, *Hemichromis* sp., *Polypterus palmus*, *Protopterus aethiopica* and *P. dolloi*, and all of these have been identified at Yangambi and at Malebo Pool. Other species found in the rivers include *Heterobranchus* spp., *Hepsetus odoe*, *Hydrocynus goliath*, *H. vittatus*, *Lates niloticus*,

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Malapterus electricus, shoaling species of *Microthrissa* and small open water species of *Barbus*.

Reptiles: Three crocodiles occur in Congo wetlands, *Crocodilus cataphractus*, *C. niloticus* and *Osteolaemus tetraspis*, also a water monitor, *Varanus niloticus*, and several aquatic or semi-aquatic snakes including *Boulengerina annulata*, *Natriciteres olivacea*, *Naja melanoleuca* (sometimes in lakes), *Philothamnus irregularis*, *Psammophis sibilans* and *Python sebae*. Arboreal species include *Dasypeltis fasciata*, *Dendroaspis* cf. *jamesonii*, *Thelotornis kirtlandii* and reputedly, *Thrasops occidentalis* (in the north). Terrapins, *Pelomedusa* sp. and *Pelusios subniger*, are also present.

Birds: The avifauna is rich and includes *Acrocephalus schoenobaenus*, *A. arundinaceus*, *Actitis hypoleucos*, *Anhinga rufa*, *Ardea purpurea*, *Ardeola ralloides*, *Botaurus stellaris*, *Calidris minuta*, *Ceryle rudis*, *Chlidonias leucoptera*, *Corythornis cristata*, *Eupodotis* spp., *Francolinus* spp., *Gallinago media*, *Glareola nordmanni*, *Haliaeetus vocifer*, *Ixobrychus minutus*, *Hirundo rustica*, *Larus fuscus*, *Megaceryle maxima*, *Motacilla flava*, *Nycticorax nycticorax*, *Pandion haliaetus*, *Phalacrocorax* spp., *Riparia riparia*, *Rhynchops flavirostris* and *Scotopelia peli*.

Mammals: The large mammals resident in, or visiting, Congo wetlands include *Cephalophus sylvicultor*, *Hippapotamus amphibius*, *Hyemoschus aquaticus*, *Hylachoerus meinertzhageni*, *Kobus ellipsiprymnus*, *Loxodonta africana africana*, *L. africana cyclotis*, *Phacochoerus aethiopicus*, *Potamochoerus porcus*, *Redunca redunca*, *Sylvicapra grimmia*, *Syncerus caffer nanus*, *Tragelaphus euryceros*, *T. scriptus* and *T. spekei*, with *Trichechus senegalensis* in the estuarine parts of rivers. Both *Gorilla gorilla* and *Pan troglodytes* have been observed in swamp forest during unflooded periods.

Smaller mammals which live in, or visit, the swamps, the flooded gallery forests and the riverbanks include *Aonyx congica*, *Atherurus africanus* (gallery forests), *Atilax paludinosus*, *Dasymys bentleyi* (herb swamps), *Felis aurata*, *Genetta tigrina*, *Herpestes ichneumon*, *H. naso*, *H. sanguineus*, *Lutra maculicollis*, *Manis gigantea* (gallery forests), *M. tetradactyla* (swamp forests), *Potamogale velox* and *Thryonomys* cf. *swinderianus* (papyrus swamps). Arboreal species in the palm and swamp forests include *Anomalurus beecrofti*, *Cercocebus albigena* (W Congo), *C. torquatus*, *Cercopithecus ascanius*, *C. cephus*, *C. neglectus*, *Colobus badius oustaleti*, *C. polykomos*, *Epixerus ebii*, *Funisciurus congicus*, *F. pyrrhopus*, *Galago demidovii*, *Heliosciurus rufobrachium*, *Nandinia binotata*, *Paraxerus poensis* and *Protoxerus stangeri*.

List of Wetlands Described

1. The Cuvette Congolaise
2. The Ivindo/Djoua Headwater Basin
3. The Dihésé Plain & Niari Valley
4. Wetlands of the Coastal Plain
5. Wetlands of the Lower Congo River

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1. The Cuvette Congolaise

Location: 3°34'N-3°30'S/15°30'-18°40'E
Area: 10 890 000 ha (wetland = c. 6 900 000 ha)
Altitude: 324-330 m asl
Nearest Towns: Brazzaville (285 km SSW); Gamboma; Impfondo

General: This vast area, which measures 700 km from north to south, is scarcely above river level and is virtually all wetland. It is inundated, either temporarily or permanently, from the Oubangui/Congo Rivers in the east to the low hills in the west, a distance of 220 km in places. Most of the area is covered by swamp forest, but broad belts of floating grasses occur in the middle of the forest along the courses of the Likouala aux Herbes and Likouala Rivers. An herbaceous swamp extends for 300 km up the Likouala aux Herbes River (a tributary of the Sangha River) in a continuous belt 10-20 km wide, and for 180 km up the Likouala River, in a narrower and discontinuous belt. Altogether these floating prairies cover close to 342 000 ha. Permanent swamp forests are well developed at several points along the west bank of the Congo River, between Liranga (0°43'S/17°32'E) and a point 2°07'S/16°15'E, opposite the town of Bolobo, in places where streams have deltaic confluences with the Congo. The largest of these deltas is that of the Alima River, but permanent swamp forests also occur behind the herbaceous swamps on the Likouala and Likouala aux Herbes Rivers, and in the north on the meandering Motaba and Mbongoumba Rivers, and also in small patches along many headwater streams along the western boundary of the cuvette. Temporarily inundated swamp forests fringe many of the rivers and cover the inter-riverine flats. Evergreen rain forests interdigitate with the swamp forests on narrow tongues of higher land extending out from the hills in the north, and also along levées and other higher land flanking the Oubangui and Sangha Rivers. In the south, patches of marshy savanna and boggy steppes form mosaics with each other and the temporarily inundated swamp forest, being prominent at the mouth of the Sangha River, and between the Alima and Kouyou Rivers.

Human Impact & Utilisation: The Cuvette is sparsely populated and mostly undeveloped. Pygmies live and hunt in the forests, but overall the wetlands are little disturbed. The Congo/Oubangui Rivers are navigable above Brazzaville and the river is the scene of much passenger and cargo traffic.

Conservation Status: A National Park, Odzala National Park, and the adjacent Reserves of Lekoli-Pandaka and M'Boko protect some 284 000 ha on rising land at the western extremity of the Cuvette, between the Mambili and Likouala Rivers. The area is relatively undisturbed and there is no tourism. Swamp forest occurs at the lowest levels, while hygrophilous *Andropogon* savanna occupies much of the higher area where there are also some salt pans. Lake Moba, a lake with conspicuously blue water, occurs in the National Park.

2. The Ivindo/Djoua Headwater Basin

Location: 1°00'-2°10'N/13°11'-14°26'E (in Congo)
Area: 1 000 000 ha (c. 330 000 ha wetland in Congo)
Altitude: 480-600 m asl
Nearest Towns: Souanké (10 km E); Brazzaville (650 km SSE)

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General: Swamp forests occur on several of the headwater tributaries of the Ivindo and Djoua Rivers in Congo, south of Souanké (2°03'N/14°09'E), but are best developed on the Karangoua, Ouaga and Ebaka Rivers. The former enters the Ivindo, and the last two the Djoua, some way above the confluence of these major streams (1°13'N/13°13'E), 473 m asl. The three major swamp forest blocks on these rivers all reach 15 km in width and over 50 km in length and cover a total of 205 000 ha. The individual blocks have areas of 50 000 ha (Karangoua), 90 000 ha (Ouaga) and 65 000 ha (Ebaka), and all comprise both permanent and temporarily inundated forests. Primary forest along the Djoua River, which forms the border with Gabon, is subject to inundation on both banks for a distance of more than 150 km above its confluence with the Ivindo. The flood may extend more than 25 km into the forest on both banks of the river, and it is estimated that there are at least 100 000 ha of swamp forest in Congo.

Human Impact & Utilisation: This area east of the Ivindo River and north of the Djoua River is very isolated. There are no proper roads to the area, which is very sparsely populated on both sides of the border, and the swamp forests are undisturbed.

Conservation Status: Unprotected.

3. The Dihésé Plain & Niari Valley

Location: 3°13'-4°00'S/12°25'-12°57'E
Area: 300 000 ha (c.60 000 ha permanent wetland)
Altitude: c. 100-200 m asl
Nearest Towns: Dolisé (50 km S); Brazzaville (300 km ESE)

General: Swamps of various types accompany several NW-SE oriented tributaries of the Kouilou River on the Plain of Dihésé. On the northern side of the plain the Gokango supports extensive swampy areas, but inundated lands are best developed between several minor streams which enter the Kouilou on its south bank in the centre of the plain, where they cover 50 000 ha, and along the lower course of the Niari River where it meanders along the eastern edge of the Plain. Here it flows in a narrow valley between the escarpment of the Massif du Chaillu and a low parallel ridge on the margin of the Dihésé Plain proper. A floodplain, up to 8 km wide, accompanies the river for a straight line distance of 43 km, but in this section the river bed is over 100 km long, so much does it meander. The floodplain covers about 26 000 ha, and the river channel is accompanied by intermittent patches of permanent swamp.

Swamp forests are found in galleries along all the rivers of the region, but papyrus occurs in inter-riverine situations in the central plain, south of the Kouilou River. In the far south, a large papyrus swamp, 56 km long and up to 9 km wide, oriented SE-NW, lies to the west of the Loma/Louila Rivers (4°17'-4°35'S/12°46'-13°13'E). Close by there are no less than a dozen large patches of evergreen forest on hydromorphic soils which are sometimes flooded. Some measure as much as 20x6 km, and all are oriented SE-NW along the axis of the Dihésé Plain. This area drains from its southern end, into the Loma and Louila Rivers, which flow into the Loudima River and thence to the Niari River, or from the northern end, via the Loubomo and Louvakou Rivers, directly to the Kouilou River.

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Human Impact & Utilisation: The many rivers and lagoons on the plain are fished by the local population, and hunting occurs on the wetland margins. The wetlands are otherwise little exploited.

Conservation Status: An important wetland area is afforded faunal protection in the Tsoulou Faunal Reserve. This covers 30 000 ha on the Dihésé Plain, including the confluences of the Kouilou River with the Niari and Léboulou Rivers. However, the reserve is not patrolled effectively and poaching is common. Apart from this reserve, wetlands on the plain are unprotected.

4. Wetlands of the Coastal Plain

Location: 3°39'-5°00'S/11°09'-12°22'E
Area: 900 000 ha (wetland)
Altitude: 0-80 m asl
Nearest Towns: Pointe Noire (on plain); Brazzaville (330 km E)

General: In the north, a strip of papyrus and *Raphia-Pandanus* swamp, several kilometres wide, extends across the border from Gabon, connecting the head of M'Banio Lagoon (3°46'S/11°10'E) in that country with Lake Tchibenda and Conkouati Lagoon. Immediately inland of this there are swamps on the Louboumou River centred at 3°48'S/11°55'-11°59'E.

From the Conkouati Estuary (4°00'S/11°15'E) to the Kouilou River mouth (4°29'S/11°43'E) the coast is of high relief, and an almost continuous belt of littoral steppes, 10-40 km wide, extends along the coastal hills. This is backed by littoral forest, but along the courses of the rivers, which have cut narrow valleys through the coastal hills, papyrus and palm-pandan swamps are well developed, with pockets of swamp forest on their fringes. Papyrus and palm-pandan swamps enclose the inland parts of Conkouati Lagoon, occupying some 35 000 ha behind the tidal forests. They also occur along stretches of the Noumbi and Loemé Rivers with blocks of 7000 and 27 500 ha respectively. Lakes Cayo (4°55'S/11°58'E) and Loufoualeba, on the Loemé River, are almost completely enclosed by pspyrus standa over 4 m high, as are Lakes Yangala (4°07'S/11°36'E) and Yaubi (4°11'S/11°40'E) on the Noumbi River. Swamps accompany the Loemé River upstream from Lake Cayo in a strip 4 km wide and 62 km long. However, the largest papyrus swamp covers a broad and roughly rectangular depression, measuring over 30x30 km, flooded by the Kouilou River and its tributaries the Loundji and Ntombo Rivers, centred at 4°22'S/11°55'E. This includes, on the north side of the Kouilou, Lakes Kobambi (4°10'S/11°45'E), Nanga (4°14'S/11°49'E) and Dinga (4°11'S/11°54'E), all enclosed by swamplands. In total this wetland block comprises approximately 95 000 ha, and the total area of papyrus or associated vegetation on the coastal plain is more than 160 000 ha.

A series of small lakes, some 4 km inland, at an altitude of 35 m asl, have rather diffuse drainage. Some have streams entering and draining them to the sea, others are situated in swamp areas and have no permanent watercourses associated with them, e.g. Lake Laufoumbau (4°19'S/11°35'E).

Tidal forests occur in all estuaries and in Conkouati Lagoon, grading into fresh water palm-pandan swamps, backed by papyrus or fresh water swamp forests. Tidal influence

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extends 10-30 km inland on several rivers. At the Kouilou River mouth the mangrove forests have bare mudflats in their centres.

Human Impact & Utilisation: Oil exploration has occurred all along the Congo littoral and production occurs both onshore and offshore, as a consequence of which some of the coastal lagoons are now polluted by petroleum wastes, e.g. Loubi (Djeno) Lagoon. In the north, Conkouati Lagoon has been used for many years for the export of timber which is brought to a jetty at the head of the lagoon for shipment. The littoral forests are still being felled throughout the coastal region. In the south, there is a timber export point on Lake Cayo. The human population is locally quite dense, but the wetlands are comparatively little exploited, except that they are fished and reeds are used for thatching. Some mangrove forest has been cleared in forestry operations, and mangrove timber has been widely used for fuel.

Conservation Status: Unprotected. Conkouati Lagoon and the associated Lakes Kiroka, Tchibenda and Tchimba and much surrounding wetland are situated in the Conkouati Faunal Reserve, which in theory afforded protection for the wildlife from May 1980, but in effect, due to lack of enforcement, has had little impact.

5. Wetlands of the Lower Congo River

General: Wetlands have a restricted distribution on the Congolese bank of this river in its lower course. Above Malebo Pool, still strictly part of its middle course, the river is confined between hills on both banks and it is deep, c.30 m, and swift flowing. It broadens at Malebo Pool where the current slows to some 5 km/hr, and here, apart from the large central M'Bamou Island, there are several minor islands on the north side of the Pool in Congo. Rather more than half of M'Bamou Island, on its northern side, is covered by aquatic grassland which is inundated for much of the year. At high water the grasses either float, or emerge a few centimetres above the water. This aquatic prairie which is 18 km long and possibly 6 km wide at maximum, covers about 6500 ha. It is backed on the southern side by mesophile forest some of which is subject to periodic inundation. The small islands in the Pool are also flooded and support similar vegetation. Downstream of Malebo Pool, various hygrophilic associations occur, but they are not very extensive and are described in section 4.6, Zaire.

Human Impact & Utilisation: The aquatic prairies of Malebo Pool are undisturbed.

Conservation Status: Unprotected.

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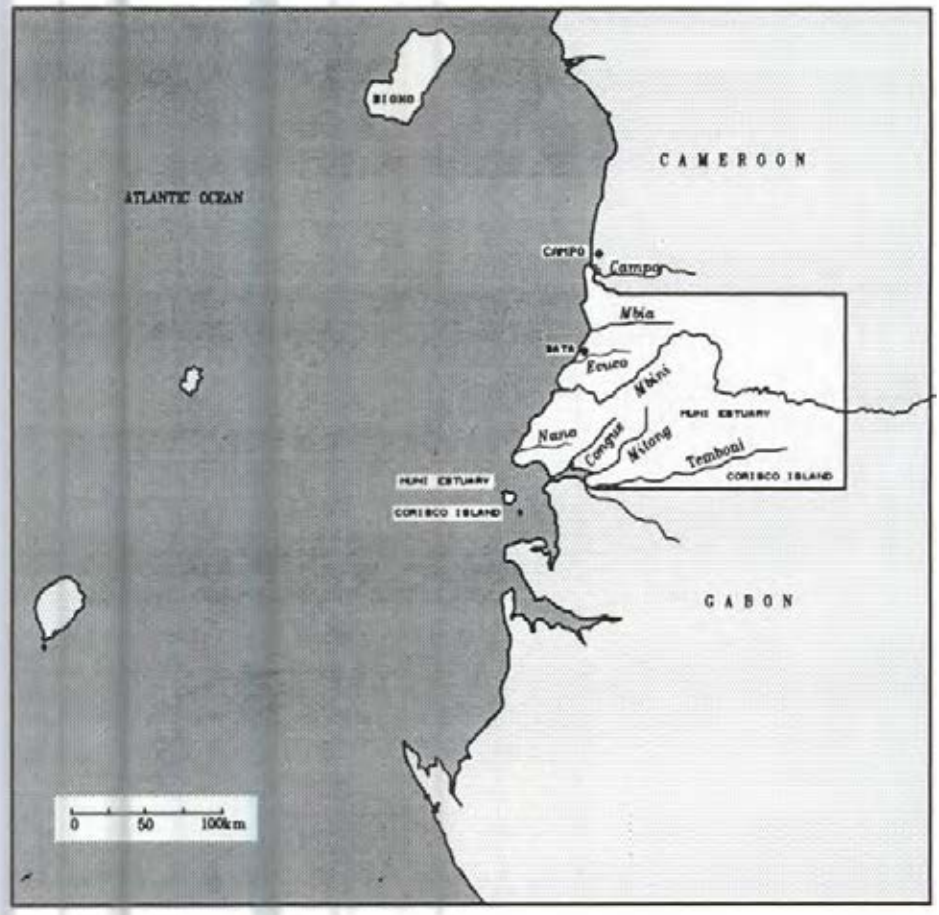

Map of Equatorial Guinea

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4.4 EQUATORIAL GUINEA

Introduction

Equatorial Guinea occupies 28 050 km^2; it has a population of 304 000 (1983 census) and a mean population density of 10.8 persons/km^2. It comprises a mainland enclave, Rio Muni, bounded by Gabon in the south and east, Cameroon in the north, and the Atlantic Ocean in the west, and several islands. These are the island of Bioko (Fernando Póo) in the Bight of Biafra (3°12'-3°47'N/8°25'-8°56'E); the oceanic island of Annobón (Pagalu) (1°25'S/5°36'E), 645 km SW of Bioko at the end of the same SW-NE volcanic ridge; and several offshore islands including Corisco o Mandyi (0°55'N/9°19'E) and the Elobey Islands (0°59'N/9°36'E).

The mainland territory has a coastline 265 km long with three major indentations; the estuary of the Campo (Ntem) River on the northern border, the estuary of the Mbini (San Benito) River in the centre, and the estuary of the Muni River on the southern border. The enclave extends from 0°56'- 2°22'N and from 9°24'-11°24'E. In the south the beaches are backed by low cliffs and there is a narrow coastal plain, some 15-20 km wide, which rises steeply to the peaks of a range of coastal mountains, with a high point of 1200 m asl at Mt. Mitra (1°21'N/9°59'E) in the south. The land falls again, immediately to the east of the mountains, but then rises steadily to a dissected plateau over 500 m asl, which covers most of the interior. The highest point, 1500 m asl at Mt. Fijelvingue, is reached on the central seaward face of this plateau (1°49'N/10°26'E). The plateau, which forms an extension of the Monts du Cristal in Gabon, is dissected by the trenches of the three main rivers, the Temboni which enters the Muni Estuary, the Mbini in the centre and the Campo in the north.

The volcanic island of Bioko is 67 km long, has a maximum width of 40 km and an area of 213 060 ha. It rises to high points of 3106 m asl at the Peak of Santa Isabel (3°35'N/8°47'E) in the north, and 2662 m asl on the rim of the great Caldera of San Carlos (3°21'N/8°37'E) in the south. Here the internal crater walls fall steeply for 1680 m to a plateau floor at an elevation of 982 m asl. There are two crater lakes in the Gran Caldera range, Lakes Claret and Loreto. Not far to the north, Mt. Biao (3°26'N/8°46'E) rises to 2009 m asl, with another lake in its crater, 1938 m asl. Slopes are steep all around Bioko and the narrow beaches are mostly backed by little cliffs, some 20 m high.

Annobón Island is also volcanic, comprising a jumble of volcanic cones, the central high point being 655 m asl at Mt. Santa Mina. It is 6.5 km long, covers 1700 ha, and supports a lumbering and fishing industry. The rectangular offshore island of Corisco o Mandyi has an area of some 1500 km. It is 5 km long and reaches a maximum width of 4 km with no prominent high points, but because of the very high rainfall, c. 3600 mm/yr, it has numerous small streams, the largest of which are the Rio Gueliba, 1.5 km long in the northwest, the Arroyo Mbandya, 1 km long in the west, and the Rio Lembue, 2.5 km long in the south. The islands of Elobey and Elobi are much smaller, measuring 2000x1000 m and 800x200 m respectively.

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Climate

The Río Muni enclave enjoys an equatorial climate, but with enhanced precipitation levels during February-June and September-December. Along the coast, rainfall is higher in the south than in the north, with an extra wet pocket centred on the Río Muni Estuary. Mean annual falls are always in excess of 3000 mm at the coast, but approach 4000 mm towards the southern border and at Calatrava (1°06'N/9°28'E) on the north side of the Río Muni Estuary, annual receipts are often over 4500 mm. Precipitation declines progressively on passing inland and is 1800 mm/yr at the eastern border. Mean annual temperatures are close to 26°C with little annual variation, and relative humidity is always high ranging from 80-94%.

Rainfall over Bioko is very variable because of the relief, with the highest recordings being made on the slopes of the Gran Caldera Range in the south of the island where the SW monsoon is intercepted. Annual receipts of 11 430 mm (450 inches) have been recorded at the town of Ureka (3°17'N/8°32'E), which thus ranks among the three wettest places known in the world. The skies over the island are almost always overcast and mean annual temperatures around the coast are close to 25°C, with absolute maxima and minima of 34°C and 17°C.

Wetlands

Because of the intensity of the rainfall several hundred minor streams, 1-2 km long, reach the coast, and at their mouths there are usually small mangrove stands. However, the coast of Río Muni, being of high relief and subject to high wave energy, is not conducive to the accumulation of sediment. The extensive development of mangroves is therefore confined to the three major estuaries.

Mangrove stands begin 1 km up the estuary of the Campo River, and extend inland for a distance of 15 km, in belts 500-2500 m wide. Here tidal forests have an area of 1800 ha. To the south a small (150 ha) block of mangroves occurs at the mouth of the Mbia River, which enters the sea at 2°04'N and yet farther south, at 1°56'N, another small tidal swamp occurs at the mouth of the Ecuco (Ekuko) River. This extends upstream for 8 km, past the confluence of the Ué and Utondé Rivers, and covers about 1000 ha. At a point 1°43'N/9°43'E, just inland of the coast, a non-tidal swamp occurs on the Boara River, covering 300 ha.

In the Mbini Estuary (1°35'N), mangroves are best developed on the south bank tributaries the Mangala and Mitambo Rivers. Again, the mangrove stands begin some 1.5-2.0 km inland of the estuary mouth, and extend upstream for over 20 km. They occur in four major blocks. The first occupies a crescent on the south bank, with an estuary frontage of 12 km, and depths of 2.5 km. The second reaches 10 km, down the Mitambo River, in a belt up to 3.5 km wide. Small scattered stands occur on the north bank, opposite these major blocks. The third important block extends upstream from the mouth of the Mitambo River, on both banks of the estuary for 6 km, and the fourth block extends perpendicularly away from the estuary, oriented due N-S, up two tributaries which enter opposite each other 20 km from the sea. The northern tributary is the Ngabe River but the southern stream is unnamed. Shortly above this double confluence, the Mbini ceases

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to be tidal, and its course is riven with rapids. In total there are approximately 5300 ha of tidal forest on the Mbini Estuary.

A small patch of mangroves, covering 85 ha, occurs at the mouth of the little Nano River on the north side of Cape San Juan, the most westerly point in Río Muni. Here the mangroves grow on a sandy substratum, and are on the lee shore of the cape. On the stretch of coast between this point and the Muni Estuary small mangrove stands occur at the mouths of the Udinga (1°08'N) and Mbindo (1°07'N) Rivers.

The Muni Estuary is the combined estuary of several rivers, the most important being the Congu, Mitong and Temboni (Utamboni, Mtemboni). The estuary is 2 km wide over much of its length, and mangroves extend from just inside the mouth to the head of the estuary, 17 km inland, and also up the tributary rivers. They reach 13 km up the Utamboni River, 8 km up the Mitong and 12.5 km up the Congué River. There are about 6500 ha of tidal forest on the estuary, and some extensive patches of freshwater swamp forest behind this. Freshwater swamps are best developed in the southernmost extremity of Río Muni, between the Miteinele River, itself a tributary of the Utamboni River, and the head of the Muni Estuary. Along the former stream, and to the north of it, there are some 800 ha of palm-pandan and freshwater tree swamps. Inland in Río Muni, there are several small isolated permanent swamps on the interior plateau, e.g. those situated at 1°12'N/10°54'E near the village of Nkoro (620 m asl); 1°35'N/11°11'E near the village of Anzem (612 m asl); and 2°16'N/10°44'E near the village of Ngoa in a bend of the Campo River (340 m asl). Each of these occupies about 300 ha.

There is little coastal plain on Bioko. Streams tumble down deep ravines to the sea, but in the SE, the River Muchuchumuano has formed a small swampy delta (1.5x1 km) in the Bay of Conception (3°23'N/8°47'E). Another swampy area occurs 5 km to the NE at Punta Caracas. Mangroves occur at these places, and at several other sites including the Bay of San Carlos on the west coast. Inland are the three crater lakes previously mentioned.

There is a chain of small lakes (Lakes Bodungüe, Ucatí and Abela) on the Lembue River in the centre of the island of Corisco o Mandyi, and mangroves occur at the mouths of most, if not all of the little streams there. The largest patch covers 24 ha at the mouth of the Lembue River near the town of Gobe. Small strips of swampy woodland occur inland on some of the small streams. There are no important wetlands on the island of Annobón.

Wetland Flora

All the typical West African tidal forest species have been collected on the coast of Río Muni. *Rhizophora racemosa* and *Avicennia africana* dominate the more seaward areas with *Acrostichum aureum, Laguncularia racemosa*, and *Rhizophora harrisonii* in brackish to freshwater sites, and *Caesalpinia bonduc, Carapa procera, Conocarpus erecta, Dalbergia ecastaphyllum, Dodonaea viscosa, Drepanocarpus lunatus, Laguncularia racemosa, Ormocarpum verrucosum* and *Ternstroemia africana* in less frequently inundated zones on the dry fringes.

Sea grasses occur on the mudflats prior to their colonisation by *Rhizophora racemosa*, which is almost always the seaward pioneer. The height of the canopy rises in passing landwards from the seaward face, until a zone of mature *Rhizophora* forest is reached.

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Here the canopy may be more than 30 m high. This high mangrove forest occupies belts up to 500 m wide in the Muni Estuary.

Hibiscus tiliaceus often appears on sandy banks along rivers, in brackish sites, where it forms dense groves, sometimes with *Avicennia africana* as an associate. Both *Avicennia africana* and *Rhizophora mangle* extend into freshwater tidal swamps. There is virtually no understorey in the mangrove forests, but *Acrostichum aureum* occurs in clearings in the upper tidal reaches, and may fill them with dense vegetation up to 2 m high. *Schizolegnia ensifolia* is another terrestrial fern found in the less deeply flooded parts of mangrove swamps. The epiflora of the mangroves is well developed in the Muni Estuary and is quite prolific on Bioko, where *Nephrolepis biserrata* and *Platycerium stemaria* are common epiphytic ferns and *Bulbophyllum falcipetalum, Cyrtorchis aschersonii, Genyorchis pumila, Polystachya* sp., and *Tridactyle anthomaniaca* are epiphytic orchids. However, *Nephrolepis biserrata* grows terrestrially in the mangroves of Bioko, its fronds reaching 2 m in height.

Chrysobalanus sp., *Cynometra mannii, Crudia klainei, Manilkara obovata, Phoenix reclinata* and *Oxystigma mannii* occur on levées and in the wet fringes of tidal swamps in Río Muni, in transitions to littoral forest. In transitions to palm swamps, which back much of the mangrove forest around the Muni Estuary, *Rhizophora mangle*, and sometimes *R. harrisonii*, occurs with *Pandanus candelabrum, Phoenix reclinata* and *Raphia palmapinus*. These swamps grade, upstream and inland, into pure *Raphia* palm swamps, with *R. regalis* and *R. laurentii*, which are often rendered impenetrable by the development of spiny climbing palms belonging to the genera *Ancistrophyllum* and *Eremospatha*. In their turn the palm swamps grade into freshwater swamp forests.

The flora of permanent and seasonally inundated forests, including gallery forests, is rich, and varies from place to place. The commonest species include *Albizia zygia, Alstonia boonei, Anopyxis klaineana, Anthocleista liebrechtsiana, A. nobilis, Anthonotha pynaertii, Anubias affinis, Baikaea insignis, Berlinia grandiflora, B. sapinii, Berteria laurentii, Bridelia ripicola, Carapa procera, Ceiba thonningii, Chrysobalanus atocarensis, Coelocaryon botryoides, Coffea congensis, Cola attiensis, Dacryodes edulis, Dialium pachyphyllum, Dichaetanthera africana, D. strigosa, Dichostemma glaucescens, Elaeis guineensis, Entandrophragma palustre, Eriocoelum microspermum, Ficus mucoso, Gambeya africana, Garcinia smeathmannii, Gilbertiodendron dewevrei, Gluema ivorensis, Guibourtia demeusei, Hymenocardia heudelotii, Irvingia grandiflora, Lasiodiscus marmoratus, L. mannii, Mallotus oppositifolius, Mimusops warneckei, Mitragyna ciliata, Nauclea diderrichii, N. pobeguinii, Octolobus heteromus, Oubanguia africana, Paramacrolobium coeruleum, Parinari glabra, Pseudospondias microcarpa, Pycnanthus marchalianus, Raphia hookeri, R. laurentii, Sersalia palustre, Spondiathus preussii, Sterculia bequaertii, Symphonia globulifera, Synsepalum dulcificum, Uapoca guineensis, U. heudelotii, Uvaria laurentii, Uvariodendron mayumbense, Wildemaniodoxa laurentii, Ventilago africana, Voacanga thouarsii* and *Xylopia staudtii*.

Cyrtosperma senegalense and *Marantochloa* spp. are common in the understorey adjacent to clearings or under a broken canopy, together with several terrestrial ferns including *Adiantum vogellii, Asplenium diplazisorum A. variabile, Bolbitis auriculata, Diplazium proliferum, Lonchitis currori, Lygodium microphyllum, Nephrolepis biserrata, Pteris mildbraedii, P. marginata* and *Tectaria angelicifolia*.

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Lianes, including *Artabotrys* spp., *Ancistrophyllum secundiflorum*, *Donella welwitschii*, *Eremospatha haullevilleana* and *Landolphia* spp. are locally abundant, and the well developed epiflora is dominated by ferns and orchids. Common species include *Lomariopsis palustris*, *Platycerium angolense*, *P. stemaria*, *Nephrolepis biserrata*, *Selaginella* spp., and *Trichomanes erosum*.

Calm shady pools may be covered by *Azolla africana*, *Lemna paucicosta*, *Pistia stratiotes* and *Salvinia nymphellula*, but these species also occur on the backwaters of some rivers. *Ceratopteris cornuta* and *Impatiens irvingii* grow in the water around the banks of ponds, lakes and slow flowing rivers, with *Impatiens gossweileri*, *I. hians*, *I. niamniamensis* and *Lycopodium cernuum* at higher drier levels. *Cyathea manniana* occurs in swampy depressions and may be found around forest pools and along streams. *Nymphaea* spp. are dominant on quiet waters open to the sunlight and in these situations *Ceratophyllum demersum* and species of *Najas* and *Potamogeton* form dense submerged beds.

Wetland Fauna

Fishes: The fish fauna of the swamps and rivers has not been reported, but it includes most of the widespread West African species of *Alestes*, *Auchenoglanis*, *Bagrus*, *Barbus*, *Channa*, *Chrysichthys*, *Citharinus*, *Clarias*, *Distichodus*, *Eutropius*, *Gnathonemus*, *Hemichromis*, *Hepsetus*, *Heterobranchus*, *Hydrocynus*, *Labeo*, *Marcusenius*, *Mormyrus*, *Mormyrops*, *Polypterus*, *Schilbe*, *Synodontis*, *Tetraodon* and *Tilapia*.

Reptiles: *Crocodylus cataphractus*, *C. nilaticus* and *Varanus niloticus* occur in the upstream swamps throughout Rio Muni, together with species of *Pelomedusa* and *Pelusios*. Among the snakes *Boulengerina annulata*, *Naja melanoleuca*, *Natriciteres olivacea*, *Philothamnus irregularis*, and *Python sebae* are widespread aquatic or semi-aquatic species, while *Dasypeltis fasciata*, *Dendroaspis jamesonii*, *Philothamnus semivariegatus*, *Thelotornis kirtlandii* and *Thrasops occidentalis* are arboreal in swamp and flooded gallery forests.

Birds: The avifauna includes several species which prey upon squirrels and monkeys, e.g. *Hieraaetus spilogaster*, *Stephanoaetus coronatus* and *Urotriorchis macrourus*, also numerous piscivorous species such as *Ceryle rudis*, *Haliaeetus vocifer*, *Lorus fuscus*, *Megaceryle maxima*, *Pandion haliaetus*, *Pelecanus onocrotalus*, *Rynchops flavirostris* and *Scotopelia peli*. There are also ducks, geese, herons, ibises, storks, egrets and bitterns. Other species, including several weavers, are abundant in the palm and pandan swamps.

Mammals: Small mammals found in the wetlands include *Aonyx capensis* (including the mangroves), *Atilax paludinosus*, *Atherurus africanus* (gallery forests), *Genetta tigrina* (palm swamps), *Herpestes ichneumon*, *H. naso* (temporarily inundated forests), *H. sanguineus* (gallery forest), *Lutra maculicollis*, *Otomys* cf. *angoniensis*, *Potamogale velox*, *Thryonomys gregorianus* and *Viverra civetta* (gallery forests). Larger mammals resident in the wetlands, or which visit them regularly, include *Cephalophus callipygus*, *C. dorsalis*, *C. leucogaster*, *C. monticola*, *C. nigrifrons*, *C. sylvicultor*, *Felis aurata*, *Hyemoschus aquaticus*, *Loxodonta africana cyclotis*, *Manis tetradactyla*, *Panthera pardus*, *Phacochoerus aethiopicus*, *Potamochoerus porcus*, *Syncerus caffer nanus*,

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Tragelaphus scriptus, *T. spekei* and *Trichechus senegalensis* (mangrove estuaries and large rivers). *Gorilla gorilla* and *Pan troglodytes* are thought to visit flooded forests along rivers in the interior.

Arboreal mammals in the wetlands include *Anomalurus beecrofti*, *A. derbianus*, *A. pusillus*, *Aonyx capensis*, *Cercocebus albigena albigena*, *Cercopithecus cephus cephus*, *Colobus polykomos satanas*, *Dendrohyrax arboreus* (gallery forests), *Epixerus ebii*, *Funisciurus lemniscatus*, *F. pyrrhopus* (including mangroves), *Galago demidovii*, *Heliosciurus rufobrachium*, *Idiurus macrotis*, *Miopithecus talapoin* (including mangroves), *Myosciurus pumilio*, *Nandinia binotata* (gallery forests), *Paraxerus poensis*, *Poinana richardsoni*, *Protoxerus stangeri* and *Zenkerella insignis*.

Species in Bioko include *Anomalurus beecrofii*, *A. derbianus*, *Atherurus africanus*, *Cercopithecus l'hoesti insularis*, *C. pogonias*, *Cephalophus monticola*, *C. ogilbyi*, *Cercocebus torquatus*, *Colobus badius*, *C. pennanti*, *C. polykomos satanas*, *Dendrohyrax arboreus*, *Funisciurus leucogenys*, *Galago demidovii*, *Genetta tigrina*, *Manis tricuspis*, *Miopithecus talapoin* (introduced), *Myosciurus pumilio*, *Nandinia binotata*, *Paraxerus poensis*, *Poiana richardsoni* and *Protoxerus stangeri*.

Human Impact & Utilisation: Río Muni reverted to a subsistence economy after achieving independence, but there have been attempts to revive lumbering and plantation farming. However, the country has few interior wetlands, and those it does have are little disturbed. At the coast, the mangroves also have suffered little depradation. Traditionally they have been exploited for firewood and building materials.

Conservation Status: No part of the country is protected. It appears that the reserves created under the colonial administration prior to 1970 have been abandoned.

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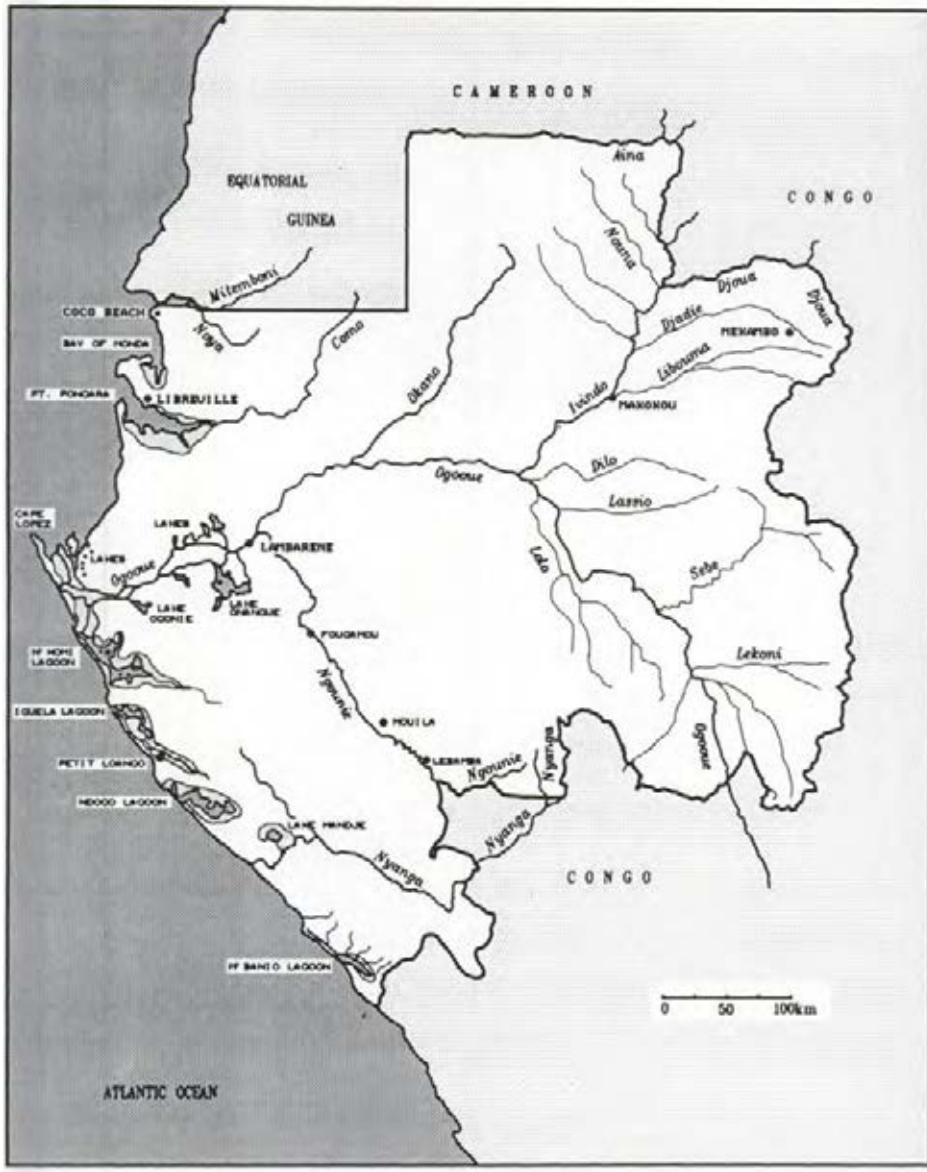

Map of Gabon

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4.5 GABON

Introduction

Gabon has an area of 267 665 km^2, a population of 1 292 000 and a population density of 4.8 persons/km^2. It is bounded by Equatorial Guinea and Cameroon in the north, by Congo in the east and south, and by the Atlantic Ocean in the west. The northern, eastern and western borders are in hills at elevations of 500-700 m asl, and by far the greatest part of the country drains towards the centre, into the Ogooué River and thence to the Atlantic Ocean. However, in the extreme northwest, the Nye and Ntem Rivers flow into Cameroon and the Woleu River flows into Equatorial Guinea. All the way down the coast little streams, draining the coastal hills, flow directly to the sea across the coastal plain. In the southeast the Nyanga River rises in the Moukandé Mountains and flows south into Congo, then in an arc back into Gabon, where it enters a deep trough running SE-NW between the highlands of the Massif du Chaillu and the Koungou Mountains. This latter range it breaches, in a narrow valley, to reach the sea. The highest point in the country is Mt. Iboundji (1°06'S/11°48'E), 1575 m asl in the Moukandé Mountains, and only in the immediate vicinity of this peak does land rise above the 1000 m contour.

Gabon straddles the equator between latitudes 2°17'N and 3°57'S, but the coastline extends only from 1°00'N to 3°57'S. Although this is a straight line distance of 545 km, the coastline is highly indented and exceeds 1460 km in length. The short northern strip of coast is 'set back' and sheltered, but from Cape Lopez (0°37'S/8°45'E) southwards, coastal form is dictated by a powerful northward longshore drift. Most of the central and southern coast is sandy and of low relief, and river mouths have been deflected northwards behind long sandspits, each of which subtends a large lagoon, the principal ones, from north to south, being N'Komi, Iguéla, Ndogo and M'Banio.

Climate

Mean annual precipitation at the coast decreases from north to south. It is over 3500 mm at Cocobeach on the northern border, 2645 mm at Libreville, 1768 mm at Mayumba and about 1650 mm at the southern border. In the far north rainfall is almost aseasonal, but in the south most of the rain falls during the 8 months from October to May. Here the June-September period is almost rainless and insolation is correspondingly higher. Rainfall decreases and then increases again, in passing inland. The high borderlands in the north receive mean annual falls in excess of 1700 mm, but this increases to 2000 mm on the eastern border and to more than 2200 mm in a wet pocket in the southeast around Franceville (1°40'S/13°31'E). However, rainfall is still seasonal, July is the driest month, and the town of Franceville, which is situated in a valley, receives only 1890 mm/yr.

The mean annual temperature is close to 26°C along the coast, but with little monthly fluctuation in the north and increasing seasonal variation towards the south. At Mayumba (3°23'S/10°38'E) for example, where the climate is distinctly seasonal, the warmest month is March, with a mean maximum temperature of 30°C, a mean minimum temperature of 23°C, and a mean monthly temperature of 27°C. By contrast, in July, the coolest month, the corresponding figures are 26, 18.5 and 22°C.

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Wetlands

Because of the longshore drift river mouths are deflected northwards behind sandy spits, and tidal forests are well developed below the 'elbows' where the rivers turn north. From these sites of northward deflection low lying areas extend southeastwards, down the coast, immediately to landward of the beach. Mangroves are more extensive on the south banks of rivers than on the north banks. The flow of water in the Ogooué River is so great that a mass of fresh water backs up behind the tide, and fresh water tidal areas occur upstream, which are forested by a community distinct from that which occupies the saline areas downstream. Tidal (mangrove) forests occur in all estuaries, bays and lagoons along the coast. An IUCN report (Saenger *et al.*, 1983) suggests that there are 250 000 ha of 'mangrove' forest on the coast, but this could well be an underestimate, and refers only to forests dominated by *Rhizophora* and *Avicennia*. The total area of tidal forest, in its broadest sense, is probably in excess of 350 000 ha. Numerous shallow lakes, fringed by extensive swamps, occur on the coastal plain, and there are other deeper lakes at the lower ends of valleys where the Ogooué traverses the coast range. A large area of swamp forest, still in pristine condition, is situated in the headwater basins of the Ivindo and Djoua Rivers, and swamps accompany the Ogooué River for almost its entire course. The valleys of the Nyanga and Ngounié Rivers are also swampy.

Wetland Flora

All the typical West African tidal forest species have been collected on the Gabonese coast, with two species of *Rhizophora* (*R. harrisonii* and *R. racemosa*) and *Avicennia africana* dominating the more seaward areas, and *Acrostichum aureum*, *Caesalpinia bonduc*, *Conocarpus erecta*, *Dalbergia ecastaphyllum*, *Dodonaea viscosa*, *Drepanocarpus lunatus*, *Heteropterys leona*, *Laguncularia racemosa*, *Ormocarpum verrucosum*, *Rhopalopilia marquesii* and *Ternstroemia africana* in less frequently inundated zones, and in the dry fringes.

Sea grasses occur on the mudflats prior to their colonisation by *Rhizophora racemosa* which is almost always the seaward pioneer. Stands on rapidly prograding shores are usually size-graded, with the forest canopy ascending smoothly away from the sea until a zone of mature *Rhizophora* forest is reached, where the canopy may be more than 30 m high. This high mangrove forest occupies belts up to 700 m wide in the Bay of Cape Lopez. *Nypa fruticans* was introduced to West Africa at the turn of the century, and became established in Cameroon and has been reported from Gabon. Another Indo-Pacific strand species, that occurs naturally in mangroves in Madagascar, *Calophyllum inophyllum*, has also become naturalised in West Africa and is reputedly present in Gabon.

Hibiscus tiliaceus often appears on sandy banks along rivers, in brackish sites, where it forms dense groves, sometimes with *Avicennia africana* as an associate. *Afrosersalisia afzelii*, *Aucoumea klaineana*, *Lecomtedoxa nogo*, *Manilkara lacera*, *Sideroxylon mayumbense* and *Synsepalum congolense* are common on lagoon margins and often occur in the fringes of mangroves. Both *Avicennia africana* and *Rhizophora harrisonii* extend into fresh water tidal swamps. There is virtually no understorey in the mangrove forests, but *Acrostichum aureum* occurs in clearings in the upper tidal reaches, and may

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fill them with dense vegetation up to 2 m high. *Schizolegnia ensifolia* is another terrestrial fern found in the less deeply flooded parts of mangrove swamps, and *Nephrolepis biserrata* and *Platycerium stemaria* are common epiphytes. The lagoon grasses, *Anadelphia* spp., also occur in the fringes of mangroves in the brackish areas of deltas, estuaries and lagoons.

Chrysobalanus sp., *Cynometra mannii*, *Crudia klainei*, *Manilkara obovata*, *Phoenix reclinata* and *Oxystigma mannii* occur on levées and in the wet fringes of tidal swamps, in transitions to non-tidal swamp forest. In transitions to palm swamps, *Rhizophora harrisonii* occurs with *Pandanus candelabrum*, *Phoenix reclinata* and *Raphia hookeri*. These swamps grade, upstream and inland, into pure *Raphia* palm swamps, which are often rendered impenetrable by the prolific development of lianoid palms belonging to *Ancistrophyllum*, *Calamus* and *Eremospatha*. Palm swamps, or 'raphiales' as they are known, frequently grade into fresh water swamp forest.

The flora of permanently and seasonally inundated forests, including gallery forests, is rich, and is very variable from place to place. The commonest species include *Albizia zygia*, *Alstonia boonei*, *A. congensis*, *Anopyxis klaineana*, *Anthocleista liebrechtsiana*, *A. nobilis*, *Anthonotha pynaertii*, *Anubias affinis*, *Aucoumea klaineana*, *Baikaea insignis*, *Berlinia bruneelii*, *B. grandiflora*, *B. sapinii*, *Berteria laurentii*, *Brazzea congoensis*, *Bridelia macrantha*, *B. ripicola*, *Ceiba thonningii*, *Chrysobalanus atocorensis*, *Coelocaryon botryoides*, *Coffea congensis*, *Cola attiensis*, *C. lepidota*, *Crotonogyne giorgii*, *C. paggei*, *Dacryodes edulis*, *Dialium pachyphyllum*, *Dichaetanthera africana*, *D. strigosa*, *Dichostemma glaucescens*, *Elaeis guineensis*, *Entandrophragma palustre*, *Eriocoelum microspermum*, *Ficus mucoso*, *Gambeya africana*, *G. subnuda*, *Garcinia smeathmannii*, *Gilbertiodendron dewevrei*, *Gluema ivorensis*, *Guibourtia demeusii*, *Hymenocardia heudelotii*, *Irvingia grandiflora*, *I. smithii*, *Lannea welwitschii*, *Lasiodiscus marmoratus*, *L. mannii*, *Mallotus oppositifolius*, *Mimusops warneckei*, *Mitragyna ciliata*, *M. stipulosa*, *Monopetalanthus pteridophyllus*, *Nauclea diderrichii*, *N. pobeguinii*, *Octolabus heteromus*, *Oubanguia africana*, *Paramacrolobium coeruleum*, *Parinari congensis*, *P. glabra*, *Pseudospondias microcarpa*, *Pycnanthus marchalianus*, *Raphia hookeri*, *R. laurentii*, *R. sese*, *Ricinodendron palustre*, *Sersalia polustre*, *Spondiathus preussii*, *Sterculia ambacensis*, *S. bequaertii*, *Symphonia globulifera*, *Synsepalum dulcificum*, *Syzygium gilletii*, *S. guineense*, *Treculia africana*, *Trichelia retusa*, *Uapaca guineensis*, *U. heudelotii*, *Uvaria laurentii*, *Uvariodendron mayumbense*, *Wildemaniodoxa laurentii*, *Ventilago africana*, *Voacanga thouarsii*, *Xylopia aethiopica*, *X. rubescens* and *X. staudtii*.

Buttresses, loop roots, stilt roots and erect pneumatophores are common in the swamp forests, and undergrowth is scant except in clearings and along watercourses. *Cyrtosperma senegalense* and *Marantochloa* spp. are common in these situations, as are several terrestrial ferns, among them *Adiantum vogellii*, *Asplenium diplazisorum* (raphiales), *A. variabile*, *Bolbitis auriculata*, *Diplazium proliferum* (raphiales), *Lonchitis currori*, *Lygodium microphyllum*, *Nephrolepis biserrata*, *Pteris mildbraedii* (raphiales), *P. marginata* and *Tectaria angelicifolia* (raphiales). *Leea guineensis* forms straggling woody thickets, supported by prop roots, in open spaces, and *Bequaertiodendron magalismontanum* occurs as an occasional small tree which develops knee roots in streamside

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situations under a broken canopy (it also grows on the Drakensberg Mountains in Swaziland and South Africa).

Lianes, including *Artabotrys* spp., *Ancistrophyllum secundiflorum*, *Donella welwitschii*, *Eremospatha haullevilleana* and *Landolphia* spp., are locally abundant, and the well developed epiflora is dominated by ferns and orchids. Common species include *Lomariopsis palustris*, *Platycerium angolense*, *P. stemaria*, *Nephrolepis biserrata*, *Selaginella* spp. and *Trichomanes erosum*.

Forest pools may be covered by *Azolla africana*, *Lemna paucicosta*, *Pistia stratiotes* and *Salvinia nymphellula*, but these species also occur in backwaters of the Ogooué and other rivers. *Ceratopteris cornuta* and *Impatiens irvingii* grow in the water around the banks of ponds, lakes and slow flowing rivers, with *Impatiens gossweileri*, *I. hians*, *I. niamniamensis* and *Lycopodium cernuum* at higher drier levels. *Cyathea manniana* occurs in swampy depressions and may be found around forest pools and along streams. *Nymphaea* spp. are dominant on quiet waters open to the sunlight, and in these situations *Ceratophyllum demersum* and species of *Najas* and *Potamogeton* form dense submerged beds.

Cyathea camerooniana lines watercourses in the highlands, and *Cyperus papyrus* dominates some swamps in the upper valleys of streams and also occurs on the coastal plain, with lower growing associates such as *Cyclosorus striatus* and *Vossia cuspidata*. In the south, there are areas of short marshy littoral steppes dominated by *Loudetia simplex* with *Bulbostylis laniceps* and *Rhytachne rottboellioides*.

Wetland Fauna

Fishes: The fish faunas of the majority of the rivers have not been reported in detail, but that of the Ogooué is known to include species with either West African or Zaire Basin affinities. *Gymnarchus niloticus* and *Protopterus annectens* occur in seasonally flooded areas, and species of *Alestes*, *Auchenoglanis*, *Bagrus*, *Barbus*, *Channa*, *Chrysichthys*, *Citharinus*, *Clarias*, *Distichodus*, *Eutropius*, *Gnathonemus*, *Hemichromis*, *Hepsetus*, *Heterobranchus*, *Hydrocynus*, *Labeo*, *Marcusenius*, *Mormyrus*, *Mormyrops*, *Polypterus*, *Schilbe*, *Synodontis*, *Tetraodon* and *Tilapia* occur in the lakes and rivers. The fishes of the Ivindo Basin have been described by Gery (1965).

Reptiles: *Crocodylus cataphractus*, *C. niloticus* and *Varanus niloticus* occur in the upstream swamps throughout coastal Gabon, together with species of *Pelomedusa* and *Pelusios*. The African dwarf crocodile, *Osteolaemus tetraspis* also occurs locally, e.g. in the coastal swamps around Ndogo Lagoon. Among the snakes *Boulengerina annulata*, *Naja melanoleuca*, *Natriciteres olivacea*, *Philothamnus irregularis* and *Python sebae* are widespread aquatic or semi-aquatic species, while *Psammophis sibilans* inhabits herb swamps and wet grasslands, and *Dasypeltis fasciata*, *Dendroaspis jamesonii*, *Philothamnus semivariegatus*, *Thelotornis kirtlandii* and *Thrasops occidentalis* (N only) are arboreal in swamp and flooded gallery forests.

Birds: The avifauna includes several species which prey upon squirrels and monkeys, e.g. *Hieraaetus spilogaster*, *Stephanoaetus coronatus* and *Urotriorchis macrourus*, also numerous piscivorous species such as *Ceryle rudis*, *Haliaeetus vocifer*, *Larus fuscus*, *Megaceryle maxima*, *Pandion haliaetus*, *Pelecanus onocrotalus*, *Rynchops flavirostris*

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and *Scotopelia peli*. There are also ducks, geese, herons, ibises, storks, egrets and bitterns. Other species, including several weavers, are abundant in the palm, pandan and papyrus swamps.

Mammals: Small mammals found in the wetlands include *Aonyx capensis* (including mangroves), *A. congica*, *Atherurus africanus* (gallery forests), *Atilax paludinosus*, *Dasymys bentleyi* (herb swamps), *Genetta tigrina* (palm and papyrus), *Herpestes ichneumon*, *H. naso* (temporarily inundated forests), *H. sanguineus* (gallery forest), *Lutra maculicollis*, *Otomys* cf. *angoniensis*, *Potamogale velox*, *Thryonomys gregorianus*, *T. swinderianus* (herb swamps) and *Viverra civetta* (gallery forests). Larger mammals resident in the wetlands, or which visit them regularly include *Cephalophus callipygus*, *C. dorsalis*, *C. leucogaster*, *C. monticola*, *C. nigrifrons*, *C. sylvicultor*, *Felis aurata*, *Hippopotamus amphibius*, *Hyemoschus aquaticus*, *Loxodonta africana cyclotis*, *Manis gigantea* (N only), *Manis tetradactyla*, *Panthera pardus*, *Phacochoerus aethiopicus*, *Potamochoerus porcus*, *Syncerus caffer nanus*, *Tragelaphus scriptus*, *T. spekei* and *Trichechus senegalensis* (mangrove estuaries and large rivers). *Kobus ellipsiprymnus* is reported by some authorities and both *Gorilla gorilla* and *Pan troglodytes* are thought to visit temporarily flooded forests.

Arboreal mammals comprise *Anomalurus beecrofti*, *A. derbianus*, *A. pusillus*, *Cercocebus albigena albigena*, *Cercopithecus cephus cephus*, *C. neglectus* (E only), *Colobus polykomos satanas*, *Dendrohyrax arboreus* (gallery forests), *Epixerus ebii*, *Funisciurus lemniscatus*, *F. pyrrhopus* (including mangroves), *Galogo demidovii*, *Heliosciurus rufobrachium*, *Idiurus macrotis*, *Miopithecus talapoin* (including mangroves), *Myosciurus pumilio*, *Nandinia binotata* (gallery forests), *Paraxerus poensis*, *Poinana richardsoni*, *Protoxerus stangeri* and *Zenkerella insignis*.

List of Wetlands Described

1. Wetlands of the Coastal Plain
2. Wetlands of the Ivindo River Headwater Basin
3. Wetlands of the Upper Ogooué Valley
4. Wetlands of the Ngounié River

1. Wetlands of the Coastal Plain

Location: 1°00'-3°57'S/9°15'-11°19'E
Area: 2 975 000 ha (650 000 ha wetland)
Altitude: 0-100 m asl
Nearest Towns: Libreville; Mayumba (both on Plain)

General: At the coast, the Mitemboni River marks the northern boundary and a few kilometres from its mouth it is joined on the Gabonese bank by a short tributary, the Noya, which meanders for some 40 km across a flat coastal plain. Tidal swamps exist at the Mitemboni River mouth, and upstream and along the Noya River for many kilometres, covering some 3 000 ha, but from Pointe Bini, just to the south, the coast is at first sandy and runs due south for 31 km to the Bay of Monda. Low hills run parallel to the coast with a watershed 22 km inland, reaching a maximum altitude of 210 m asl. Many

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small streams flow down from these hills, across the narrow coastal plain which is mostly covered by evergreen rain forest. The short streams terminate in a diffuse pattern of channels at the coast between latitudes 0°48'-0°35'N, where there is a tidal swamp some 1.5 km wide and 22 km long. At its northern end the swamp extends inland behind the sandy coastal dunes, and here the mangrove forest has a transition to dune forest on the seaward side and grades into swampy rain forest on the landward side.

Farther south, mangrove forests occupy all the shores of the Bay of Monda (0°38'N/9°33'E) in a wide belt which extends inland for 18-22 km up the estuaries of the Ayondo River, and several other streams which enter the head of the bay. Altogether there are close to 17 400 ha of tidal swamp in the bay. The city of Libreville (0°24'N/9°27'E) is situated on the seaward side of the sandspit that forms the outer arm of Monda Bay, facing southwest towards Pt. Pongara across the mouth of the Gabon Estuary. Several streams enter this broad estuary and mangrove forests fringe its entire shoreline. On the northern side they form a belt 1-2 km wide and over 44 km long, but they stretch for almost 90 km along the concave southern shore, reaching inland for up to 21 km in huge blocks in those areas watered by tributary streams. There are approximately 45 200 ha of tidal forest here, backed on the southern side by rain forest or fresh water swamp forest, and again the mangrove canopy exceeds 30 m in height.

The rather rugged and indented coast, with a densely forested hinterland, continues south from Pt. Pongara to the Bay of Cape Lopez (Nazare) at latitude 0°37'S. Small indentations support minor mangrove stands, and the coast is backed by dense littoral forest grading into swamp forest or wet savanna inland. The Bay of Cape Lopez is protected on its seaward, western, side by the sandspit of Cape Lopez, and is filled with mangroves on vast alluvial mudbanks produced at the mouths of some distributaries of the Ogooué River. This tidal forest forms a continuous block 22 km wide and 28 km deep between the sea and the land, broken only by the courses of distributary streams. The bay contains over 61 600 ha of tidal forest.

On the landward, eastern, shore of the bay, the coastal plain is dotted with little lakes, many receiving inputs from one or more streams, but having no canalised outflow in most cases, while others are arranged in chains along indistinct drainage lines. In this region, densely forested coastal hills, which reach 245 m in height, approach to within 12 km of the coast. They drain to the sea via these little lakes through everchanging watercourses in the sandy substratum. The lakes are enclosed by permanent swamplands, and in the hills behind, at altitudes up to 200 m, there are other small endorheic crater lakes, the largest measuring 2x1.5 km.

The main course of the Ogooué River passes south of the Bay of Cape Lopez to another part of its delta on the coast. Here it discharges through its main channel and several tributaries, reaching the sea behind a sandy barrier island. Alluvium from the river is swept northwards up the coast, contributing to the spit of Cape Lopez. To the south, fresh spits are continuously extending northwards from below the delta, slowly growing across its face before detaching from the mainland at their bases and becoming barrier islands. These continue to move north. Eventually they join or are dispersed along earlier northward spits if they catch them. The present barrier island is some 4 km wide and 55 km long with a N-S channel 7 km wide between it and the delta face. On the south bank of the principal mouth of the Ogooué a block of tidal forest covers 14 000 ha,

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backed by a block of palm and *Pandanus* swamp of equivalent area, while upstream, on both banks, there are large areas that are regularly inundated by a combination of tides and fresh water floods. In total, swamplands occupy 109 400 ha, some 55% of which are forested, while 45% support herbaceous cover, with local, but very small, areas of bare mudflat.

On either side of the Ogooué River, backing the floodplain, there is a series of lakes. These abut a line of low hills, rising to 80 m asl, which the Ogooué traverses in a valley about 30 km wide. The lakes on the northern side extend far up tributary valleys into the hills so that they have the highly indented shapes so characteristic of flooded valleys. Along this bank of the Ogooué most of the lakes have direct connection with the river. They are, in passing upstream, Lakes Iwandé, Ingoyo, Gomé, Logé, Ntchonié, Igouloué, Akombié, Nkomié and Ogonobié. Lake Gomé is nearly 17 km long with a mean width of 2 km. On the south bank the river drains Lakes Ogonié, Auanga and Onangué, the latter being the largest group with a maximum width of 25 km and a length of 30 km. Swamps occur in patches around the shores of the north bank lakes and may continue up valleys into the hills in tracts several kilometres wide and up to 17 km long. These valley swamps reach elevations of 45 m asl. There is however, far more swampy land around the lakes on the south bank and this supports palm-pandan swamps and swamp forest. The Ogooué flows in multiple channels between the delta and its confluence with the Ngounié River at Lambarene (0°42'S/10°16'E) some 150 km inland. A broad floodplain accompanies it throughout this stretch and much of the land between the river channels, which in places are 18 km apart, is subject to periodic inundation.

The Ogooué Delta extends over a whole degree of latitude between 0°38'S at Pt. Fetiche in the Bay of Cape Lopez, to 1°37'S where the southernmost distributary discharges near the mouth of N'Komi (Fernan Vaz) Lagoon, the next most southerly lagoon. The lagoon covers an area of 31 500 ha and has large areas of forested tidal swamp on its periphery. The swamps are best developed at the head of the lagoon where the River Rembo N'Komi enters and a large tidal area extends back upstream for some 20 km. 10 000 ha of tidal swamp and forest occur in this region.

From N'Komi Lagoon to Igúela (N'Gové) Lagoon the beaches are low, sandy and backed by littoral forest festooned with climbers. Igúela Lagoon is again fringed by mangrove forests which are in their turn backed by areas of freshwater swampland. Just south of Igúela Lagoon is the small stranded and very swampy Gamba Lagoon. From this place swamps extend SE along the course of the N'Gové River, a coastal stream, which rises inland of Petit Loango (2°15'S/9°40'E), a small village on the coast. This little riverine swamp covers 16 000 ha, and stretches 20 km along the stream, almost parallel to the coast.

Farther south, the large island studded Ndogo (N'Dogau) Lagoon opens from the coast with a channel which branches northwards to the smaller Sounga Lagoon. Ndogo Lagoon has an open water area in excess of 50 000 ha and measures 42 km in length with a mean width of 12 km, excluding the entrance channel which is 1 km wide and 14 km long. The lagoon margin is highly indented and together with the islands is very largely fringed by mangrove forests. These are best developed at the northern and southern ends of the lagoon and along the eastern, landward, shore. Mangroves also fringe much of Sounga Lagoon.

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A sandy coast reaches south from Ndogo Lagoon, with parallel sandy ridges separating swampy swales. Numerous small lagoons open to the coast in this sector, and most are continuously fringed by mangrove forests, grading into fresh water swamps at their heads where little streams flow in. Inland, moist savanna woodlands occupy the parallel ridges. Still further inland, 19 km from the coast, is Lake Mandjé (Cachimba), a rectangular expanse of water 12x6 km (2°50'S/10°22'E). The lake is almost completely surrounded by 17 400 ha of permanent swamps, except along parts of the western shore. The swamps reach south to the Nyanga River, with which the lake appears to have no permanent open connection, but into which it drains in diffuse fashion.

Hills rise 14 km east of Lake Mandjé (36 km from the coast) and are drained by the Nyanga River which rises in the Massif de Chaillu in Congo. This river has 11 sets of rapids. The first is just 26 km from the sea in a straight line, but extends 62 km upstream. In its lower reaches the river meanders and is flanked by broad swamps grading from fresh water tidal to salt water tidal in passing downstream. The largest swamp covering 39 780 ha, is continuous along the south bank for 14 km near the river mouth, and reaches 36 km in depth. Numerous small streams flow into the swamp from hills which rise abruptly to 160 m asl along its eastern flank, and there are several small islands of dry land in it, which support dense littoral forest.

In proceeding farther south, the Koungou Mountains attain heights of over 600 m asl, and approach to within 11 km of the long sandy coast. In this southernmost section of the Gabonese coast, Lagoon M'Banio, extends SE for 80 km from the town of Mayumba (3°26'S/10°38'E), situated near the end of the long spit which separates the lagoon from the sea. The mountains and hinterland are densely forested, while the coastal strip supports swamps, moist savannas and large patches of high forest. Many small streams run down from the mountains, reaching the sea to the north of M'Banio Lagoon, e.g. the Boumé Boumé Rivulet, but most enter the lagoon along its eastern shore, e.g. the Louzibi, Djaungou and N'Douma Rivers. These streams all support tidal forest at their mouths and swamp forest upstream. The head of M'Banio Lagoon is situated 16 km inland and is completely fringed by tall swamp forests which are traversed by a road from an inland timber collection point to an export point on the lagoon.

Human Impact & Utilisation: Major centres of population, e.g. Libreville, Port Gentil and Mayumba, are situated on the coastal sandspits, away from the swampy mosquito infested coastal lowlands. Timber has traditionally been the basis of the national economy, and has been brought from interior collection sites to jetties constructed on the landward sides of all the major lagoons, from where it is taken to Libreville or Port Gentil for export overseas. The principal species exploited have been *Aucoumea klaineana* (a tree of swampy depressions), *Chlorophora excelsa* and *Terminalia superba*. Oil exploration is proceeding along the coast, both in the coastal strip and offshore, and a pipeline reaches 100 km north from the present centre of extraction to Port Gentil. The indigenous population of the Coastal Plain is sparse and there are no metalled roads, only forestry roads. The main road linking Libreville with Pointe Noire in Congo runs through the Ngounié Valley well inland, and the only road leaving this for the coast goes to Mayumba. All traffic to Port Gentil is by sea. The many lakes along the Ogooué River, and the rivers themselves, are fished quite intensively.

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Conservation Status: Two major coastal areas are protected. An area midway between Libreville and Port Gentil comprises the National Park of Wonga Wongué (55 000 ha) and an associated hunting reserve (330 000 ha). Farther south, 100 000 ha in the Moukalaba Faunal Reserve is intended for total protection, but is at present, still subject to some residual forestry leases. It is contiguous with the Petit Loango Faunal Reserve of 80 000 ha, and together these areas may be combined as the Petit Loango National Park, which will then extend from the head of Igúela Lagoon to the mouth of Ndogo Lagoon. All these protected areas have extensive open sea frontages and all extend inland over the flat or gently undulating coastal plain. All include areas of coastal wetland, including lakes, herb, palm and tree swamps, although no large mangrove area is included. It is not yet clear whether any lagoon shore will be included.

2. Wetlands of the Ivindo River Headwater Basin

Location: 0°00'-2°00'N/12°00'-14°16'E
Area: 3 630 000 ha (c. 432 000 ha wetland, i.e. 12% landsurface)
Altitude: 200-650 m asl
Nearest Towns: Makokou (in basin); Libreville (350 km W)

General: In the highest part of the basin, the Aïna (Ayina) River meanders along the border with Cameroon, flowing due east and descending from 557 to 543 m asl, largely in one rapids section. An extensive block of swamp forest occurs along the river, centred at 2°15'N/13°05'E. At 13°17'E the river swings southwards, forming the border with Congo, and from this point a floodplain extends along its entire length, reaching an average width of 2 km in Gabon before the river traverses a narrower valley between Misséke Mountain in Congo and the Kokamégue Mountains in Gabon. Immediately south of this point, at an altitude of 495 m asl, the river is known as the Ivindo. At an altitude of 492 m asl (1°45'N), the river flows through a series of channels and the floodplain broadens to 5 km on either bank. Permanent swamps and forested floodplains occur along the tributaries, e.g. the Bémvoula River which joins the Ivindo at 1°35'N. All these periodically flooded plains are covered by dense undisturbed swamp forest, with isolated depressions containing permanently flooded forest.

The principal headwater tributary, the Djoua River, flowing westwards along the Congolese border, descends the Eyoa Rapids and joins the Ivindo at an altitude of 473 m asl, just above the town of Mvadi (1°11'N/13°11'E). Above the rapids a seasonally flooded area follows the Djoua for 120 km to the east. At first the flood extends 5-10 km into Gabon, but between longitudes 13°30'-14°00'E it spreads 30 km southwards away from the Djoua River, contracting again upstream. There are at least 210 000 ha of swamp forest on the Djoua River in Gabon.

A floodplain follows the Ivindo 75 km southwestwards from Mvadi to its confluence with the Djadié (Zadié) River, where it merges with the Djadié Floodplain. This latter floodplain extends upstream from the confluence and is well developed north of latitude 1°N. It extends for 175 km upstream, in a strip 2-5 km wide, reaching an altitude of 521 m asl near the head of the valley. The town of Makambo (1°03'N/13°49'E) is surrounded by wetlands and there are some 55 000 ha of swamp forest along this river. All the other tributaries, e.g. the Nouma and Sing Rivers, also have narrow floodplains.

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From the Ivindo/Djadié confluence to the meeting of the Ivindo and Ogooué Rivers, 135 km SW, the Ivindo is mostly slow flowing and again has a floodplain, although this is often only a few kilometres wide. The total wetland area in the basin, including permanent and temporarily inundated forests, and areas of *Raphia* and papyrus along some rivers, probably exceeds 400 000 ha.

Human Impact & Utilisation: The upper part of the basin is very sparsely inhabited. There are no roads and the forests are virtually undisturbed. However, in the lower basin seasonal roads link the town of Makokou with several other centres, and the forests have been exploited for timber locally.

Conservation Status: A small area, c. 15 000 ha, on the banks of the lower Ivindo River, centred on 0°31'N/12°48'E, 15 km from the town of Makokou, is protected in the Ipassa-Makokou Strict Nature Reserve. A large part of the area is situated on riverine alluvium and is densely forested. No less than 2000 plant species have been collected from the Reserve and its resident animals include the drill, *Mandrillus sphinx*. All the valleys of the basin are densely forested and little disturbed, while the upper ones, e.g. that of the Djoua River, are in pristine condition, but are unprotected.

3. Wetlands of the Upper Ogooué Valley

Location: 0°00'-2°00'S/12°00'-14°00'E
Area: 2 986 875 ha (between 200-500 m asl)
Altitude: 200-500 m asl
Nearest Towns: Franceville (in head of valley); Libreville (350 km ESE)

General: The Ogooué River rises in Congo and flows into Gabon over a wide flat valley floor over 500 m asl, descending at the waterfall of Poubara (1°45'S/13°33'E) into a broad upper valley at about 470 m asl. From here the river flows northwestwards for 600 km, to a point just south of the equator. Here it swings west, descends below the 200 m contour, receives the Dilo and Ivindo Rivers, and passes over a series of six waterfalls and rapids in an 80 km section before reaching the coastal plain. A forested floodplain with large pockets of permanent swamp accompanies the river throughout most of the upper valley.

Immediately below the Poubara Falls, the valley broadens and in a roughly rectangular area (1°07'-1°44'S/13°15'-13°38'E), covered by 20 anastomosing rivers, the Ogooué receives 10 tributaries. The most important of these are, from south to north, the Mpasa, Lebombi, Lékédi, Lékati and Lékoni Rivers. The floor of this valley is flooded periodically between the many watercourses, creating a semi-continuous wetland area covering 144 000 ha. North of the confluence with the Lékoni River, the Ogooué enters a much narrower valley, into which the Sébé River descends over a series of 6 falls, and where the current is much swifter, and the accompanying floodplain much narrower. However, the valley widens again close to the parallel 1°S, and from here to 0°05'S, where it turns west, the river flows in a wide bed over a broad floodplain. To the west, a major tributary, the Lolo River, flows in parallel for much of this distance, and permanent swamps and floodplain extend in places across all the intervening land. The two rivers approach to within 5 km of each other and then diverge around some elevated land before reaching

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a confluence at a point 0°19'S/12°20'E. In this latter part of the valley wetlands cover a total of some 162 000 ha. The entire upper valley floor is forested.

Human Impact & Utilisation: The Ogooué Valley is the main communication route between Libreville and the interior of Gabon. It carries a main road and railway line, both of which terminate at Franceville, and several towns have developed along the railway. Another railway connects the head of the valley at Franceville, to Pointe Noire and Brazzaville in Congo. The forests of the valley have been intensively exploited, the timber being taken to Libreville and Congo by road and rail. The valley is thus comparatively densely populated and the rivers and swamps are fished heavily.

Conservation Status: The Lope-Okanda Reserves straddle the Ogooué River towards the lower northern end of the valley. The river separates the two sections, but it is intended to redesignate both as one National Park. The total protected area amounts to about 500 000 ha, and includes the river bed and a substantial area of floodplain and swamp. At present the protected area comprises a conservation park, a faunal reserve and a hunting reserve. Precise details of the boundaries are not available.

4. Wetlands of the Ngounié River

Location: 0°42'-2°14'S/10°16'-11°31'E
Area: 450 000 ha (lower valley floor); c. 250 000 ha wetland
Altitude: 30-100 m asl
Nearest Towns: Lambarene (on river); Libreville (150 km NE)

General: The Ngounié River rises on the southern slopes of the Birougoo Mountains at a point 2°04'S/12°12'E, and flows south and then west for 60 km, over which distance it forms the border with Congo. At its confluence with the Polo River it turns northwest, leaving Congo, and after descending 3 waterfalls develops a floodplain in its 220 km long valley between the parallel ranges of the Moukandé Mountains and the Massif du Chaillu. The Ngounié is a lowland stream almost throughout. It descends below the 100 m contour at the head of its valley, and meanders for 400 km over the valley floor before joining the Ogooué just above Lambarene (0°42'S/10°16'E), still 150 km from the sea. The floodplain is best developed in two sections; from Lébamba (2°14'S/11°31'E) to Mouila (1°51'S/11°01'E), and from just above Fougamou (1°17'S/10°35'E) to the Ogooué at Lambarene. Estimates of the total area of flooded land in the valley vary between 150 000 - 300 000 ha, but 150 000 ha appears to be a very conservative figure.

Human Impact & Utilisation: A main road connecting Libreville and Lambarene with Pointe Noire and Brazzaville runs through the valley and there are a number of small centres of population on the road throughout the length of the valley. The area has been exploited for its timber, which is shipped from Libreville or Pointe Noire. The valley is densely forested, although there is much secondary forest. The swamp forests have been little exploited compared with unflooded forests and the land which is regularly flooded has not yet been cleared for agriculture on any scale.

Conservation Status: Unprotected.

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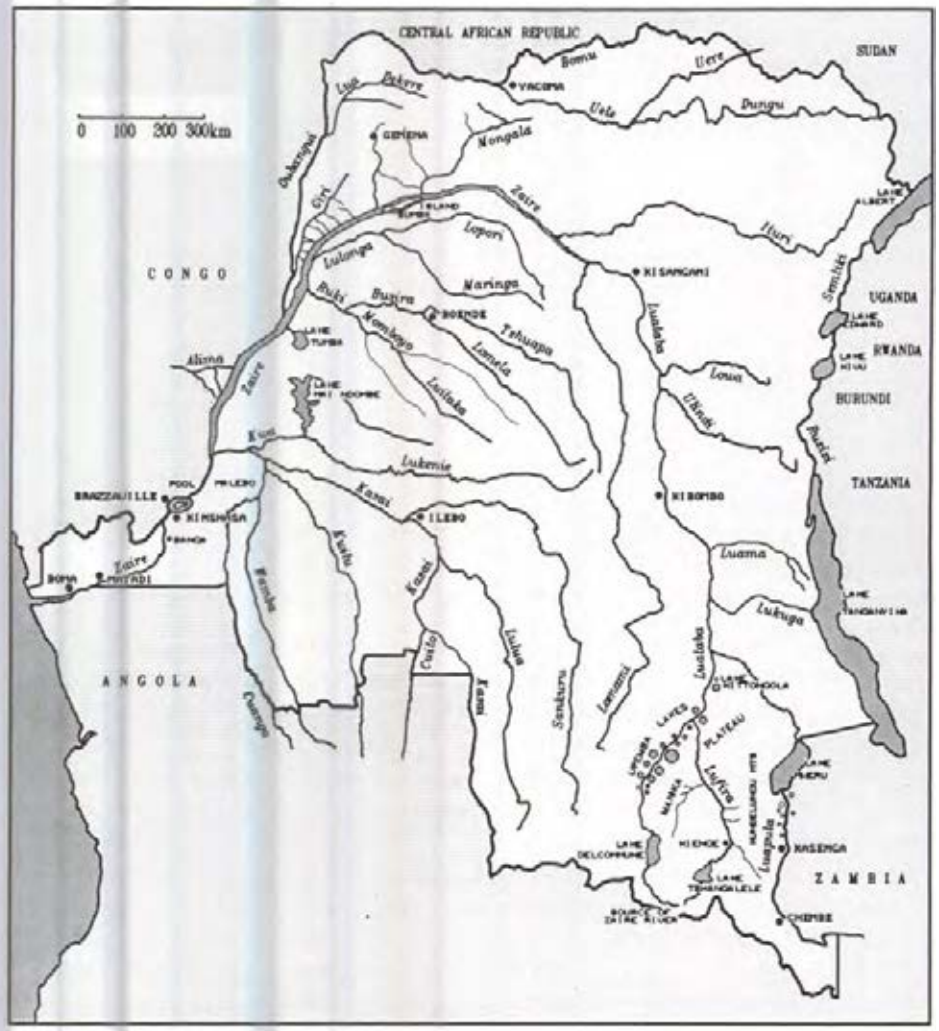

Map of Zaire

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4.6 ZAIRE

Introduction

Zaire is the third largest country in Africa, after Sudan and Algeria, and the fourth most populous. With an area of 2 345 410 km^2, and 33 944 000 people (1983), it has the comparatively high population density of 13.6 persons/km^2. It lies across the equator, reaching 13°25'S in the southeastern extremity, and 5°23'N in a bend of the Bomu River on the northern frontier. It is bounded by Angola in the southwest, Zambia in the south, Tanzania, Burundi, Rwanda and Uganda in the east, Sudan and The Central African Republic in the north, and Congo and the Cabinda enclave of Angola in the west. It is has an Atlantic coastline of 40 km at the mouth of the Zaire River, between Angola and Cabinda, and extends some 2099 km from east to west and 2062 km from north to south.

The eastern border is mountainous, all the way from Zambia to Uganda. The mountains of Shaba (Katanga) Province in the extreme SE rise to 1889 m asl at Mt. Kiapulka, and along the western side of Lake Tanganyika the Mungila Mountains rise to more than 2000 m in several places. Beginning at the northern end of this lake the Mitumba Mountains run north to Uganda, reaching over 3000 m asl near Uvira (3°24'S/29°05'E) and along the western shore of Lake Kivu, while to the north of this lake they reach 4507 m asl at Mt. Karisimbi (1°31'S/29°27'E) and 3645 m asl at Mt. Sabinyo (1°23'S/29°36'E). This same chain again rises above 3000 m asl near Lubero (0°16'S/29°45' and 0°10'S/29°40'E) and to a maximum elevation of 5110 m asl at Mt. Stanley (0°24'N/29°55'E). Mt. Aburo (2°01'N/30°50'E), at 2437 m asl, is the highest point at the northern end of the chain. Along this border, which follows the western rim of the Great Rift Valley, there are large areas of very high land. In the vicinity of Mt. Stanley alone, 35 000 ha rise above 3000 m asl, and along the entire mountain chain, a total of more than 4 275 000 ha lies above 1500 m asl. The southern and northern borders of Zaire are situated on elevated plateaux which slope gently towards the interior, but with numerous scarps so that almost all rivers flowing off the plateaux to the central depression traverse several waterfalls or rapids. The southern plateau reaches heights of 1500 m asl on the Zambian border, but mostly lies between 500 and 1100 m asl, while the northern plateau is 500-700 m asl.

A lake occupied the central depression of the Zaire Basin during the Pliocene, and the present effluent stream, the lower Zaire River, arose when a coastal river cut back to capture the lake water before the end of that epoch. The lake was thus drained, but a large swampy and seasonally flooded area now occupies the western, lowest, part of the basin. Here Lakes Tumba and Mai Ndombe may be regarded as remnants of the huge Pliocene lake. Although during the dry phases of the Pleistocene the vegetation of the Zaire Basin was drastically altered, the river system has persisted with comparatively little change throughout the Quartemary, and indeed the entire Zaire Basin has been characterised by environmental stability over very long time periods, which in concert with the wide range of habitats it provides has favoured speciation. Thus 669 species of fish have been described from the river system, of which 558 are endemic, and it may well be that before zoological exploration is complete, over a 1000 fish species will be identified. Almost equally remarkable are the 22 different freshwater crabs (Potamonidae) so far described.

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More than 90% of Zaire drains to the Zaire River. The two principal Zairean headwater streams of this river, the Lualaba and Lufira, rise in Shaba in the southeast, close to the Zambian border at the points 11°52'S/26°25'E (Lualaba) and 11°52'S/26°52'E (Lufira). The Zaire River is called the Lualaba in its upper course, and at first flows north, then west and south, crossing the equator twice in a great arc as it traverses a vast swampy basin over 1050 km from east to west and up to 850 km from north to south. Here, and extending into the neighbouring state of Congo, over 65 000 000 ha of very flat lowland lies between the 300 and 500 m contours in an ancient depression. This depression was invaded by the sea during the Mesozoic, subsequent to which its basin-like nature has been emphasized by persistent subsidence at the centre and compensatory uplifting of the margins, so that now, at the western extremity, the Zaire River traverses the low rim on its way to the sea. It flows through a gorge some 360 km long and containing no less than 32 rapids, between Kinshasa (4°18'S/15°18'E) and Matadi (5°50'S/15°52'E), descending in this section, from 307 m to 3 m asl. From the last rapids to the Atlantic Ocean is a distance of about 150 km, and the river is tidal for the last 95 km. Even below Matadi it flows through narrow gorges, and where it enters the ocean its bed occupies a deeply graven submarine canyon. Only in the northeast is there a part of Zaire which does not drain to the Zaire River. Here, on the border with Uganda, some short streams enter the Nile Basin via Lake Edward, the Semliki River and Lake Albert.

Climate

Rain falls over the central basin throughout the year, but is more seasonal on the borders. A broad per-humid belt extends inland along the equator from the Atlantic coast, over Gabon, across Congo and into Zaire. Throughout this belt, which reaches 3°40'S, but only 1°N, mean annual rainfall exceeds 1800 mm. In its central section a vast area around Boende (0°15'S/20°51'E) receives more than 2000 mm. In the east another vast area, mainly south of the equator, extending into the basin from the mountains of Rwanda and Burundi, also receives mean annual falls in excess of 2000 mm, while the western slopes of the mountains near Bukavu (2°30'S/28°50'E) receive up to 2800 mm. Mean annual rainfall at Kisangani (= Stanleyville, 0°32'N/25°14'E) at the eastern end of the Zaire Basin, 415 m asl, and just north of the equatorial rainbelt proper, is 1703 mm. October is the wettest month with falls of over 200 mm, while December, January and February are the driest months. Mean monthly rainfall at Kisangani in January is 50 mm. However, 110 km to the south, Ubundu (0°24'S/25°30'E) receives over 1800 mm/yr, and 215 km SE, Lubutu (0°45'S/26°37'E) receives over 2000 mm with no distinctly dry months.

There is cloud cover over the equatorial region for much of the year and incident solar radiation is lowest there. It is less than 130 Kcal/cm^2/yr in a zone extending from the coast inland over the western part of the central basin, including Kinshasa, Lake Mai Ndombe and the entire courses of the Lukenie and Lokoro Rivers. At the far eastern side of the basin Lubutu receives 140 Kcal/cm^2/yr and the mountainous border with Rwanda and Burundi about 150 Kcal/cm^2/yr. Radiation increases progressively away from this equatorial cloudy zone towards the borders, north and south. Thus at the far end of the basin Kisangani and Kibombo (3°58'S/25°54'E) both have mean annual receipts of 145 Kcal/cm^2. Along the northern border Bangui (4°23'N/18°37'E), Mobayi-Mbongo (4°21'N/21°10'E), Bondo (3°47'N/23°50'E) and Bambesa (3°25'N/25°43'E) receive

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165-170 Kcal/cm^2/yr. In the southeast the central part of Lake Tanganyika, and Lake Mweru, both have mean annual receipts of 170 Kcal/cm^2, while farther west the Upemba Lakes (8°37'S/26°24'E) receive 166 Kcal/cm^2/yr, and the southern central border with Angola 145-155 Kcal/cm^2/yr.

Sunshine follows a slightly different pattern. The coast receives 1700 hours/yr, decreasing up the Zaire Estuary to 1300 hours/yr at Matadi. From here passing inland, sunshine increases to 1650 hours at Kinshasa and 2000 hours/yr at the western end of the interior basin. Most of the basin and the northern borderlands receive this same level of sunshine, i.e. 5.6 hours/day, but there is an increase southwards to maximum levels of 2600 hours/yr at Lakes Mweru and Upemba, while the rest of the southern borderlands receive 2300-2500 hours/yr. Relative humidity follows a similar pattern to insolation and precipitation, with a large central area astride the equator having a mean annual RH of over 85%, decreasing to 80% along the northern border and 70-75% on the eastern and southern borders. Only the Shaba Plateau in the extreme SE experiences mean annual RH values below 70%.

As might be expected from the foregoing, mean annual temperatures vary little over the central parts of Zaire. Most of the country experiences a mean annual temperature of 24°C, with an area south of the equator, centred on Lake Mai Ndombe, having a mean figure of 25°C. The coastal sector is cooler, c. 23°C, the Shaba Plateau cooler still, with mean temperatures of 19-20°C, while along the eastern border mean temperatures vary with site, falling below 15°C in the mountains locally. Mean daily maxima are 30°C over most of the country, falling below this in the mountains and on the Shaba Plateau. Mean daily minima are 21°C around Lake Mai Ndombe, 20°C in the rest of the western basin, 19°C in the eastern half of the basin, 14-15°C on the Shaba Plateau and 12-15°C along the eastern border. However, frosts occur on the highest mountains where precipitation may be in the form of snow. The snowline is about 4500 m asl and there is a permanent snowfield at Mt. Stanley.

Wind velocities are very light over the entire country. Estimated at 2 m above ground, mean annual wind velocities are below 3 km/hour in the western part of the central basin, and 3-4 km/hour in the eastern half. Winds are higher on the borders, with mean annual velocities of 4 km/hour along the northern border and 4-5 km/hour in the south. Along the eastern border mean annual velocities exceed 6 km/hour. Maximum wind speeds recorded at various stations include 28.3 km/hour at Kinshasa (310 m asl), 25.8 km/hour at Bambesa (621 m asl), 28.5 km/hour at Simana (09°37'S/27°01'E - 852 m asl) and 24 km/hour at Rubona (02°29'S/29°46'E - 1706 m asl).

Wetlands

A number of large lakes lie along the eastern border of Zaire in the trough of the Great Rift Valley, which are, from south to north, Lakes Tanganyika, Kivu, Edward and Albert. Hard against the eastern border between Lakes Kivu and Tanganyika, the valley of the Ruzizi River contains extensive wetlands, as does the plain to the south of Lake Edward, and the valley of the Semliki River draining Lake Edward to Lake Albert. Wet swampy plateaux occur at intervals all along the high watershed immediately to the west of the lakes of the Rift Valley system. In the extreme southeast, part of Lake Mweru is situated in Zaire, and there is an extensive floodplain along the Luapula River to the south of this

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lake, where that river forms the border with Zambia. There are also wetlands associated with the mountains of the Shaba Plateau to the west. Here are the two principal reservoirs of Zaire, Lake Tshangalele, on the Lufira River, over 1000 m asl, and Lake Delcommune, where the Lualaba River is dammed. Some 20 substantial lakes occur farther downstream on the Lualaba where it traverses the Kamolondo Depression. Extensive swamps and floodplain systems occur around Lake Tshangalele and the Upemba Lakes.

Other wetlands occur along the upper courses of the large rivers flowing northwards across the southern plateau in Kasai Province, and there are innumerable large bogs and swamps in the headwaters of their tributaries. For example, in the vicinity of Sandoa (9°41'S/22°56'E), swamps are well developed along the Lulua and its tributaries, and wetlands comprise 20-45% of the land surface over very large areas. To the south, in the vicinity of Dibaya (6°31'S/22°57'E), a vast block of land exceeding 4000 km^2, is covered by *Encephalartos poggei* entangled by thickets of the spiny twiner *Smilax kraussiana*. Here, countless gullies containing periodically inundated gallery forests are tributary either to the Lulua River, or the Miao and Lukula Rivers in the east. From the air the galleries on the dendritic drainage system give the landscape the look of alveoli in a lung. Throughout this region the bed of the Lulua is broad and sandy, 400-650 m wide, with numerous little islands.

Having descended from the Shaba Plateau, the Lualaba flows comparatively slowly for several hundred kilometres, with accompanying riverine forest and some swamps, before descending a waterfall and reaching the 500 m contour at Kasongo (4°32'S/26°33'E), and a rapids section and a further waterfall above Kindu (3°00'S/25°56'E). North of here the river becomes much wider, 2-3 km in places, and descends the 7 cataracts of Boyoma or Stanley Falls (0°18'N/25°29'E) before its middle course is deemed to begin and it becomes known as the Zaire River.

In its middle course the Zaire River varies in width between 3-15 km and in depth between 3-10 m, and loses only 115 m in altitude over a river distance of 1740 km between Boyoma Falls and Malebo Pool (4°11'S/15°35'E), therefore having a mean gradient of 1:15 000. Over 1500 km of this stretch, between Kisangani and Tshumbiri (2°36'S/16°16'E), the river itself provides some 1 400 000 ha of very slow flowing open water which has many of the characteristics of a lacustrine, rather than a riverine water body. For much of this distance it flows in a shallow bed with pronounced levées, around almost continuous chains of islands and sand banks, through virtually unbroken primary rain forest. The two major tributaries, the Oubangui (Ubangi) and Kasai (Casai), which join the river towards the western side of the depression, provide a further 680 000 ha of open water and similar riparian environments. For distances of 1000 km and 700 km respectively, these two rivers attain mean widths of 4 km and are also island studded, although the Kasai is only markedly so in its lower reaches. Many of the islands are partially or fully inundated at periods of high water. Behind the levées, permanent and periodically inundated swamp forests extend for distances of up to 35 km on either side of the rivers on continuous alluvial tracts. The Oubangui joins the Zaire River opposite Lake Tumba, almost on the equator, where land is lowest and swamps most extensive. The total area of swamp forest in the central Zaire Basin is difficult to assess, because virtually every river, large and small, overflows its banks periodically and is accompanied by a tract of poorly drained alluvium which supports wetland vegetation. There are

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at least 12 000 000 ha of permanently or seasonally inundated forest in the Zairean part of the Zaire River Basin, with another 6 500 000 ha on the west bank of the Oubangui in Congo, and it is quite possible that the former figure is a substantial underestimate.

All the tributaries of the Zaire River are perennial, and flow in the river is fairly constant throughout the year. Mean annual flow rate at Kisangani is 7000 m^3/sec, but 41 300 m^3/sec at Kinshasa, second in volume only to the Amazon. A maximum discharge rate of over 65 000 m^3/sec was recorded in 1908, and over 75 000 m^3/sec in 1961, while the record low discharge rate was 21 422 m^3/sec in the exceptionally dry year of 1905. Although the equatorial rain belt moves from north to south across the equator, and rain is seasonal over the peripheral catchments, the rainy season in the north coincides with the dry season in the south and *vice versa*; thus heavy rain in the north tends to compensate for light rain in the south and river flow does not change dramatically over the course of a year. Nevertheless, levels in the watercourses of the flat central basin normally exhibit two maxima and two minima each year. The main peak at both Lake Tumba and Malebo Pool is in December-January, coincident with the austral summer rains, followed by a minimum in March-April. A second peak occurs in May-June, coinciding with the onset of the boreal summer rains, while the lowest levels occur in July-September. During the high water periods vast areas of land adjacent to rivers in the central basin are flooded. These areas drain during the low water periods, which occur twice a year, but the main rivers do not contract significantly within their beds.

Downstream at Tshumbiri the river enters a 220 km stretch known as the Chenal, where it is confined by low hills to a narrow channel, 900-1600 m wide, and where swamp forest is largely absent. In this section the river deepens to 25-30 m, and the current becomes more swift, and it is here that the Kasai enters on the south bank. The Chenal ends in Malebo Pool, formerly known as Stanley Pool, an almost circular lacustrine expanse of about 52 000 ha containing a large central island.

Other wetlands occur in Bas-Zaire, the province between Kinshasa and the Atlantic Ocean, which encompasses Malebo Pool and the lower course of the Zaire River and several of its tributaries. The wetlands include reed and papyrus swamps around Malebo Pool and in the valleys of the Luina and Lunionzo Rivers, peat bogs and grass swamps in the valley of the Inkisi River, and periodically inundated savannas. The many rivers of the region all support forests subject to varying degrees of inundation. The periodically inundated sandy banks of rivers, including the Zaire River, support riparian forests along tranquil river stretches, with variant types along unstable and stable banks in the cataract regions. *Pandanus* forest occurs along some rivers, even colonising parts of the river bed, e.g. that of some tributary streams in the basin of the Inkisi River. Immediately behind levées on many streams there are extensive riverine swamp forests, subject to alternate flooding and exposure, and dominated by *Dracaena* and *Pseudospondias*. Other forests, comprising a different spectrum of species depending upon edaphic conditions but all subject to permanent inundation, are found around Malebo Pool, in depressions in the large valley of the Nsele River and in choked valleys on schisto-calcareous soils in the Songolo region. Such forests also have a scattered occurrence in small depressions throughout Bas-Zaire.

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Other seasonal wetlands, reed, sedge and grass swamps, flooded savannas, and riparian and riverine forests, occur on the plateau in the north of the country between the Oubangui and Zaire Rivers.

Flora & Fauna

Zaire is greater in area than the other five countries of the region combined, and judged by mean annual precipitation intensity, which is close to 1700 mm, it is among the wettest of countries in Africa. It contains more wetland than any other African country and presents a wider range of edaphic, climatic and topographical conditions than the other countries of the region, except perhaps Cameroon. In consequence there is a greater floristic and faunistic variation within each wetland type than is observed in the other countries, apart from that which arises simply from differing inundation regimes. In consequence, the floras and faunas of the wetlands and lakes are described separately for each of the areas or systems discussed below.

List of Wetlands Described

1. Wetlands of Bas-Zaire
2. Wetlands of South Bandundu, Kasai Occidental & Oriental
3. Wetlands of Shaba Province
    (a) The High Plateau Country
    (b) Lake Mweru
    (c) The Luapula Floodplain
    (d) Lake Tshangalele & the Lufira River
    (e) Lake Delcommune
    (f) The Upemba Lakes & the Upper Lualaba River
4. Wetlands of the Central Zaire Basin
    (a) Riverine Swamps & Forests
    (b) Lake Tumba
    (c) Lake Mai Ndombe
5. Wetlands of the Eastern Highlands
6. Lake Tanganyika & the Ruzizi Plain
    (a) Lake Tanganyika
    (b) The Ruzizi Plain
7. Lake Kivu
8. Lake Edward
9. The Semliki River Valley
10. Lake Albert

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1. Wetlands of Bas-Zaire

Co-ordinates of Region: 4°00'-6°00'S/12°20'-16°00'E
Area of Region: c. 65 227 km^2
Altitudinal Range: 0-1000 m asl

General: The Atlantic coast of Zaire is generally of high relief, with cliffs along much of its length. Miniature mangrove stands occur where these are breached by little coastal streams, e.g. at the mouth of the Creek de Mosquitos, just north of Banana (5°58'S/12°27'E). A short southward facing promontory extends from Banana into the mouth of the Zaire River, sheltering two large, and numerous small, islands in bays on the north shore of the estuary. The islands extend more than 90 km up estuary, past the town of Boma (5°50'S/13°03'E), and are separated from the mainland by broad channels. However, the main stream and channel of the river pass south of the islands, and tidal (mangrove) forests fringe all the channels between the islands and the mainland. They occur in narrow strips, 100-500 m wide, for 30 km up both the 'Crique de Banana' and the 'Crique des Pirates', and are again well developed at Chango Creek 30 km farther upstream. They also cover many sand or mud banks which are emergent at low tide, but are best developed on mainland shores where small streams enter the estuary. Spring tidal amplitude is 1.7 m at the mouth, 1.5 m at Quissanga, 0.85 m at Mateba and 0.08 m at Boma near where the estuarine section ends and to where mangroves extend.

Cliffs rise to 244 m asl on the north bank of the river near Matadi, and upstream of this place, 150 km from the ocean, the first torrential section is encountered, extending for some 60 km between Yellala Falls and Isingila Falls, with many rapids. From here, in proceeding farther upstream, the river is generally more tranquil, although deep, with a strong current, and confined to a narrow bed for nearly 170 km. Although there are turbulent patches the second major torrential section is not encountered until Manyanga Falls, from where it extends for another 55 km upstream to the vicinity of Sanga. Above Sanga, the river is less turbulent, but still deep, confined to a narrow bed and swift flowing, until Malebo Pool is reached after a further 75 km.

The Pool is 25 km wide and 35 km long, occupying a depression encircled at a distance by hills rising to 500 m asl, while the water level in the Pool is close to 300 m asl. The area of the Pool is about 50 000 ha and the central part is occupied by M'Bamou Island (18 000 ha), which is Congolese territory. There are several groups of small islands, and a little archipelago in the channel on the south side of M'Bamou Island, opposite the mouth of the Nsele River, which discharges into the pool. These islands are Zairean territory and are entirely submerged at high water. The southern shore of the pool is swampy for 30 km between the mouths of the Ndjili and Nsele Rivers, with swamps extending ? km inland at the western side near the Ndjili. Counting the islands, some 10 800 ha of swampland occurs in Zaire on the southern side of the pool. The Nsele is the largest river entering Malebo Pool and swamps extend back up its valley for 22.5 km, with a mean width of 2 km, and then farther upstream, another stretch, some 1.6 km wide, extends for 70 km along the river, totalling some 16 800 ha. The current in the pool is variable but averages 5 km/hr. The pool is shallow with depths of 3-10 m, while water levels vary by as much as 3 m over the course of a year.

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Climate: The estuary mouth is comparatively arid receiving only 800 mm rain/yr, while the town of Banana receives a mere 740 mm, but mean annual rainfall increases upstream to 900 mm at Boma, 1023 mm at Matadi and 1374 mm at Kinshasa where the dry season has a duration of about 120 days. The hills on either side of the river are wetter than the river valley, receiving 1400 mm on the border with Cabinda, 1498 mm at Mbanza-Ngungu (5°17'S/14°51'E) on the south side, and nearly 1600 mm over the upper valley of the Nsele River on the Angolan border. The mean annual temperature at Banana is 25.2°C, while the absolute maximum recorded is 33.6°C and the absolute minimum 15°C. Corresponding figures for Matadi are 23.5, 35.4 and 15.2°C, while for Kinshasa at the eastern end of the region on the banks of Malebo Pool they are 23.3, 33.3 and 13.2°C. In the hills to the south of the river, at Mbanza-Ngungu, they are 23.1, 37.5 and 9.8°C. Malebo Pool experiences 1650-1700 hours of sunshine each year, with monthly figures of 120-150 hours. During the dry season the wind at Malebo Pool is consistently from W or SW, but it is more variable during the wet season.

Water Quality: Poll (1959) quotes the water temperatures at Malebo Pool in September 1957 as being 27.3°C at the surface and 27.4°C at 3 m depth, when the air temperature was 26.8°C. The water is turbid with Secchi depths of about 50 cm. It is analysed monthly at Kinshasa and the mean figures for the year 1976-77, in mg/l, were calcium 2.23; magnesium 0.86; sodium 1.99; potassium 1.33; bicarbonate 7.11; sulphate 2.0; chloride 2.71 and silicate 9.7. The waters are comparatively well oxygenated. In 1957 Poll obtained a reading of 5.45 mg O/l.

Wetland Flora

Tidal Forests: The tidal forests are dominated by *Rhizophora racemosa* in the frontal swamp and by *R. harrisonii* and *R. mangle* in the middle zones, the first two species reaching heights of 25-30 m locally. *Avicennia africana* also occurs in these mangrove swamps, frequently associated with *Laguncularia racemosa*, and on the landward margins, with *Conocarpus erecta*. *Avicennia* occupies some sandy seaward sites near the mouth of the estuary, and occurs along the back of the swamp, behind the *Rhizophora* forest, in downstream sites where the transition to terrestrial vegetation is saline and fairly dry. Other species commonly associated with *Avicennia* along the landward fringe of the mangrove are *Caesalpinia bonduc*, *Chrysobolanus icaco*, *Dalbergia ecastaphyllum*, *Drepanocarpus lunatus*, *Hibiscus tiliaceus*, *Ternstroemia africana* and *Ximenia americana*. In upstream sites, and especially where small tributary streams enter the estuary through the mangrove, the *Rhizophora* forest grades into fresh water swamp forests, many of which are weakly tidal. These are dominated by *Pandanus candelabrum* and/or *Raphia vinifera*, the latter often in association with *Phoenix reclinata* and the spiny climbing palms *Ancistrophyllum secundifolium* and *Eremospatha haullevilleana*, which render the vegetation impenetrable. *Raphia* swamps, or 'raphiales', frequently occur in mosaic with other types of swamp forest throughout Bas-Zaire.

Riparian Associations: Forests subject to semi-permanent inundation occur behind the raphiales along the Zaire Estuary, on almost level banks which slope imperceptibly into the river. These same forests occur on the Zaire River in placid sites upstream, and also on some of the larger tributaries. Floristically they are usually dominated by *Mitragyna stipulosa*, but are quite diverse, containing such associate species as *Acioa dewevrei*,

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Alstonia congensis, Anthonotha pynaertii, Baikiaea insignis, Blighia welwitschii, Brazzeia congoensis, Bridelia ripicola, Dialium pachyphyllum, Dichaetanthera africana, D. strigosa, Eriocoelum microspermum, Guibourtia demeusei, Mallotus oppositifolius, Nauclea diderrichii, N. pobeguinii, Oubanguia africana, Parinari glabra, Sterculia bequaertii, Symphonia globulifera, Uapaca heudelotii, Voacanga thouarsii and *Uvariodendron mayumbense*. There is often an understorey of coarse herbs, among which *Marantochloa mannii* and *M. hensii* are important.

A type of swampy gallery forest, subject to less permanent inundation, is found on rivers in deep valleys cut into impermeable polymorphic sandstones in the hills south of the river. Here, *Syzygium gilletii* and *S. guineense* ssp. *huillense* are the dominant trees, generally accompanied by *Anthocleista liebrechtsiana, Bertiera laurentii, Coelocaryon botryoides, Dichaetanthera corymbosa, Gaertnera leucothyrsa, Quassia undulata, Raphia sese, Uapaca guineensis* and *Xylopia rubescens*. *Ancistrophyllum secundiflorum, Eremospatha cabrae* and *E. haullevilleana* are common climbing palms in this forest, while in the understorey *Impatiens kasaiensis* is perhaps the commonest plant. Numerous ferns and selaginellas grow low down on the tree trunks.

Although, above tidal limits, water levels in the Zaire River do not fluctuate greatly, those of the tributaries in Bas-Zaire have markedly seasonal flows, because they are short rivers and the local climate has a pronounced dry season during the austral winter. They rise in the local hills, but in the case of the Inkisi, far south in Angola. On these rivers gallery forests may be deeply inundated for half the year and dry for the other half. Floristically they are characterised by the abundance of *Dracaena capitulifera* and *Pseudospondias microcarpa*, with *Berlinia bracteosa, B. bruneelii, Cleistopholis patens, Lannea welwitschii, Mallotus oppositifolius, Mimosa pigra, Symphonia globulifera, Treculia africana* and *Uvariodendron mayumbense* as common associates.

Pandanus butayei occurs in almost monospecific stands along some minor streams in the Inkisi Basin to the southwest of Madimba (5°00'S/15°08'E). The pandans grow on the stream banks, and where flow rates are not vigorous, possibly even petering out at times during the dry season, they may be seen to have invaded the stream beds, the water flowing through their stilt roots, and around the outside of clumps.

Where small rivers form pools with muddy banks, and along tranquil stretches of the Zaire River, especially on muddy backwaters, there may be a dense bushy pioneer association. This grows on flat banks, in shallow waters or on muddy soil, and is characterised by the dominance of *Alchornea cordifolia* and *Anthocleista liebrechtsiana*, with the presence of other species including *Aeschynomene* cf. *elaphroxylon, Clappertonia ficifolia, Mimosa pigra, Phyllanthus reticulatus* and *Sesbania sesban*. In deeper water *Cyperus papyrus* becomes dominant and large stands occur around Malebo Pool, in the Nsele Valley, and in many small choked valleys of the Luina and Lunionzo Basins. In these latter places, landslips or other local disturbances have led to drainage from the lower parts of valleys being impeded. The papyrus and *Alchornea* associations may abut and even intricate with each other.

By contrast, sparse herbaceous vegetation occurs on young sand banks and unstable sandy river banks. Various short sedges occur in these situations, together with *Artanema longifolium, Cassytha filiformis, Eleusine indica, Eragrostis atrovirens, Glinus oppositifolius, Grangea maderaspatana, Mitracarpus scaber, Portulaca foliosa* and *Scoparia*

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dulcis. Most are of wide distribution, pantropical or palaeotropical, and penetrate far upstream into the central Zaire Basin. Where soil is more stable and subject only to the weakest currents, *Phragmites mauritianus* beds develop, or rarely, swards of *Pennisetum nodiflorum*.

In the swift flowing and cataract ridden section of the Zaire River between Matadi and Kinshasa, other low thickets develop in sites subject to frequent but short periods of inundation. Here *Manilkara lacera* and *Pachystela brewiceps* are the most characteristic species. They are usually found with some or all of the following: *Baphia verschuerenii, Dalbergia lauisii, Deinbollia laurifolia, Eugenia dewevrei, Garcinia* spp., *Guibourtia demeusei, Ochtocosmus congolensis, Phyllanthus reticulatus, Schotia bequaertii, Strychnos* spp., *Synsepalum dulcificum* and *Xylopia parviflora*. Climbers are abundant in this kind of forest, especially *Ageloea dewevrei, Artabotrys pynaertii, Calycobolus klaineanus, Memycylon* spp., *Popowia littoralis, P. oliverana, Pouchetia africana, P. gilletii, Salacia elegans, Uvaria dacremontii* and *Uvariopsis congensis*. These thickets are often very dense.

In the cataract regions, rocks subject to alternate inundation and exposure, and the walls of cascades subject to constant spray, are dominated by bryophytes, with some specialised higher plants belonging to Podostemaceae and Lentibulariaceae. Perhaps the most characteristic of these are *Inversiodicraea tenuissima* and *Utricularia andongensis*.

Where the banks of the Zaire River are sandy but stable, with a high water table but seldom deeply inundated, the riverine forest has a closed canopy up to 25 m high, composed almost exclusively of *Irvingia smithii* and *Parinari congensis*. Frequently this type of forest succeeds the foregoing type. Among the occasional associates are *Allophyllus africana, Chrysobalanus atacorensis, Dialium excelsum, Guibourtia demeusei, Trichilia retusa* and *Uapaca heudelotii*. The Araceous climber and creeper, *Culcasia scandens* is frequently abundant, both on the soil and on the boles of the trees. Some woody lianes also occur in this forest type. Mostly they are common to the *Manilkara* thickets described above, and possibly persist from a preceding seral stage.

The edges of quiet lakes and pools, formed for example in abandoned river channels in the lower valleys of some of the tributaries, are often fringed by stands of *Polygonum senegalense* in a transition from aquatic to terrestrial vegetation. The open waters support carpets of *Nymphaea caerulea, N. lotus* and *Nymphoides indica*, with *Aponogeton subconjugatus*, and *Trapa natans* var. *bispinosa*. These species are also common in front of *Phragmites* and papyrus in some swamps, for example on Malebo Pool. *Ceratophyllum demersum* and *Utricularia* spp. are common submerged associates. In other places, on acid peaty soils, the margins of small oligotrophic pools are dominated by *Eleocharis acutangula*. These pools are common in the upper parts of some tributary valleys. Numerous species of *Utricularia* are present in the water, and in the most shallow places *Sphagnum* and *Xyris* spp. Calm forest pools are often covered by *Lemna paucicosta, Pistia stratiotes* and *Salvinia nymphellula*. *Eichhornia crassipes* and *Salvinia auriculata* have become naturalised on some ponds and rivers. At times floating meadows of the former species have been known to completely obstruct the channel of the Bundi River near its confluence with the Zaire River, and it also forms vast carpets in the swamps bordering Malebo Pool.

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Floodplains occur behind the papyrus swamps on the southern shore of Malebo Pool and also in the valleys of the Ndjili and Nsele Rivers. Here typical species which, although rooted, contribute to vast floating prairies, are *Echinochloa pyramidalis, E. stagnina, Ipomoea aquatica, Neptunia prostrata, Oryza barthii* and *Vossia cuspidata*.

Non-Riverine Wetlands: Sedge/grass swamps occupy swampy depressions on schisto-calcaerous soils, where surface water is almost permanent. The most common species in these sites is undoubtedly *Echinochloa pyramidalis*, but others which accompany it include *Clappertonia ficifolia, Cyrtosperma senegalensis, Eulophia angolensis, Jardinea congoensis, Loudetia flammida, Phragmites mauritianus* and *Polygonum salicifolium*. Other depressions in savanna regions are covered by almost pure swards of *Setaria anceps*, with species of *Bulbostylis, Cyperus* and *Scleria* as the most common associates.

A complex of peat bogs and flat peaty swamps occurs in the upper parts of some river valleys, but are best developed in the eastern parts of the Inkisi Valley on schists and Kalahari sands. Usually these bogs form a mosaic with the acid pools containing *Eleocharis acutangula* described above. They are characterised by an abundance of *Rhynchospora candida*, but with diverse groupings in the ground layer. Here *Sphagnum* spp. and various Eriocaulaceae and Xyridaceae are most common. The species with the highest fidelity are *Mesanthemum radicans, Paspalanthus lamarckii, Xyris hildebrantii, X. sphaerocephala* and *X. vanderystii*. *Drosera madagascariensis, Microchloa kunthii, Panicum parviflorum, Paspalum commersonii, Utricularia arenaria, U. spiralis* and *U. subulata* grow on the elevated hummocks of *Sphagnum*, increasing the diversity of the mosaic. Occasionally the wettest parts of these bogs are invaded by *Andropogon virganum* and in many sites a graminaceous stratum develops. This is, however, generally composed of *Leersia hexandra, Rhytachne rottboellioides, Sacciolepis africana, Setaria anceps* and *Trichopteryx dregeana*, with a substantial admixture of *Bulbostylis laniceps, Cyperus halpan* (= *C. haspan*) and *C. laxispicatus*.

Some circular depresssions on the plain of Lukunda are inundated for the greater part of the year, and are covered by a type of swamp forest dominated virtually exclusively by *Irvingia smithii*, with *Holarrhena floribunda* and *Pseudospondias microcarpa* as uncommon associates. The sparse understorey comprises *Grewia seretii*, together with *Cleistopholis patens, Glyphaea brevis* and *Memecylon* spp.

Wetland Fauna

Fishes: The fish fauna below Boma has many euryhaline species, e.g. pristids, elopids, sphyraenids and mugilids, together with freshwater representatives of predominantly marine families, such as clupeids, gobiids, tetraodonts and the mangrove mudskippers *Periophthalmus* spp., and a number of secondary freshwater cichlids and cyprinodonts. Thereafter the rapids sections provide what are probably the largest expanses of torrential water in the tropics, and here many fish species exhibit special adaptations to fast flowing, dark, well oxygenated water, and are able to spend much of their lives under rocks. Examples are *Gymnallabes tihoni*, a clariid catfish, *Caecomastacembalus brichardi*, the cichlids *Leptotilapia rouxi* and *L. tinanti*, also the blind cave fish, *Caecobarbus geertsi* (Cyprinidae), and species of *Atopochilus, Chiloglanis, Euchilichthys, Garra, Labeo, Steatocranus* and *Teleogramma*. Adaptations to torrential water are however, not con-

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fined to the lower Zaire River. They are found again, involving different species, in the rapids sections of many streams tributary to the upper sections of the river.

Some 235 species of fish have been described from Malebo Pool, of which 5 are sometimes said to be endemic to the pool. The Mormyridae, with 36 species in 4 genera, are better represented in Malebo Pool than any other family, both in terms of numbers of individuals and numbers of species. Important mormyrid species are *Gnathonemus greshoffi* and *Mormyrops deliciosus*. Among clupeids, *Microthrissa royauxii* and *Poecilothrissa congica* are important, while characids include species of *Alestes, Bryconaethiops* and *Hydrocynus goliath* and *H. vittatus*. *Barbus pleuropholis* and *Leptocypris modestus* are common cyprinids, and *Chrysichthys cranchii* and *Gephyroglanis longipinnis* are important bottom dwellers. The lungfishes, *Protopterus aethiopicus* and *P. dolloi*, inhabit the swamplands, together with *Phractolemus ansorgei* and several species of *Clarias, Micralestes, Synodontis* and *Tetraodon*.

Amphibia: The swamps throughout Bas-Zaire support large and diverse amphibian populations, with many species of frogs and toads.

Reptiles: Among the aquatic or semi-aquatic reptiles are *Amyda* sp., *Boulengerina annulata, Crocodylus cataphractus, C. niloticus, Naja melanoleuca, Pelomedusa sp., Pelusios sp., Psammophis sibilans, Python sebae* and *Varanus niloticus*, while *Dasypeltis fasciata, Dendroaspis jamesonii, Philothamnus semivariegatus* and *Thelotornis kirtlandii* are arboreal in swamp and gallery forests.

Birds: The avifauna of the swamps, rivers, lakes, swamp forests and palm swamps is rich and comprises several hundred species, many of which are found throughout the central Zaire River Basin. Widespread species, including migrants, include *Acrocephalus arundinaceus, A. schoenobaenus, Actitis hypoleucos, Anas* spp., *Anastomus lamelligerus, Anhinga rufa, Apus apus, Ardea melanocephala, A. purpurea, Ardeola ralloides, Bias musicus, Botaurus stellaris, Butorides striatus, Calidris minuta, Ceryle rudis, Chlidonias leucoptera, Corythornis cristata, Egretta intermedia, Ephippiorhynchus senegalensis, Gallinago media, Glareola nordmanni, Haliaeetus vocifer, Halcyon leucocephala, Hieraaetus spilogaster, Hirundo rustica, Ixobrychus minutus, Lanius collurio, L. minor, Larus fuscus, Megaceryle maxima, Merops apiaster, Motacilla flava, Muscicapa striata, Nycticorax nycticorax, Pandion haliaetus, Phalacrocorax africanus, P. carbo, Phylloscopus trochilus, Riparia riparia, Rynchops flavirostris* and *Tringa glareola*.

Mammals: Among the mammals *Hippopotamus amphibius* is rare, having virtually disappeared from Malebo Pool, but *Aonyx congica, Atilax paludinosus, Dasymys bentleyae, Lutra maculicollis, Potamochoerus porcus* and *Tragelaphus spekei* are common. Several monkeys live in the gallery forests, palm swamps and seasonally inundated forests of Bas-Zaire, e.g. *Cercocebus torquatus, Cercopithecus aethiops cynosurus, C. ascanius* (south of the Zaire River), *Cercopithecus cephus, Colobus polykomos angolensis* and *Miopithecus talapoin*, the latter pair occasionally found in the mangroves.

Human Impact & Utilisation: Two large cities are situated on the edges of Malebo Pool, Brazzaville in Congo, with a population of 300 000, and Kinshasa in Zaire, with a population of 3 500 000. Both towns are important ports, serving centres upstream, and over a million tons of merchandise pass through them each year. Human influence

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on Malebo Pool is therefore quite pronounced, and the local fishery lands catches of 1500-2000 tonnes/yr. Further, and particularly in Zaire, most of the land escaping annual inundation has been cleared for agriculture or horticulture, but there has been comparatively little destruction of the swamps. Away from the cities, towns and villages have grown up on the edges of floodplains, and the seasonally flooded areas are utilised in various ways during the dry season, and are fished during the wet. In the estuarine section, both Boma and Matadi are ports, Boma serving the north shore and Matadi, which is linked to Kinshasa by rail, serving the south. The mouth of the estuary is sparsely populated. Inland, while most forest types in Bas-Zaire have suffered serious depradations, swamp forests have largely escaped, since they have, until very recently, been deemed valueless. Now some clearing is being undertaken for rice production.

Conservation Status: A small area of the Mayumbe Massif in Bas-Zaire north of the Zaire River, approximately 5°35'S/13°10'E, and containing the headwater areas of the Luki River, is protected in the Luki Forest Reserve. However, little wetland is found here, and much of the forest in the reserve is of secondary character. Total protection for the forest has been in operation since 1963, when all felling ceased. Hunting and fishing are also prohibited.

2. Wetlands of South Bandundu, Kasai Occidental & Oriental

Co-ordinates of Region: 4°15'-8°00'S/16°00'-26°00'E
Area of Region: c. 401 175 km^2
Altitudinal Range: 450-1150 m asl

General: All parts of this region experience a dry season of 100-130 days duration, and a rainfall of between 1400-1750 mm/yr. There is a double periodicity over most of the region. December and March are the wettest months, when respective falls of 200-250 mm and 180-230mm are received. Mean monthly temperatures are in the region of 23°C, rising to 24-25°C in the wet season. Daily temperature range is greater in the dry season than the wet, with mean maxima and minima close to 32 and 15°C in July, while the corresponding figures for December are 29 and 19°C. Absolute maxima at most stations are in the region of 37°C and absolute minima in some southern stations is below 9°C.

The area is drained by many rivers and their innumerable tributaries, all eventually flowing in parallel, northwards off the southern plateau. The largest of these are, from west to east, the Kwango (Cuango), Kwilu (Cuilo), Loange, Kasai, Lulua, Kelagne Bushimaie, Lubilash and Lomami Rivers, but between the Kwango and Kwilu alone, there are no less than 9 major streams, the Wamba, Bakali, Konzi, Inzia, Luie, Lukula, Kafi, Gobari and Kwenge Rivers. All except the Lomami eventually discharge into the Kasai, which, north of the area presently under consideration, swings westwards and skirts the southern border of the central Zaire depression. The individual swamps in this geographic region are too numerous to be described in detail. Periodically or permanently inundated lands follow the lowest parts of all the river valleys, in strips 100 m to 10 km wide. There are for example 11 major swamps, totalling some 155 000 ha, on the Kwilu River and its tributaries between 6-7°S, together with many minor swamps, and there is

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no less than 450 000 ha of wetland in the vicinity of Sandoa (9°41'S/22°56'E) associated principally with the drainage basin of the Lulua River at altitudes of 750-1050 m asl.

Wetland Flora

The region is characterised by extensive savanna plains with gallery forests along the rivers, but with more extensive valley bottom forests towards the central Zaire depression. The savannas are dominated by a *Julbernardia-Brachystegia* association in the south, reaching latitudes of 7°20'S in places, but farther north this gives way to other associations, e.g. a *Tristachya nodiglumis-Diectomis fastigiata* association in the west, and an *Encephalartos poggei-Smilax kraussiana* association in the east. Large blocks of pseudo-steppe vegetation interdigitate with these, characterised by *Aristida vanderystii* and *Boophane disticha*. Most of the valley bottom forests are periodically inundated, but some, in depressions, are inundated almost permanently. Numerous grass, reed and papyrus swamps occur in the upper valleys, with extensive peat bogs in some choked valleys, and in very shallow depressions on plateau areas. There are also substantial areas of hygrophilic grassland.

Riparian & Floodplain Associations: In southern Bandundu, sandy banks in and along major rivers, subject to periods of inundation by quite swiftly flowing water, are colonised by a woody *Malouetia bequaertiana-Uapaca heudelotii* association, forming dense thickets adjacent to the water. The principal associates are *Berlinia giorgii, Cathormion altissima, C. obliquifoliolata, Dioclea reflexa, Homalium eolaense, Irvingia smithii, Mucuna flagellipes, Opilia sparsiflora, Syzygium guineense* and *Uvariopsis congensis*. Here are to be found a number of epiphytes, including *Ancystrorhynchus clandestinus, Angraecum distichum, Asplenium africanum, Calyptrochilum emarginatum* and *Platycerium stemaria*. Elsewhere, *Alchornea cordifolia* is the pioneering woody species.

Along the banks of the big rivers, north of the parallel 5°S, one encounters outliers of floodplain forests dominated by *Lannea welwitschii, Monopetalonthus pterydophyllus, Pseudospondias microcarpa, Rauvolfia mannii* and *Thomandersia laurifolia*. They occur on alluvium and are found to intercalate with the association previously described, and a *Gilbertiodendron dewevrei* association, which dominates the valley sides and extends down onto the fringes of the floodplain.

The lowest parts of valley floors in this region are occupied by swamp forests and several distinct types can be recognised. Wide galleries of swamp forest occur along rivers in broad valleys on impermeable polymorphic sandstones, which ensure that the soil surfaces are permanently waterlogged. The most characteristic species are *Newtonia devredii* and *Uapaca guineensis*. These forests are primitive in character and provide a refuge for several Guinean species, the distribution of which was significantly constricted during the Quarternary. Some other species commonly found in these galleries are *Acioa dewevrei, A. lujae, Berlinia grandiflora, B. sapinii, Dacryodes edulis, Dalbergia louisii, Epinetrum villosum, Eriocoelum microspermum, E. petiolare, Homalium molle, Mitragyna stipulosa, Monopetalanthus pteridophyllus, Paramacrolobium coeruleum, Pararistolochia promissa, Parinari glabra* and *Symphonia globulifera*, together with species of *Anthonotha, Chrysophyllum, Culucasia, Dialium, Lonchitis* and *Nephrolepis*.

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In ravines and deep narrow valleys, swamp forests cling to the courses of streams and are dominated by *Mitragyna stipulosa* with *Sarcophrynium schweinfurthianum* a feature of the ground layer. *Sterculia bequaertii* and *Symphonia globulifera* are the principal associates. At the heads of broad trough-like valleys swamp forests are dominated by *Xylopia rubescens*, with several species of *Syzygium*. The flanks of these forests tend to comprise *Syzygium cordatum* and *S. parvifolium* in narrow girdling belts, while in the interior *Syzygium giorgii* is the typical associate. On the banks of swift flowing rivers, subject to sudden high floods, *Pandanus buiayei* sometimes forms long monospecific stands. However, in the upper reaches of the Kwango River, where the river is deeply entrenched in the vicinity of Swa Tende (7°14'S/17°07'E), below the two waterfalls of Kasondo-Lunda and Guillaume, *Raphia laurentii* (= *R. monbuttorum*) swamps cover the valley floor.

Along the sandy courses of lower reaches of the eastern rivers in Kasai, e.g. the Lulua and Sankuru Rivers, the banks subject to frequent inundation and rapid changes in water level are colonised by woodland in belts several kilometres wide. Here the lower stratum is discontinuous and poorly developed and there are scattered patches of herbs. The spectrum of species differs from that in the west of the region and typically includes *Acioa lujae, Alsodeiopsis poggei, Baikiaea insignis, Berlinia sapinii, Cathormion altissimum, Cynometra pedicellata, Gilletiodendron mildbraedii, Gouania africana, Hexalobus crispiflorus, Irvingia smithii, Morelia senegalensis, Ouratea arnoldiana, Tessmannia dewildemaniana, Uapoca heudelotii* and *Uvariopsis congensis*, with the lianes *Oxymitra sayauxii* and *Pleioceras gilletii*. In the herbaceous stratum one finds *Dracaena poggei* and *Hypolytrum heterophyllum*.

In depressions away from rivers on floodplains, on the land behind levées, and in wet valley heads, sandy lithosols are frequently colonised by a well stratified swamp forest attaining 20 m in height. This contains a range of species, but is given special character by the presence in its canopy of an abundance of *Syzygium guineense* ssp. *guineense* and *Voacanga thouarsii*. The forest is heliophilic, generally has a second stratum at a height of 10-15 m, a bushy layer at 2-5 m, and a ground layer up to 1.5 m high. In addition to the two species already cited, the most characteristic trees of the upper strata are *Ficus congensis, Gardenia imperialis, Mitragyna stipulosa*, and locally *Elaeis guineensis*. In the lower strata, *Adenostemma viscosum, Costus lucanusianus, Cyclosorus striatus, Nephrolepis biserrata* (growing terrestrially), *Orestias foliosa* and *Scleria racemosa* are common. *Adenia dinklagei* (Passifloraceae) and *Culcasia scandens* (Araceae) are bole climbers, while *Pleopeltis scolopendria* grows epiphytically. Upstream this woody association frequently gives way to an herbaceous swamp dominated by the hygrophilous grasses *Loudetia phragmitoides* and *Trichopteryx dregeana*, which may extend to the very head of the valley.

The woody vegetation just described tends to be succeeded by a climax swamp forest, with a canopy exceeding 30 m in height and providing up to 90% cover, with a lower arborescent stratum at 15-20 m. An abundance of *Coelocaryon botryoides* and *Uapaca guineensis* typify this forest, but other co-dominants include *Alstonia congensis, Baikiaea insignis, Eriocoelum microspermum, Macaranga saccifera, Mitragyna stipulosa, Parkia filicoidea, Raphia* spp., *Rothmannia megalostigma, Strombosiopsis tetrandra, Symphonia globulifera* and *Treculia africana*. Climbing palms, *Ancistrophyllum* and

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Eremospatha spp. also reach the canopy. *Pauridiantha pyramidata* dominates the understorey, but is associated with *Ataenidia conferta, Cyrtosperma senegalense, Dicellandra barteri, Marantochloa congensis, Memecylon myrianthum, Napoleana imperialis, Sarcophrynium schweinfurthianum* and *Xylopia acutiflora. Anthoclitandra robustior, Atroxima congolana, Cercestis congoensis, Microsorium punctatum, Milletia gossweilleri* and *Popowia bicornis* grow either as climbers or epiphytes, together with those species mentioned in this context in the preceding paragraph. This type of forest occupies the sites in gallery forests where the soils are permanently waterlogged. The narrowness of most valleys limits the extent of this forest type, which is seldom great.

Hygrophilous evergreen forests, dominated by *Gilbertiodendron dewevrei*, occur on alluvial flats which may be waterlogged for much of the year, but flooded only briefly. These forests attain heights of 20-30 m and are generally well stratified. While *Gilbertiodendron* comprises the canopy layer almost exclusively, it has associates in the upper strata, notably *Alphanocalyx cynometroides, Garcinia smeathmannii* and *Monopetalanthus microphyllus*. Occasionally relict species from swamp forest may be present, indicating that the area once supported this type of vegetation. Perhaps the most common of the relict species are *Asystasia vogeliana, Dicranolepis oligantha, Eremospatha haullevilleana, Palisota thyrsiflora* and *Raphia* spp. Among lianes, *Agelaea dewevrei, Anthoclitandra robustior, Saundea pubescens* and *Landolphia foretiana* are most abundant.

Elsewhere, e.g. in the vicinity of Mweka (4°51'S/21°34'E), hygrophilous semi-deciduous forests occupy this same habitat, with an abundance of *Autranella congolensis, Cynometra hankei, Julbernardia seretii* and *Scorodophloeus zenkeri*, and the two forest types may intergrade.

Where periodically inundated swamp forest has been cleared by man in the more elevated regions, between 6-8°S, and has not been able to regenerate, it tends to be replaced by a *Loudetia phragmitoides* grassland, containing characteristically the labiate, *Briquetastrum africanum*. This latter association occurs in the west, between the Kwango and Kwenge Rivers, but is especially common in Kasai Oriental, to the NE of Dibaya, where the landscape is highly dissected. The association comprises only herbs and suffrutescent species. In addition to the two species already cited, the following are important: *Acriulus grigiifolius, Aeschynomene sensitiva, Andropogon tenuiberbe, Crassocephalum picridifolium, Crotalaria sessilis, Cyelosorus striatus, Cyperus auricomus, C. distans, C. latifolius, C. laxispicatus, Desmodium salicifolium, Dissotis princeps, Eriochrysis brachypogon, Eulaphia latilabris, Fimbristylis miliacea, Fuirena umbellata, Hydrolea guineensis, Hyparrhenia bracteata, Hypogynium spathiflorum, Kotschya stolanifera, Kyllinga pungens, Otometria elatior, Panicum nervatum, Rhynchospora candida, R. corymbosa, Scleria melanomphala, Selaginella congoensis, Trichopteryx dregeana* and *Vigna nigrita*. This marshy association is generally bounded by a monospecific band of *Loudetia simplex*, 10-20 m wide.

Shady backwaters along rivers and ponds in swampy riverine forests support a *Lemna paucicosta-Pistia stratiotes* association. Many rivers, e.g. much of the Kwango, are fringed along the waters edge by meadows of *Echinochloa pyramidalis* with an abundance of *Polygonum senegalense*. A variety of vegetational types occur on hydromorphic soils in broad sandstone valleys, especially above some of the waterfalls where the river water spreads in a thin sheet over a large area. In places the waterlogged soils extend in

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flat belts, 2-3 km wide, along the rivers, and here the several associations are determined primarily by edaphic factors. Where there is often a sheet of free water at the surface, *Aeschynomene fulgida* is common in association with *Craterostigma goetzii*, *Dissotis debilis*, *Emelia* sp., *Fuirena umbellata*, *Heteranthoecia guineensis*, *Leersia hexandra*, *Rhytachne rottboellioides*, *Sacciolepis typhura*, *Sphagnum planifolium*, *Stipularia africana*, *Utricularia* spp., *Trichopteryx dregeana*, *Xyris hildebrandtii* and *X. imitatrix*.

On sandy rivers those parts of shallow banks which are periodically submerged are colonised by dense beds of *Rhynchospora candida*, together with *Axonopus compressus*, *Drosera* sp., *Eriochrysis brachypogon*, *Mesanthemum radicans*, *Paepalanthus poggeanus*, *Sphagnum planifolium*, and species of *Torenia*, *Utricularia* and *Xyris*. In adjacent situations lawns develop on superficially swampy sites, being characterised by the presence of *Craterostigma latibracteatum* and *Neurotheca longidens*, together with *Andropogon huillensis*, *Eragrostis plurigluma*, *Melinis macrochaeta* and *Panicum lindleyanum*. In river valleys, where the sheet of groundwater remains close to the surface throughout the dry season, *Dissotis thollonii* and various sedges predominate.

Non-Riverine Wetlands: An association of very wide distribution throughout the region under consideration is distinguished by the presence of *Loudetia vanderystii*. It occurs on a range of hydromorphic soils, away from the immediate vicinity of rivers, but its precise floristic composition depends upon water levels, the duration of the dry season, local edaphic and climatic conditions and geographic location. Among the many species found in this type of vegetation the following are representative: *Andropogon huillensis*, *Aristida atroviolacaea*, *Ascolepis protea*, *Bulbostylis pumila*, *Commelina umbellata*, *Crotalaria glauca*, *C. sessilis*, *Cyperus lanceolata*, *C. serpens*, *C. tenax*, *Elyonurus brazzae*, *Eragrostis racemosa*, *Fimbristylis dichotoma*, *F. umbellata*, *Gladiolus melleri*, *Glinus oppositifolius*, *Helichrysum alismatifolium*, *Hypogynium spathifolium*, *Kyllinga erecta*, *Panicum brazzavillense*, *P. ianthum*, *Polygala claessensii*, *P. ukirensis*, *Pycreus scaettae*, *Rhytachne rottboellioides*, *Scleria hirtella*, *Schizachyrium mukulense*, *Setaria restioides*, *Sparobolus barbigerus* and the arborescent *Syzygium guineense* ssp. *huillense*. In places Xyridaceae are dominant with *Xyris hildebrandtii*, *X. imitatrix*, *X. sanguinea* and *X. vanderystii* well represented. In the wettest sites Eriocaulaceae are prominent, e.g. *Synogonanthus poggeanus* and *S. walbergii*. This vegetation often has two strata, an upper one 100-150 cm high and a lower one 30-40 cm high, with occasional clumps of trees. Generally this association is confined to alluvial deposits of white oligotrophic sands, in which, as the level of the water table varies from season to season, the upper layers are subject to alternate periods of anoxia and aeration. Surface waters may at times reach depths of 20-40 cm.

In southern Bandundu the waters of ponds on the granite massifs support an *Azolla pinnata* association. Other ponds, open to higher insolation, are covered by *Nymphaea* spp., and are fringed by *Cyperus papyrus* with low growing *Cyclosorus striatus* and *Vossia cuspidata* in the water at the bases of the culms. Permanent swamps of this latter type are well developed in the Tungila Valley.

Wetland Fauna

The fish faunas of the rivers and swamps are strongly affiliated to those of the central Zaire Basin, but since the rivers of the region under consideration here all have rapids

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or waterfalls, and are all tributary to the Kasai which enters the Zaire River in the Chenal section, the faunas of their upper reaches differ from that of the middle Zaire River. Most subsystems of the Kasai are thought to have high proportions of endemic species, although only a few have been investigated in any depth. However, of 60 species described from the upper Kasai River, 19 are endemic (Poll, 1963). The presence of Zambezian fish in the Kasai system suggests that at some point in its history the river, or one of its tributaries, captured the headwaters of a stream which once flowed into the Zambezi. Many of the Kasai rivers share a watershed with the Zambezi and its tributaries. *Aplochellichthys* and *Hypsopanchax* are genera confined to rivers flowing through savanna country, while *Aphyosemion* and *Epiplatys* (all Cyprinodontidae) are genera found in the lower reaches of rivers traversing tropical rain forest.

Frogs and toads are abundant throughout the wetlands. The reptile and bird faunas of this region are similar to those described in section 1, Bas-Zaire. Mammals present in the swamp and gallery forests are *Aonyx congica*, *Atilax paludinosus*, *Cephalophus monticola*, *C. sylvicultor*, *Cercocebus aterrimus*, *Cercopithecus aethiops cynosurus*, *C. ascanius*, *C. mona pyrogaster*, *C. neglectus*, *Colobus polykomos*, *Dasymys* sp., *Funisciurus pyrrhopus*, *Galago demidovii*, *Hippopotamus amphibius*, *Leptailurus serval*, *Miopithecus talapoin*, *Nandinia binotata*, *Pan paniscus* (pygmy chimpanzee), *Pellomys fallax*, *Potamochoerus porcus*, *Potamogale velox*, *Sylvicapra grimmia*, *Syncerus caffer*, *Tragelaphus scriptus* and *T. spekei*.

Human Impact & Utilisation: Much primary forest has been disturbed, having been exploited by the indigenous people traditionally, and since the middle of this century by Europeans. The Europeans exported huge quantities of timber during the second world war, subsequent to which intensive exploitation has continued along the railway line from the port of Ilebo on the Kasai River, to Kananga, Kamina, Bukama and Lubumbashi. In this region some wet forested areas cut through a long time ago have been reduced to a *Carapa procera* woodland with an under-storey of *Ananas sativa*.

Conservation Status: Unprotected.

3. Wetlands of Shaba Province

Co-ordinates of Region: 8°00'-13°30'S/22°00'-29°40'E
Area of Region: c. 321 120 km^2
Altitudinal Range: 590-1889 m asl

General: Shaba is situated in the extreme SE of Zaire where much of the land is over 1000 m, and several elevated blocks rise to over 1500 m asl. The largest of these are the Plateau of Manika and the Kundelungu Mountains, both oriented SW-NE and roughly parallel to each other. On either side of these highlands, and between them, are large swampy depressions. Lake Mweru and the Luapula Floodplain lie to the east of the Kundelungu Range, the headwater swamps of the Lufira River lie between the highland blocks, and the Upemba lake system lies to the west of the Manika Plateau in the Kamolondo Depression. The border with Zambia and then Angola follows a watershed eastwards across the south of Shaba Province, and for most of the way, is very wet and swampy.

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(A) THE HIGH PLATEAU COUNTRY

General: Above 1000 m, the valleys of most streams carry dambo or dembo vegetation in their uppermost reaches, sometimes with central strips of low forest along the watercourses. Along the southern border the commonest tree in these strips is *Acacia caffra* var. *campylacantha*, and downstream broad galleries of this species replace the dembo vegetation. Here the periodically flooded forest may reach widths of several kilometres, but frequently within it there are expanses of open water along the stream bed, covered by *Nymphaea* spp., or there may be extensive stands of *Typha domingensis*, or mixed stands of short sedges, *Cyperus papyrus* swamps, reedbeds of *Phragmites mauritianus* or aquatic meadows dominated by *Leersia hexandra* and *Echinochloa stagnina*. The Muniama River near Lubumbashi provides a good example of such a valley floor, occluded by *Acacia caffra* forest, but with broad central herb swamps. On other watercourses herbaceous swamps completely dominate the valley floors, and arborescent vegetation is only poorly developed, e.g. on the Kafuba and Kisanga Rivers, also near Lubumbashi, in an area where wetlands account for more than 6% of the land surface.

The deeply dissected highland block to the west of the Kamolondo Depression, centred on Kamina (8°46'S/25°00'E), where the Lubilash, Lumembe, Lomami and Lovoi Rivers rise, is covered by dry savanna forest, with gallery forest along the rivers. *Pandanus candelabrum* forms depleted galleries near Tshibonde and Mwadi-Kayembe, but forests dominated by *Canarium schweinfurthii* with an understorey of *Mellera lobulata* (Acanthaceae) occur along watercourses in the deeper valleys, while *Mitragyna stipulosa* and *Spondianthus preussii* are predominant in the broader ones. Grassy floodplains occur where inundation is deep and prolonged, and in these places the watercourses frequently carry a *Pandanus candelabrum-Thalia welwitschii-Floscopa glomerata* association. This may be followed on higher ground by a *Pennisetum purpureum* zone, or a *Cyperus latifolius-Rhynchospora triflora* zone, and these in turn by *Loudetia kagerensis-Fimbristylis gabonica* zones. Patches of *Centratherum englereanum* (Compositae) and *Hyparrhenia bracteata* also occur in the least deeply flooded areas.

Highland bog pools, such as are found on the Manika and Kundelungu Mountain plateaux, contain *Drosera madagascariensis*, *Nyphaea sulphureus*, *Utricularia* spp., and are fringed by various sedges. Montane stream sides are often lined by thin beds of *Phragmites mauritianus*, while *Psychotria mushiticola* is a common stream side tree at altitudes above 1400 m.

The Kundelungu National Park, an integral nature reserve, protects the southern plateau of the Kundelungu Mountains, the 400 m escarpment by which they fall to the Lufira Valley, and a narrow strip of valley floor beneath the escarpment. On the plateau various pools and areas of bog are protected, and the courses of some minor streams, tributary to the Lufira River, are protected together with their gallery woodlands.

(B) LAKE MWERU

Location: 8°29'-9°28'S/28°23'-29°10'E
Area: c. 200 000 ha open water in Zaire
Altitude: 919 m asl
Nearest Towns: Pweto (at N end lake); Lubumbashi (280 km SW)

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General: Lake Mweru is an almost rectangular lake, 120 km long and 48 km wide, situated in SE Zaire, on the border with Zambia, at the end of the broad Luapula Floodplain. The national boundary crosses the lake from SW-NE and approximately half of the open water surface is in Zaire. The lake is quite shallow, increasing in depth from south to north. Over the southern half the mean depth is 3 m, while in the northern half it is 10 m, with a maximum recorded depth of 37 m. The lake contains several islands but the principal ones are Zambian territory. About 155 km of shoreline is situated in Zaire, on the western and southern sides of the lake. The western shoreline is steep, with low cliffs broken by scattered bays, but the southern and southwestern shores are flat and swampy, and dip very gently into the lake. The lake is filled by the Luapula River and several lesser streams which enter the lake in this region, and is drained by the Luvua River, which leaves the lake immediately SW of Pweto.

Climate: Mean annual rainfall over the lake is 1020-1120 mm depending upon site, but higher in the catchments. December is the wettest month, with falls of up to 275 mm, and the rainy season persists for about 195 days. Mean annual temperature at the lake is 22-23°C depending upon site. October is the warmest month with mean daily maxima of 31-34°C and mean daily minima of 18-19°C. July is the coolest month with a mean temperature of 20°C and mean daily maxima and minima of 28°C and 14°C. Sunshine receipts are in the region of 2600 hours/yr, with a monthly maximum of 310 hours in July and a minimum of 125 hours in December. Incident radiation approximates 170 Kcal/cm^2/yr on the lake and evaporation from the lake surface has been estimated as 1700 mm/yr.

Hydrology & Water Quality: The drainage basin, for which Lake Mweru forms a collecting point, is vast, up to 500 km wide and 550 km long with a total area of some 200 000 km^2. The waters of the lower Luapula are high from March to May, and low between September and January. A maximum flood level of 8 m has been recorded at Kasenga (10°22'S/28°45'E), but the mean maximum level is 3.8 m at this point. The waters of the lake itself are high from April until July, reaching their lowest between October and February. The mean annual fluctuation is 1.5 m, but a maximum variation of 4.7 m has been recorded. Water leaving the lake via the Luvua, enters the Lualaba and eventually the Zaire River en route to the Atlantic Ocean.

The lake is polymictic. Surface water temperatures reach 25-30°C during October-May, but fall to 22-25°C during June-September. Secchi depths vary from 0.6-1.46 m, and total dissolved solids amount to 41-69 mg/l depending upon the season. The pH of lakewater varies between 7.0-9.3, while in the swamps it is 6.0-6.9. The lake is well oxygenated, the surface waters containing 5.4-8.9 mg O/l depending upon the season.

Wetland Flora: Hydrophytes in the lake include *Azolla pinnata*, *Ceratophyllum demersum*, *Lagarosiphon ilicifolius*, *Najas pectinata*, *Nymphaea caerulea*, *N. lotus*, *Pistia stratiotes*, *Potamogeton* spp., *Ottelia* spp., *Utricularia* spp., and *Vallisneria aethiopica*. Beds of aquatic grasses, including *Echinochloa* spp., *Leersia hexandra* and *Vossia cuspidata*, occupy the lowest levels of the seasonally inundated zone around the lakeside, and are backed by *Cyperus papyrus* in sites along the southwestern shore, with *Phragmites mauritianus* and *Typha domingensis* as typical associates. Rocky shores are dominated by Chlorophyceae, with some hygrophilous herbs at higher levels, including species of *Alternanthera*, *Ipomoea* and *Oldenlandia*.

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Wetland Fauna: The fish fauna of the system is diverse. 146 species have been described from the system, 94 from Lake Mweru. There are numerous representatives of Characidae, Cichlidae, Clariidae, Cyprinidae and Mormyridae. *Oreochromis macrochir* is the most important economic species in Lake Mweru, the adult fishes living a pelagic life mainly in the deeper waters of the northern part of the lake, while the juveniles tend to be confined to bays and swamps in the south where they shelter among the floating vegetation, especially *Vossia*. The adults migrate south to spawn from August-September, and remain in the area until January-February. Other species important to the fishery are *Labeo altivelis*, which migrates up rivers to spawn, and *Alestes macrophthalmus*, which seems to comprise two populations, one which spawns in swiftly flowing waters of the Kalungwishi River (in Zambia) and one which spawns in Lake Mweru itself.

Amphibia are abundant, and reptiles in Lake Mweru include two species of crocodiles, *Crocodylus cataphractus* and *C. niloticus*, which are both considered vulnerable, and the aquatic snake *Boulengerina annulata*. Man-eating crocodiles are a problem on parts of the southern lakeshore. The avifauna of the lake and its environs is rich. Very many of the typical Central African wetland species occur here, including most of those listed in section 1, Bas-Zaire, together with *Actophilornis africana*, *Ardea goliath*, *Balaeniceps rex*, *Dendrocygna viduata*, *Musciscapa aquatica*, *Pelecanus onocrotalus*, *Phoeniconaias minor*, *Phoenicopterus ruber*, *Ploceus pelzelni* and *Porzana pulsilla obscura*. *Acrocephalus schoenobaenus*, *Chlidonias leucoptera* and *Larus fuscus* are palearctic migrants.

Hippopotamus amphibius is found in the southern parts of the lake, while several small mammals, e.g. *Atilax paludinosus* and *Lutra maculicollis* are more widely distributed.

Human Impact & Utilisation: The lake waters are fished from both Zambian and Zairean sides, the catches being exported to Copperbelt towns in Zaire, to the SW of the lake.

Conservation Status: Unprotected.

(C) THE LUAPULA FLOODPLAIN

Location: 9°23'-12°00'S/28°29'-28°47'E
Area: c. 330 000 ha
Altitude: 919-980 m asl
Nearest Towns: Kasenga (on upper floodplain); Lubumbashi (190 km SW)

General: The Luapula Floodplain begins at Chembe (12°00'S) where the river descends below the 1000 m contour. The floodplain is oriented due N-S and extends for almost 300 km along a section where the river forms the border with Zambia. However, for the first 180 km from Chembe to Kasenga (10°22'S/28°45'E), it is confined by a narrow valley. Peak water level rises of 8 m have been measured at Kasenga, with a mean annual rise of 3.8 m, but from here north the floodplain widens, and in places a wetland extends 46 km west of the river on the Zairean side of the border. The floodplain includes several peripheral lakes and numerous riverside lagoons, and substantial areas of permanent swamp. These latter fringe some of the lakes and lagoons, occupy abandoned river channels and extend back as riparian swamps along several tributaries flowing east from the Kundelungu Mountains to the Luapula. The most important tributaries are the

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Lutsipushika and Kalala Rivers, the former with 46 km of riparian swampland. The largest of the lakes is almost circular with a diameter of 7 km, and three others are more than 5 km long.

Wetland Flora: Papyrus swamps fringe lagoons along the Luapula and dominate large areas of permanent swampland, with the typical associate species *Phragmites mauritianus* and *Typha domingensis*, and the aquatic grasses *Echinochloa stagnina* and *Vossia cuspidata*. Other tall grasses found in the swamps include *Miscanthidium violaceum* and *Pennisetum purpureum*. Wetland herbs found in the swamps in shallow water, and in rafts of floating vegetation, include *Cyperus imbricatus*, *Ethulia conyzoides*, *Ludwigia leptocarpa*, *Melanthera scandens* and *Polygonum senegolense*. The most important floodplain grasses are *Oryza barthii*, which occupies the most deeply flooded sites, and *Echinochloa pyramidalis* and *Sacciolepis africana* on less deeply inundated sites. The peripheral areas, where inundation is less than 40 cm and which are only briefly flooded, carry many graminaceous species, including *Acrocerus macrum*, *Heteropogon contortus*, *Hyparrhenia* spp., and *Vetiveria nigritana*, with *Loudetia simplex* and *Themeda triandra* on the very margins. Little groves of *Aeschynomene elaphroxylon* occur on isolated and elevated sandy patches along the river, and often these are accompanied around their outer, lower, margins by *Hibiscus diversifolius* which may be deeply inundated at high water. Patches of swamp forest typical of the interface between the Guineo-Congolean region and the Zambezian region, comprising *Aporrhiza nitida*, *Ficus congensis*, *Garcinia smeathmannii*, *Syzygium* spp., *Uapaca guineensis* and *Xylopia* spp. occur in some permanently wet sites along rivers and streams. Gallery forests containing *Chlorophora excelsa*, *Khaya nyasica* and *Parkia filicoidea* occupy river banks subject only to shallow and very temporary inundation upstream.

Brachystegia-Julbernardia woodland covers much of the surrounding, unflooded country, on sandy-loam soils, but within this woodland there are numerous large dambos, often containing patches of mushitu, i.e. swampy evergreen forest.

Wetland Fauna: The fish fauna of the Luapula between Lakes Mweru and Bangweulu has both Zambezian and Zairean affinities. It is an isolated fauna, being cut off from the Zambezi system by the watersheds along the Zambia/Zaire border, and from the Upper Lualaba River by two sets of rapids and a dam on the Luvua River below Lake Mweru. Of 120 species so far identified, 33 are endemic to the Luapula system (Poll, 1963). The lungfish, *Protopterus annectens brieni*, occurs in the associated riverine swamps and floodplains, together with *Nothobranchius taeniopygus*. Many species of fish from Lake Mweru migrate up the Luapula to spawn.

Frog populations in the swamps reach prodigious sizes, the animals falling prey to a variety of fish, snakes and birds. Reptiles found in the system include the snakes *Natriciteres olivacea*, *Naja melanoleuca*, *Philothamnus irregularis*, *Psammophis sibilans* and *Python sebae*. Arboreal species in the swamp and gallery forest are *Dispholidus typus*, *Dasypeltis scabra*, *Philothamnus semivariegatus*, *Thelotornis kirtlandii* and possibly *Dendroaspis angusticeps*. The water monitor, *Varanus exanthematicus angolensis*, occurs in the swamps, and there are two terrapins, *Pelomedusa subrufa* and *Pelusios subniger*. The avifauna is typical of that found in association with floodplains, lakes and reedbeds, and is very similar to that of Lake Mweru.

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Hippopotamus amphibius and *Kobus leche leche* occur in the swamps of the lower floodplain. Other species visiting the area are *Alcelaphus lichtensteini*, *Hippotragus equinus*, *H. niger*, *Kobus ellipsiprymnus*, *K. vardoni*, *Taurotragus oryx*, *Tragelaphus scriptus*, while *Loxodonta africana*, *Redunca arundinum* and *Syncerus caffer* are found in the swampy regions along the rivers. *Cercopithecus ascanius katangae* and *C. mitis opisthostictus* are arboreal species in the riparian forests, while *Potamochoerus porcus* and *Phacochoerus aethiopicus* frequent the fringing woodland. Among small mammals, *Aonyx capensis*, *Atilax paludinosus*, *Lutra maculicollis*, and the rodents *Dasymys incomtus*, *Pellomys fallax* and *Thryonomys swinderianus* occur in the swamps.

Human Impact & Utilization: The area is virtually undeveloped, but some 150 000 persons live in the region. There is no mining nor manufacturing, and tourism has not yet developed. Outside the small and widely separated towns there are few villages. Small scale agriculture takes place on the floodplains, with cassava, millet, maize, groundnuts and sweet potatoes the chief crops. Fishing is locally intensive along the lower Luapula and catches have exceeded 5000 tonnes/yr. A substantial proportion of the annual catch is sent south to the railway and copperbelt towns. The bulk of the catch comprises *Oreochromis macrochir*, with some *Serranochromis* and *Tylochromis* spp., and much smaller quantities of *Alestes*, *Auschenoglanis*, *Clarias*, *Gnathonemus* and *Synodontis*. A motor boat service for passengers and cargo operates with a fortnightly schedule between Kasenga, nearly 150 km upriver, and Pweto at the northern end of Lake Mweru.

Conservation Status: Unprotected.

(D) LAKE TSHANGALELE & THE LUFIRA RIVER

Location: 9°00-13°13'S/26°40'-27°57'E
Area: c. 400 000 ha (total wetland in system)
Altitude: 700-1100 m asl
Nearest Towns: Likasi (20 km W); Lubumbashi (80 km S)

General: The Lufira River has two sources (11°34'S/26°29'E and 11°52'S/26°52'E) to the west of Lubumbashi (Elizabethville), in both places rising in swampy areas. It flows from the headwater confluence, again flanked by a series of swamps, north to Lake Tshangalele (10°45'-11°00'S/26°56'-27°16'E), one of the two major reservoirs in Shaba. Thereafter it flows north, receiving, at a point 10°30'S/27°30'E on the right bank near Kienge, a major tributary which also drains a swampy valley. Then the Lufira meanders NW across the floor of a large triangular depression, which has its apex at Kienge, and its base oriented SW-NE along the escarpment of the Manika Plateau. The triangular depression is 160 km wide at the base, and 130 km long from base to apex, thus having an area close to 10 400 km^2. Much of this area is of low relief. Numerous tributary streams flow down from the Kundelungu Mountains which form the eastern side of the triangle, while 3 major tributaries cross the broadest part of the depression parallel to the Manika Escarpment, having confluences just above the Lufira Rapids (9°31'S/27°02'E). From here, close to the base of the triangle, the Lufira has cut a much steeper sided valley through the Manika Plateau whence it flows to a junction with the Lualaba River 20 km north of Lake Upemba.

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Lake Tshangalele is roughly rectangular in shape, some 25 km long and 15 km wide, with a narrow arm (5x15 km) pointing NE, from the tip of which it drains. It has an open water area of approximately 36 250 ha, approximately 1000 m asl. The area of wetland in the valleys of the Lufira and its tributaries north of Lake Tshangalele probably exceeds 350 000 ha.

Wetlands accompany the Lufira almost all the way from Kienge to the Lualaba, a distance of 275 km in a straight line, but possibly 440 km along river. Riparian reed and papyrus swamps, and flooded gallery forest, occupy sections of the river banks. The river and its swamps are largely confined to the eastern side of the triangular depression, along the line of the Kundelungu Mountains, but wetlands also spread along the base of the triangle, adjacent to the Manika Escarpment, along the courses of tributaries, such as the Dikuluwe. Towards the confluence of these two streams, several deeply inundated areas of up to 3600 ha, lie away from the rivers, with less deeply inundated land closer. A chain of almost 100 recent oxbow lakes, situated to the west of the Dikuluwe River, indicates a former course. Another cluster north of the Lufira, below the confluence of the two streams, indicates that that river too has recently changed its course on the flat valley floor. Some of the lakes are 15-18 km long and 200 m wide, while others are just 200 m long and 50 m wide. Tracts of inundated land reach 17 km in width across the Lufira in places, and up to 9 km across the Dikuluwe. Where the Lufira traverses the narrow pass through the highlands of the Manika Plateau, swamps are much less extensive, but they expand again on the far side of the gorge, in the Upemba region.

Wetland Flora & Fauna: The flora and fauna of the Lufira system is similar to that of the Upper Lualaba/Upemba Lake System dealt with in section 3e.

Human Impact & Utilisation: There are fishing villages along the Lufira Floodplain, cattle are grazed in the region, and there is small scale agriculture. Fires often burn into the wetlands in the dry season.

Conservation Status: Unprotected, except for the lower part of the Lufira River immediately above its confluence with the Lualaba.

(E) LAKE DELCOMMUNE

Location: 10°27'-10°55'S/25°24'-25°51'E
Area: c. 60 000 ha
Altitude: c. 1100 m asl
Nearest Towns: Kolwezi (23 km W); Lubumbashi (200 km SE)

General: The Lualaba (Zaire) River rises at a point approximately 11°52'S/26°25'E close to the Zambian border, and incidently, some way south of the source of the Zambezi, 240 km to the WNW. The Lualaba at first flows WNW, parallel to the border, before swinging north to enter the impoundment of Lake Delcommune. Some land along the river is swampy, also land along the border which follows the watershed between the Zaire and Zambezi Basins. Then, other swamps occur around parts of Lake Delcommune, the area having been a wetland prior to impoundment.

Wetland Flora & Fauna: The lake has become an important site for aquatic birds and has been stocked with fish. A large proportion of the species described for the Upemba Lake System (next section) are present. The borderland swamps are mostly grass and

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sedge filled dambos, draining sluggishly to small streams, which may support swamps containing bushy species along their courses, once they have become entrenched in distinct valleys. The riverine swamps are dominated by *Phragmites mauritianus* and its typical associates, but *Cyperus papyrus* occurs in the valley. Floodplain grasses similar to those described for the Luapula are also present, and there is some gallery forest, also of composition similar to that on the Luapula.

Human Impact & Utilisation: The lake is artificial and its creation destroyed most of an existing wetland.

Conservation Status: The lake and its immediate environs are afforded a degree of protection as a Natural Water Reserve.

(F) THE UPEMBA LAKES & THE UPPER LUALABA RIVER

Location: 4°00-10°00'S/25°20'-28°45'E
Area: c. 1 444 000 ha (total wetland on Lualaba System in region)
Altitude: 500-650 m asl
Nearest Towns: Kibombo (at N end); Bukama (at S end)

The Upemba Lakes: This section deals with wetlands on the Lualaba River between Lake Delcommune and Kibombo (4°00'S), a straight line distance of 750 km. Some 40 km after leaving Lake Delcommune the Lualaba enters the broad trough-like Kamolondo Depression, a graben, 100 km wide and 400 km long, oriented SW-NE, between the Manika Plateau on the east and the Hakansson Mountains on the west. The highlands of the Manika Plateau reach 1889 m asl, but the Hakansson Mountains attain heights of just over 1200 m asl. The floor of the trough is 1000 m asl at its SW end, and slopes down quite abruptly to 610 m, at which point it flattens and the Upemba Lakes and Marshes begin. The Upemba System comprises about 30 shallow lakes, the principal ones being, from south to north, Lakes Kabwe, Kabele, Sangwe, Tungwe, Malenda, Upemba, Kisale, Niangwe, Zimbambo, Kibala and Kabamba. These lakes extend along the trough for 225 km, in a belt up to 55 km wide, with a mean width of 37 km. They are set in a continuous belt of swamps, and are filled by the overflowing of the river, which winds through the swamps and between the lakes, communicating with the majority through shallow channels which are often hidden by the dense vegetation. However, it flows through Lakes Kabwe and Kisale, which are thus expansions of the main river bed. In total there are about 800 000 ha of wetland in the trough, and a further 79 000 ha immediately to the west on the Lululwe, Kilubi and Lovoi Rivers, between 8°-9°S and 24°50'-25°40'E. These latter swamps are typical riparian swamps which follow the rivers in belts up to 7 km wide for distances of up to 60 km. These swamps drain into the Lualaba via the Lovoi River, which reaches a confluence between Lakes Kisale and Zimbambo. According to Welcomme (1979) the permanently inundated part of the Kamolondo Depression extends to about 704 000 ha, while in the wet season the flood covers about 1 184 000 ha.

Lake Upemba is the largest of the lakes, situated between 8°32'-8°49'S/26°13'-26°30'E. It has maximum open water dimensions of 40x20 km, and some 53 000 ha of open water in contracted state. However, the lake basin is over 70 km long, the northern half being practically occluded by vegetation. In profile the basin is very shallow, with a maximum

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measured depth of 3.2 m in November, at the end of the dry season. The bottom is covered by soft black mud and much plant debris.

The Upper Lualaba: Having left the Upemba lakes, the Lualaba, after a few kilometres, again enters a swampy belt extending 60 km along the river, with another cluster of small lakes between 6°55'-7°15'S, the largest of these being Lakes Kiltongola and Towe. The river flows almost due north in this sector, and indeed does so all the way to Kongolo (5°20'S/27°00'E), traversing a very flat plateau and picking up two important tributaries on the east bank en route. These are the Luvua River which drains Lake Mweru and the Bangweulu System, and the Lukuga River which drains Lake Tanganyika. The river then loses height in traversing two sets of rapids below Kangolo, and then receives the Luama River on the east bank, before veering northwest to reach Kibombo on the parallel 4°S. Here, extending many kilometres northwards, the west bank is again swampy. Altogether 14 major tributaries enter the Lualaba between Lake Kabamba and Kibombo, but those of the east bank are more important in terms of volumetric discharge, rising as they do in the very wet mountains along the eastern border.

Another extensive wetland system occurs in the headwater regions of the Luama River. This stream has 5 sources in the mountains, two rising at altitudes over 2000 m. The river descends 3 waterfalls and several minor rapids in its lower course, but upstream of Pene Mende (4°18'S/28°11'E), it drains a flat swampy valley, the head of which bifurcates, with a branch leading NE. A tributary, coming down this much narrower valley, drains valley floor swamps right back to its source near Fizi (4°18'S/28°56'E). In their entirety, the Luama Swamps accompany the river and its tributaries for 130 km and comprise about 60 000 ha of wetland.

Climate: Mean annual rainfall over the Upemba Lakes is 1000 mm, with December the wettest month, when falls are in the vicinity of 170-180 mm. The dry season lasts for 155-165 days. Mean incident radiation is 166 Kcal/cm^2/yr, and the system enjoys 2400-2500 hours sunshine/yr, with July the sunniest month (c. 395 hours) and January the most overcast month (c. 130 hours). Mean annual temperature is 24.4°C; the September mean is 27°C, with mean monthly maxima and minima of 36 and 19°C, and the corresponding June figures are 23, 33 and 14°C. Rainfall increases progressively along the Lualaba, north of the Kamolondo Depression, reaching 1400 mm in the vicinity of Kasongo (4°30'S) and 1700 mm at Kindu (3°00'S). Between this point and Kisangani, where the middle course of the Zaire River begins, the Lualaba flows due north through a very wet zone, where over 2000 mm of rain falls each year and there is no distinct dry season.

Hydrology & Water Quality: In the Upemba System, the waters of the Lualaba are high from February-April and low from August-October. The mean fluctuation in water level at Bukama, at the southern end of the system is 2.8 m, with minimum depths of 3 m and maximum depths of 5.8 m. At Maka the change in level is only 1.1 m over the course of a year, with a low level of 1.9 m and a maximum of 3 m. Lake Upemba is high from March-June and low from October-January. The depression is exorheic and drains from the north via the Lualaba.

The waters of the Upemba Lakes are warm with mean surface temperatures close to 23°C in July and 33°C in November. The lakes are polymictic and even bottom temperatures

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reach 31°C in November. The pH range is 6.4–8.0 and the waters may be brown, or yellowy-green in colour.

Wetland Flora: The Upemba Lake/Swamp system presents vistas of tall herbaceous swamps, dominated either by *Cyperus papyrus* or by *Typha domingensis*, but with *Pycreus mundtii* and *Paspalidium geminatum* common on the sides of water courses. All these species line the Lualaba River and the numerous lakes, and huge rotting floating mats of *Cyperus papyrus*, some of which reach 10–15 ha in extent, may detach from the banks and begin to drift on the lakes. This species has, among its lower growing aquatic associates, *Cyclosorus striatus*, *Impatiens* cf. *kasaiensis*, *Ipomoea aquatica*, *Panicum repens*, *Polygonum salicifolium* and *Vossia cuspidata*, and these may all be found on or in the rafts. Other small rafts are found to be composed of *Pycreus* and *Paspalidium*. Little patches of swamp woodland, comprising almost exclusively *Aeschynomene elaphroxylon* and *Hibiscus diversifolius*, occur on abandoned levées and other elevated sandy sites, which are inundated to depths of 40–60 cm at high water. These support a dense avifauna and are often whitened by the guano of roosting birds. The open waters may become covered by waterlilies, *Nymphaea caerulea*, *N. lotus* and *Nymphoides indica*, together with *Lemna* sp., *Pistia stratiotes* and *Trapa natans*.

As the Lualaba flows north the surrounding savannas become more dense until eventually the canopy closes and rises, so that hundreds of kilometres before the river crosses the equator it is enclosed by high equatorial rain forest. The deciduous, and then evergreen gallery forests of the savanna zones become progressively less distinct, physiognomically if not floristically, as finally the galleries merge with the rain forest. The river broadens and its banks become sandier, and the forest front along the river is festooned with lianes. The flora of the riverine forest in this most northerly part of the region is similar to that described in the next section, Wetlands of the Central Zaire Basin.

Wetland Fauna: The fish fauna of the upper Lualaba comprises 141 species, among the most noteworthy of which are the two lungfishes *Protopterus aethiopicus congicus* and *P. annectens brieni*, several species of *Polypterus* (*P. birchir katangae*, *P. endlicheri congicus*, *P. ornatipinnis* and *P. senegalus meridionalis*), and *Ctenopoma ctenotis*, *Ichthyborus besse*, *Oreochromis upembae* and *Tetraodon mbu*. According to Poll (1976) 14 species are endemic to the Upemba system. A number of Upemba species spawn near the sand beaches at low water when they suffer intense predation, e.g. *Clarias* sp., *Labeo annectens*, *Oreochromis niloticus upembae*, *Synodontis notatus* and *S. pleurops*.

The frog and toad populations in the Upemba district are prodigious. Over 40 amphibians have been recognised in the Upemba National Park, 34 of which are known to occur in the wetlands. Some species are reputed to be endemic to the Kamolondo Depression, e.g. *Afrixalus fulvovittatus upembae* (a reed frog) and *Phrynobatrachus cryptotis*. *Hemiscus wittei* is common.

Crocodylus cataphractus is quite abundant but *C. niloticus* is less so. The water monitors *Varanus exanthematicus* and *V. niloticus* are both present, as are several terrapins. Other aquatic or semi-aquatic reptiles include *Amphisbaena quadrifrons capensis*, *Aparallactus capensis punctolineatus*, *Boulengerina annulata*, *Dromophis lineatus*, *Monopeltis scalper gerardi*, *Natriciteres olivacea*, *Naja melanoleuca*, *Philothamnus irregularis*, *Psammophis olivacea* and *Python sebae*. Among the arboreal species of gallery forests

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Darypeltis scabra, *Philothamnus semivariegatus* and *Thelotornis kirtlandii* are most common.

The avifauna of the wetlands is very similar to that of the Bangweulu Basin in Zambia, and to the Lake Mweru/Luapula Floodplain fauna. It includes most of the widespread species listed in section 1, Bas-Zaire, together with *Actophilornis africana*, *Ardea goliath*, *Balaeniceps rex*, *Butorides rufiventris*, *Dendrocygna viduata*, *Grus carunculotus*, *Larus cirrocephalus*, *Limnocorax flavirostra*, *Muscicapa aquatica*, *Pelecanus rufescens*, *Plectropterus gambensis*, *Ploceus pelzelni*, *Porphyrulo alleni* and *Sarkidiornis melanotos*. Palaearctic migrants include *Acrocephalus schoenobaenus*, *Chlidonias leucoptera*, *Larus fuscus*, *Motacilla flava*, *Riparia riparia* and *Sterna hirundo*.

Mammals associated with wetlands throughout this particular region include *Aonyx capensis*, *Atilax paludinosus*, *Cercapithecus mitis opisthostictus*, *Dasynnys incomtus*, *Hippopotamus amphibius*, *Kobus ellipsiprymnus*, *K. leche*, *Leptailurus serval*, *Laxodonta africana*, *Potamochoerus porcus*, *Potamogale velox* and *Syncerus caffer*. Other species are particularly associated with the papyrus and *Typha* swamps, e.g. *Pellomys fallax*, *Tragelophus spekei* and *Thryonomys swinderianus*, while yet others frequent the gallery forests of the Lualaba and its tributaries. Among these the following can be cited: *Cephalophus monticola*, *C. sylvicultor*, *Cercocebus aterrimus*, *Colobus badius foai*, *C. polykomos prigoginei*, *Felis aurata*, *Galago demidovii*, *Nandinia binotata*, *Pan paniscus* and *Tragelaphus scriptus*.

Human Impact & Utilisation: The southern part of the region is comparatively densely populated. The large towns of Lubumbashi, Likasi, Tenke, Kolwezi, Lubudi and Bukama are strung out from SE to NW across the southern end of the region, but the populations of these centres exert little influence on the wetlands immediately to the north, except that of Bukama at the southern end of the Upemba System. Within the Kamolondo Depression population density increases from south to north, but the only centre is Malemba-Nkulu, in the region of which there were 175 388 inhabitants in 1975. There are neither manufacturing industries nor tourism. Fishing villages occur along the Lufira, and around the northern, unprotected lakes of parts of the Upemba System. Fishing in the depression is locally intense. The total catch for 1957 was in excess of 22 000 tonnes, but the figure has declined since then. Nevertheless, the 15 424 tonnes catch of 1981 was the lowest for some years. The area is the chief fish producing centre for Shaba and most of the annual catch is exported to the afore-mentioned towns, or to Kasai. The commercial fishing centres are Maka, Kialo, Nyonga, Kalombe, Kikondja, Masango, Malemba-Nkulu, Kabala, and Mulongo.

The Lualaba River is navigable between Bukama and Kongolo, a distance of some 650 km, but in 1938 the railway line between Kongolo and Kabalo was opened, and since then regular commercial river traffic has terminated at Kabalo. Before 1956 the annual cargo haul downstream was 60 000-80 000 tonnes, while coming upstream, it was about 50 000 tonnes, with about 8000 passengers being carried in each direction. In 1956 a rail link was inaugurated between Kabalo and Kamina (107 km NW of Bukama), after which river transport rapidly diminished in importance, but there is still traffic between Malemba-Nkulu, in the centre of the Upemba System, and Kabalo. In the southern part of the Upemba System, Bukama and Malembo-Nkulu, the maintenance of a navigable channel through the papyrus has been virtually abandoned.

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In the dry season burning of peripheral wetland areas, in the Kamolondo Depression and Lufira Valley, often causes fires in the wetlands.

Conservation Status: About half of the Upemba Lake System, comprising all the local biotypes, is totally protected in the Upemba National Park, established as an integral nature reserve. The protected area includes Lakes Kabwe, Kabele, Sangwe, Malenda, Tungwe, Upemba and Kisale, and 180 km of the Lufira River, upstream from its confluence and through the gorge in the Manika Plateau, almost to Lufira Falls.

4. Wetlands of the Central Zaire Basin

Co-ordinates of Region: 3°00'N-4°00'S/16°00'-26°00'E
Area of Region: c. 774 562 km^2
Altitudinal Range: 310-500 m asl

General: The central depression of the Zaire Basin is largely covered by high tropical rain forest with a canopy often over 45 m high. This is the largest expanse of this type of vegetation in Africa, and the numerous rivers which drain it are essentially forest rivers; they are all slow flowing, the broader ones with lacustrine characteristics. The area is flat or very gently undulating, with a general inclination towards the west.

(A) RIVERINE SWAMPS & FORESTS

General: The Kasai River (known as the Kwa in its lowest course), always over 2 km wide and in one place reaching 8 km in width, skirts the southern edge of the depression between Ilebo (= Port Francqui, 4°20'S/20°35'E) and its confluence with the Zaire River (3°10'S/16°12'E), collecting the water of all the streams flowing down from Angola across Kasai and southern Bandundu Provinces. It also drains the southern part of the central depression, receiving the waters of the Lukenie River, together with those collected into Lake Mai Ndombe, through its major north bank tributary, the Fimi River.

Low plateau land, at an elevation of about 500 m, forms the eastern boundary of the depression and another block of elevated land between the Zaire and Oubangui Rivers forms the northern boundary. The Zaire River traverses the northern side of the depression, flowing from east to west in an island studded bed. This reaches 17 km in width where Sumba Island (90 km long) interrupts its course (1°44'N/19°33'E). Along the north of the depression the Zaire River receives, on its north bank, numerous tributaries draining the elevated land between it and the Oubangui, which here flows in parallel farther north. In passing downstream from Kisangani the principal tributaries are the Tshopo, Lindi, Aruwimi, Itimbiri (which forms a substantial delta in the Zaire River, so sluggish is the current) and Mongola Rivers. Large swamp forests and raphiales cover the lower valley floors of all these tributaries, e.g. there are at least 150 000 ha of swamp in the Itimbiri River system, including a solid block of over 54 000 ha which occludes the lower valley floor with a mean width of 9 km over a 60 km stretch, immediately above its delta. All the streams draining into the Itimbiri carry swamp forest almost to their sources, and such is the case for all the other north bank tributaries.

The entire plateau area between the Zaire and Oubangui Rivers is scored by the strip swamps of riverine wetlands, always comprising 5-10% of the land surface, but 20-40%

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to the south of Gemena (3°13'N/19°48'E) in the upper reaches of the Mongala and Giri Rivers, and to the west below the confluence of the Lua Dekere and Lua Vindu Rivers. In the northeastern borderlands all streams in the catchments of the Mbomou and Uele Rivers are swampy, and after their confluence, to form the Oubangui at Yacoma (4°05'N/22°22'E), both its course and that of its tributaries are swampy. The bed of the Oubangui forms the border with the Central African Republic, and thereafter, that with Congo, and its most important tributaries enter from those countries.

In the central part of the depression, south of the Zaire River, all the major streams, with the exception of the Lomami, flow roughly E-W again parallel to the Zaire, and many carry substantial areas of swamp forest in their shallow valleys, e.g. swamps occur upstream from the confluence of both the Lulonga and Ruki Rivers with the Zaire River. Both rivers bifurcate into lesser tributary streams, and on these, swamps are equally well developed. The Ruki, for example, divides to form the Momboyo and the Busira. Swamps occur on both these rivers above their confluence to form the Ruki. There is a block of 25 000 ha on the Momboyo, and another of 55 000 ha on the Busira, between 19°00' and 19°27'E. Farther upstream, near Boende, the Busira River divides at the confluence of the Tshuapa and Lomela Rivers. This is in the wet heart of the central depression where mean annual rainfall exceeds 2000 mm/yr and there is no dry season. Both the Tshuapa and Lomela carry broad swamp belts along their banks. There is a block of permanent swamp forest along 165 km of the Tschuapa from 20°33' to 22°00'E, covering about 160 000 ha, and another of 88 000 ha on the Lomela from 20°35' to 21°30'E, through which the river meanders for 110 km, and farther up this river, yet another block of 46 500 ha between 21°50' and 22°18'E. Land subject to inundation accounts for 20-25 % of the total land surface throughout parts of the Tshuapa catchment. By contrast to the foregoing rivers, the Lomami flows from south to north, parallel with the Lualaba section of the Zaire River, and joins it after that river has swung west. The confluence of the two rivers is 125 km downstream from Kisangani. Extensive swamps occur in the lower valley of the Lomami, and on the bank of the Zaire River opposite the Lomami mouth.

At a longitude of 20°E the Zaire River swings SW to Malebo Pool and in this section, along its left bank, collects all the tributaries draining the central depression, including the Ruki and finally, the Kasai. Throughout their courses the Kasai, Oubangui and Zaire Rivers flow over a broad alluvial plain, and although by no means continuous, behind their levées are seasonally flooded forests which extend away from the rivers on deep alluvium for distances of up to 50 km. Seasonally flooded forest also covers or fringes many islands in the river, and at the riverside, on low islands in midstream and in depressions in the seasonally flooded forests there are patches of permanent swamp forest. On the south bank there is a block of swamp forest, covering 68 000 ha just west of Kisangani and a major block along 250 km of river frontage from 18°45' to 21°40'E, covering some 425 000 ha, opposite Sumba Island. Here, the land is traversed by anastomosing channels, parallel with the main river, in what is effectively an inland delta. However, the largest expanse of permanent swamp forest occurs at the western side of the depression, where the streams draining the central part flow into the Zaire River. Here, a virtually continuous block of permanent and seasonally flooded forest extends along the left bank for 250 km below the Ruki River mouth near Mbandaka (= Coquilhatville, 0°03'N/18°28'E), and inland for 275 km, covering about 5 000 000 ha

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and encompassing Lakes Tumba and Mai Ndombe. Immediately south of this, opposite the mouth of the Alima River which enters from Congo, another swampy block 70 km wide and up to 30 km deep covers over 190 000 ha along the Sangasi Itoka and other small tributary streams.

Throughout the central depression, away from areas subject to inundation as a consequence of rivers overflowing their banks, rain swamps develop in depressions in which the water table is close to the surface and which may be intermittently flooded by rain.

On its right bank the Zaire River receives the Oubangui, which has also turned sharply south to form the border with Congo for 500 km, and to meet the Zaire River at point 0°27'S/17°47'E. An enormous area of permanent swamp exists in the triangle of low flat land between them. This measures 375 km along the perpendicular from base to apex (at the confluence) and 165 km across the base in the north and comprises some 3 000 000 ha of permanently waterlogged or flooded forest. The Giri River, rising near Kungu (2°50'N/19°19'E) almost bisects this triangle of land, providing a trench roughly along the perpendicular, and flowing into the Oubangui just before that river enters the Zaire River. Numerous channels, up to 50 km long, connect the Giri and Zaire Rivers through the swamps, along the eastern side of the triangle. At the confluence with the Oubangui, the Zaire River is fully 15 km wide.

Wetland Flora

The unflooded parts in the west and centre of the great depression are covered by evergreen forest, but on the elevated lands bordering it in the far northeast and southeast, where rainfall is less, the forest becomes semi-deciduous in nature. In all cases, where the forests are undisturbed, the wetlands are dominated by arborescent species, and the swamp forests tend to grade into terrestrial forests through extensive transition zones in consequence of the flatness of the land. In some places, floating grass swamps occur along the rivers in areas of deep semi-permanent inundation, with swamp forests farther away from the rivers on less deeply inundated ground.

Riparian & Floodplain Associations: In the north of the region, between the Oubangui and Zaire Rivers, where agriculture is most intense, *Thalia welwitschii* (Marantaceae) swamps become established along rivers where the gallery forest has been destroyed. The existence of this vegetation depends upon a variable water level and a fairly swift current, at least in the wet season. *Thalia* is an obligate heliophyte, and these swamps, which contain few associates, quickly deteriorate if trees reappear. If the water levels are lower and less variable, and the water movement is sluggish, *Cyrtosperma senegalense* becomes established and is usually quickly succeeded by arborescent species.

Other secondary associations occur in the higher country between the Zaire and Oubangui Rivers, between 500-700 m asl. Here, *Loudetia phragmitoides* swamps occur along the edges of gallery forests on poorly drained soils. These swamps include such other species as *Cyclosorus striatus*, *Cyperus halpan* (= *C. haspan*), *Eulophia caricifolia*, *Ludwigia africana*, *Lycopodium cernuum*, *Sauvagesia erecta* and *Torenia parviflora*. They occur where the water table is always high and periodic flooding occurs, where as on better drained soils, where fires frequently occur, *Imperata cylindrica* becomes dominant.

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Also in this region, where pools and quiet backwaters in the narrow parts of rivers are heavily shaded by gallery forest, a *Nymphaea lotus-Utricularia thoningii* community develops. This is floristically impoverished by the low light intensities. By contrast, where the canopy is open there is a much richer vegetation. Provided that water movement is minimal, water levels seem unimportant and here, *Nymphaea maculata* is dominant, while *Eleocharis acutangula*, *Fuirena stricta*, *Hydrocharis chevalieri* and *Sabicea africana* are the most common of a dozen or more associates.

Pioneer associations: The pioneer species on sandy banks along and in the large rivers of the central depression is *Panicum repens*, which is soon joined by *Acroceras zizanioides*, *Cyperus erectus*, *C. maculanus* and *Hemarthria natans*, leading finally to a sward of *Cynodon dactylon* where inundation is infrequent. By contrast on mudbanks, the pioneers are *Basilicum polystachyon*, *Commelina diffusa*, *Eclipta prostrata*, *Ipomoea reptans* and *Ludwigia repens*. Meadows of aquatic grasses develop in deep water along the banks of backwaters, and here *Echinochloa pyramidalis*, *E. stagnina* and *Vossia cuspidata* are the most frequently encountered species, but in shallower places *Phragmites mauritianus* or *Cyperus papyrus* may cover extensive areas in monospecific stands. Little depressions on islands in the river are colonised by *Cyperus longibracteatus* and *Rhynchospora corymbosa* when they fill up, usually with some persistent *Echinochloa pyramidalis*. Open surfaces in quiet backwaters tend to be covered by *Lemna paucicostata*, *Nymphaea caerulea*, *N. lotus*, *Pistia stratiotes* and *Utricularia* spp., but comparatively recently *Eichhornia crassipes* has been introduced and tends to dominate this habitat, and also to invade the areas normally supporting floating grasses. It has become a serious threat to navigation in certain localities. Steep sandy river banks and cliffs are covered at water level by plaques of *Marchantia chevalieri*, and above the water by a tracery of ferns dominated by *Dicranopteris linearis*. On any slips or shelves however, and on the tops of the cliffs, the forest vegetation quickly takes root, in particular *Anthocleista nobilis*, *Barteria nigritiana*, *Caloncoba welwitschii*, *Vernonia conferta* and occasionally, *Alchornea cordifolia*.

As they become more elevated, islands are colonised by woody species, first by single trees, or little clumps of *Alchornea cordifolia* with *Bridelia micrantha*, *Ficus mucuso* and *Spondianthus preussii*, often with abundant *Mimosa pigra*. This pioneering woody vegetation is quickly entangled by creepers, and *Alchornea* is usually dominant in the early stages of the succession. However, in the east of the region at least, a tall forest of *Lannea welwitschii*, with *Ceiba thonningii*, *Ficus mucuso*, *Oxystigma buchholzii*, *Pseudospondias microcarpa* and *Spondianthus preussii* quickly replaces the *Alchornea* association. Occasionally *Elaeis guineensis* may be encountered in this vegetation, and the understorey becomes moderately thin with *Leptonychia batangensis* the most characteristic species. At the upstream ends of islands, erosion during high floods may cause trees to be uprooted, and when the waters subside the gaps so formed tend to be filled by stands of the coarse herb *Costus lucanusianus*. Swampy depressions on the islands and along the river banks are covered by a forest containing *Albizia laurentii*, *Chrysobalanus atacorensis*, *Coffea congensis*, *Irvingia smithii*, *Uapaca heudelotii* and *Trichelia retusa*, and there may be extensive monospecific stands of *Uapaca guineensis*, both on the islands and along the mainland riverbanks. The strong currents which arise during the periods of high flood in the main river channels seem to inhibit the development of other seral stages.

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In the north of the region, between the Zaire and Oubangui Rivers, the banks of tributaries subject to regular inundation are colonised by *Alchornea cordifolia*, *Macaranga saccifera* and *Raphia laurentii*, all heliophilic species. This tends to be succeeded by *Mitragyna stipulosa* forest described below, but the floodplain forests on the valley floors of these rivers usually become separated from the water in the river channel proper, by a narrow strip of riparian fringe forest. This fringe forest grows where inundation is semi-permanent, and it contains characteristically, an abundance of *Uapaca heudelotii* with *Antidesma leptobryum*, *Embellia retusa*, *Flacourtia* sp., *Hymenocardia heudelotii*, *Parinari congensis*, *Trichelia retusa* and *Uvaria laurentii* as common associates.

Floodplain Forests: Behind the riparian strips periodically inundated forests occur. Several types of riverine swamp forest are encountered along tributary rivers, differing quite markedly in their physiognomy and depending for their existence upon different soil types. Floristically these forests are quite diverse, varying in composition from place to place across the vast central depression and often they are mosaics of different associations. However, to generalise, on muddy soils along watercourses, where inundation is periodic, but deep and frequent, and where the water flows only very slowly, the forest is usually dominated by *Mitragyna stipulosa*.

Mitragyna is found everywhere, but its associates vary. Among the most widespread are *Alstonia congensis*, *Anthocleista liebrechtsiana*, *Anthonotha pynaertii*, *Baikiaea insignis*, *Berlinia bruneelii*, *Brazzeia congoensis*, *Crotonogyne giorgii*, *C. poggei*, *Dialium pachyphyllum*, *Dichostemma glaucescens*, *Eriocoelum microspermum*, *Macaranga* sp., *Nauclea diderrichii*, *N. pobeguinii*, *Ouratea arnoldiana*, *Parinari glabra*, *Syzygium gilletii*, *S. guineense* ssp. *huillense*, *Uapaca heudelotii*, *Voacanga thouarsii*, *Xylopia aethiopica* and *X. rubescens*. *Ancistrophyllum secundiflorum*, *Calamus deeratus*, *Eremospatha* spp. and *Popowia lucidula* are scandent species. *Cyrtosperma senegalense* and *Marantochloa congensis* are common in the understorey. The canopy of this type of forest reaches 30-40 m.

In places where the water moves quite swiftly, and where inundation is less prolonged and the soils are sandy, the forests are dominated by *Guibourtia demeusei*. The forest is dense and the canopy reaches or exceeds 30 m, but the under-storey is sparse. Common associates in this forest type are *Brazzeia eetveldeana*, *Casearia congensis*, *Cleistanthus libericus*, *Coffea congensis*, *Cremaspora triflora*, *Dialium reygaertii*, *Drypetes angustifolia*, *Garcinia pynaertii*, *Hymenocardia heudelotii*, *Memycylon* sp., *Mimusops warneckei*, *Mapania bieleri* (Cyperaceae), *Morelia senegalensis*, *Popowia lucidula*, *Salacia pallescens*, *Scytopetalum pierreanum* and *Xylopia katangensis*.

Along the lower courses of tributaries to the Zaire River, in the east of the depression, the lowest parts of the valley floors, which are almost permanently flooded but constantly flushed by moving water, tend to be covered by a forest distinguished by an abundance of *Lasiodiscus mannii*, *Raphia* spp. and *Uapaca guineensis*. On either side, in the wider valleys, strips of *Mitragyna stipulosa* forest grade into broad belts of pure *Gilbertiodendron dewevrei* forest, at higher and less frequently inundated levels. *Gilbertiodendron* forest occurs on hydromorphic soils, but is transitional to terrestrial forest, and in the north often contains a substantial proportion of *Anopyxis klaineana*.

Patches of alluvium build up away from the current on the quiet sides of meander bends in all the larger rivers, and deltas have developed where tributary streams enter quiet

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stretches of the Zaire River. These muddy sites are first colonised by *Alchornea cordifolia*, but this is quickly succeeded by mixed forest, leading to a stage dominated by *Alstonia congensis*, and this in turn eventually gives way to an *Entandrophragma palustre* forest. This latter species may be found in association with *Anubias affinis*, *Dichostemma glaucescens*, *Elaeis guineensis*, *Mitragyna stipulosa*, *Myrianthus scandens*, *Pycnanthus marchalianus*, *Raphia* spp., *Ricinodendron palustre*, *Sersalia palustre* and *Symphonia globulifera*, but it sometimes occurs in almost monospecific belts more than 5 km wide. This association constitutes one of the last stages of the hydrosere, preceding *Gilbertiodendron dewevrei* forest, which usually provides a transition to terrestrial rain forest.

Permanent Swamp Forests: In some shallow basins, away from the rivers, where inundation is more or less permanent and the surface water is semi-stagnant, the forest is characterised by an abundance of *Sterculia ambacensis*. In these sites the soil surface is always muddy, and most arborescent species have either tall flanged buttresses or stilt roots. The buttresses of *Sterculia ambacensis* are narrow and plank-like, several metres tall at the base of the trunk, but often wind tortuously over the forest floor with heights of 50-100 cm for distances of up to 15 m. In this type of forest the most common associates are *Coelocaryon botryoides*, *Lasiodiscus mannii*, *Mimusops warneckei*, *Pseudagrostistachys ugandensis*, *Pseudospondias microcarpa*, *Symphonia globulifera* and *Treculia africana*.

Wetland Fauna

There is a rich fish fauna. Within the central depression, the three major rivers provide 3150 km of continuous river surface, 2-15 km wide, providing well over 2 000 000 ha of water, open to the sun and wind. On either side of the rivers there are strips of swamp forest providing, probably, a further 8 500 000 ha of seasonally aquatic habit, but throughout this area, there are permanent swamps which never drain. The myriad tributaries of these three principal rivers have a different character. They are mostly quicker flowing, and those under 50 m wide are generally shaded by the forest, with lower water temperatures. They also have narrower floodplains. The fish fauna changes across the central depression, but in any one place it is possible to distinguish different faunas in different habitats; in the open waters of the main rivers, along the banks, in the creeks, coves and meadows of aquatic vegetation, in the permanent swamps, and on the floodplains. Rapids or waterfalls isolate this giant system, situated 300-425 m asl, from the estuarine section of the river and the streams of the highland parts of the Zaire Basin.

Having said this, the fish fauna of the river is not known in any detail. Studies have been made at Malebo Pool (Poll, 1959) at the lower end of the depression, at Yangambi (0°47'N/24°24'E) far up the Zaire River (Gosse, 1963), and at Ikela (1°06'S/23°06'E) way upstream on the Tshuapa River (Matthes, 1964). Many fish leave the rivers to spawn in the forest at high water, moving back to the channels when the floods recede, but the juveniles of some species remain in the permanent swamps. The number of species found in the forests and swamps is far lower than that found in the river, and in the river the number of both individuals and species is greater along the banks than in the open waters. At Yangambi, of 43 Mormyridae identified, 38 species are found in the river, 14 in the tributaries and 6 in the swamps. Of 14 cichlids, 7 are found in the river, 6 in the tributaries

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and 1 in the swamps, and of 10 anabantids, 5 occur in the river, 8 in the tributaries and 3 in the swamps.

The permanent swamp dwelling fishes have accessory breathing organs since the swamp water is semi-stagnant, and the bottom layers are completely anoxic. Those so far identified are *Clarias* spp., *Clariallabes melas*, *Channallabes apus*, *Ctenopoma fasciolatum*, *Ctenopoma* sp., *Hemichromis bimaculatus*, *Pantodon buchholzii*, *Papyocranus* sp., *Paraophiocephalus obscurus*, *Pelmatochromis ocellifer*, *Phractolaemus* sp., *Polypterus palmus*, *Protopterus aethiopicus*, *P. dolloi* and *Xenomystus nigri*, 17 species in all. The numerous high water visitors include *Hepsetus odoe*. These swamps never dry out, so that the protopterans do not aestivate as they do elsewhere in Africa.

Huge shoals of plankton feeding *Microthrissa* are pelagic in the rivers, migrating up and downstream seasonally. Small species of *Barbus* and *Clupeopetersius*, and their predators such as *Hydrocynus vittatus*, also occur in pelagic situations. Among benthic fish there are many insect or detritus feeders in the rivers, e.g. species of *Barbus*, *Chrysichthys*, *Synodontis* and *Tylochromis*, also *Citharinus*, a mudsucker, and piscivores, including other species of *Chrysichthys*, *Mormyrops* and *Polypterus*, and species of *Labeo* and *Tetraodon* where the bottom is sandy and the current swift. Large species of *Clarias*, weighing as much as 150 kg, have been taken from deep holes on the downstream sides of islands, and here also live very large specimens of *Heterobranchus* and *Lates niloticus*, the latter attaining weights of 50 kg. *Malapterus electricus* is common throughout the system.

Two crocodiles, *Crocodylus cataphractus* and *C. nilaticus*, occur in the rivers, also *Varanus exanthematicus*, *Pelomedusa* sp., *Pelusios* sp., and aquatic or semi-aquatic snakes including *Boulengerina annulata*, *Dromophis lineatus*, *Philothamnus irregularis*, *Natriciteres olivacea*, and *Python sebae*. In the trees there are other snakes, including *Dendroaspis* sp., *Dispholidus typus*, *Philothamnus* sp. and *Thelotornis kirtlandii*. The spectrum of birds is very similar to that described in section 1, Bas-Zaire.

Mammals in the system include the usual aquatic types, *Aonyx congica*, *Atilax paludinosus*, *Dasymys* sp., *Hippopotamus amphibius* and *Lutra maculicollis*, with *Osbornictis piscivora* confined to the north. Species of the swamp forests include *Cephalophus monticola*, *C. sylvicultor*, *Genetta tigrina*, *Hyemoschus aquaticus*, *Kobus ellipsiprymnus*, *Loxodonta africana cyclotis*, *Loxodonta pumilio* (sometimes said to be another form of *L. africana cyclotis*), *Manis gigantea* (N only), *M. tetradactyla*, *Neotragus batesi* (NE only), *Syncerus caffer nanus*, *Tragelaphus scriptus* and *T. spekei*. The pygmy chimpanzee, *Pan paniscus*, is widespread though uncommon in the central depression between the Zaire, Lualaba and Kasai Rivers. It visits seasonally flooded forests during dry periods. *Potamochoerus porcus* is locally abundant, while *Phacochoerus aethiopicus* occurs in the eastern parts, but is most common east of the Lualaba and west of the Oubangui in Congo. *Felis aurata* and *Panthera pardus* are also known from the region. Many monkeys live in riverside forests, e.g. *Allenopithecus nigroviridis* (N only), *Cercocebus aterrimus*, *C. albigena*, *C. galeritus chrysogaster* (south of the Zaire River to the Lukenie and east to the Lomami), *Cercopithecus aethiops cynosurus* (S only), *C. ascanius*, *C. l'hoesti* (E only) *C. mitis maesi*, *C. stuhlmanni* (NE only), *C. mona wolfi* (W only), *C. mona elegans* (E only), *C. mona denti* (NE only), *C. neglectus*, *C. nictitans* (NW only), *C. pogonias grayi* (N only), *Colobus badius*, *C. guereza* (N only), *C. poly-*

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komos and *Miopithecus talapoin* (W only). Other arboreal species include *Anomalurus beecrofii* (NE only), *A. derbianus*, *A. pusillus* (N only), *Dendrohyrax arboreus*, *Funisciurus congicus* (WC depression), *F. pyrrhopus* (N only), *Galago demidovii*, *Heliosciurus rufobrachium*, *Idiurus macrotis* (N only), *I. zenkeri* (N only) and *Zenkerella insignis* (W only).

Human Impact & Utilisation: Throughout the central depression, land which is subject to regular inundation is generally still in pristine condition, since, traditionally, it has been regarded as having no agricultural potential. However, in a number of sites adjacent to the banks of the larger rivers, where inundation is distinctly seasonal, there have been extensive local clearances for rice production. Almost all the rivers are fished, and the major streams provide the principal communication routes to the interior, linking the railheads at Kinshasa, Ilebo, Bumba and Kisangani, and providing the only viable route for cargo from Kinshasa to many major centres. The Zaire and Oubangui Rivers are also used by traffic to ports in Congo and the Central African Republic.

Conservation Status: A large area, c. 3 600 000 ha, of the southern central depression is protected in the Salonga National Park. This is in two sections, separated by a broad corridor of land. The southern section includes the watershed separating the Luilaka River in the north from the basins of the Lukenie River in the south and the Lokoro River in the west. Part of the Lomela River system is protected in the northern section. The park is very poorly explored, from the biological point of view. Access is by river and there are neither tourist facilities nor management plans. The area has been left as wilderness.

Along the northern border, the Bomu Nature Reserve lies along the south bank of the Bomu River, extending from a point about 40 km above the confluence with the Oubangui River for about 500 km to the border with Sudan. Within this reserve, in addition to the south bank of the Bomu River, which forms the border with the Central African Republic, there are the valleys of several tributary rivers including the Asa and Gwane. The far eastern section of the park is much drier than other parts of Zaire with a long dry season, during which temperatures may rise above 35°C and desiccating NE winds blow from Sudan. There are nevertheless extensive wetland areas in the reserve, including *Loudetia* and papyrus swamps and flooded gallery forests.

(B) LAKE TUMBA

Location: 0°37'-1°00'S/17°49'-18°09'E
Area: 76 500 ha (open water)
Altitude: 325 m asl
Nearest Towns: Mbandaka (80 km NNE); Kinshasa (480 km SE)

General: The lake is shallow, increasing in depth from 3 m in the south to 8 m in the north, at the entrance to the Irebié Canal, through which it drains to the Zaire River. The banks are steep with the maximum water depths being found close to the banks. The periphery is cloaked by forest, some of which is unflooded, but much of which is seasonally or permanently inundated. In sites of deepest inundation the forest gives way to herbaceous swamp. There are several small islands in the lake, and affluent streams have formed small deltas.

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Climate: The lake enjoys about 2000 hours of sunshine a year, with little variation from month to month. Total incident radiation amounts to 133 Kcal/cm^2/yr. Wind speeds tend to rise from 4 km/hr in the early morning to about 8 km/hr at midday and then die back to 3 km/hr by the evening. Winds are predominantly from the south during low water periods but swing to the west during the high water periods. Occasionally there are violent storms. Mean annual rainfall is 1800 mm, with maximum intensity in October and November (200-220 mm/month) and February-April (170-200 mm/month), and a minimum in July when only 70 mm may fall. Relative humidity is 80-90% throughout the year, and evaporation from the lake is estimated as 1300 mm/yr. Mean annual temperature is 25.5°C. The mean monthly figure for March-April is also 25.5°C, with mean daily maxima and minima of 31.5 and 21.5°C. The corresponding figures for July are 24.5, 29.5 and 21°C.

Hydrology & Water Quality: The lake was formed in recent times by the obstruction of a tributary river close to the point where it discharged into the Zaire River, leading to the inundation of part of its shallow lower basin. It has several affluents draining a region of permanently and seasonally inundated forests. However, water may enter it from the Zaire River at times of high flood. Water level fluctuates by about 4 m a year, but there are also important fluctuations of the mean lake level from year to year.

The lake is unstratified and the water temperature varies between 26-33°C over the course of a year, with Secchi depths of 90-100 cm in mid-lake and c. 75 cm near the banks. The waters are humic, stained brown and acidic, with a pH range of 4.5-4.9. Salinity is low with a total mineral content of 30-35 mg/l. By contrast suspended organic matter is high, also accounting for 30-35 mg/l. Dissolved oxygen is however, relatively abundant throughout the water column and throughout the year, there generally being 4-6 mg O/l, representing 50-70% saturation.

Wetland Flora: In calm coves the lake water is covered by floating mats of *Echinochloa pyramidalis* and *Panicum parviflorum*, which towards the banks merges into a bed of *Jardinea congoensis* and *J. gabonensis*, with thickets of *Cyrtosperma senegalense* and *Rhynchospora corymbosa*. This peripheral vegetation may extend out into the lake for 100 m or more, where the edges may be broken up by wave action to create free drifting masses. These, if they come to shore, start fresh colonies. Pools of open water are quite common within the meadows of floating grasses, and are sometimes partly occupied by an association of *Nymphaea lotus* and *Utricularia benjaminiana*. *Eichhornia crassipes* is sometimes dragged into the lake by boats, or enters at times of very high floods from the Zaire River, but does not become established, possibly because of the acidity of the water.

The junction of the herb zone with swamp forest on the banks is marked by the development of a shrubbery, dominated by *Dissotis segregata*. Where the bank is steep, swamp forest develops on the lakeward side of the bank, in sites only exposed at the periods of lowest water, and thus submerged up to 4 m deep at high water. The dominant tree is *Irvingia smithii*, with *Alchornea cordifolia* and *Cynometra schlechteri* as the most abundant associates. A little higher, in the zone of periodic inundation, the forest is dominated by *Gilbourtia demeusei* and *Uapaca heudelotii*.

Swampy banks of gentle slope are colonised by a forest of *Oubanguia laurentii*, with an abundance of climbing palms, particularly *Eremospatha macrocarpa*. This forest merges

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with the *Guibourtia-Uapaca* forest, since on rising land the forest floor is periodically exposed. At the edge of the inundation zone, still on ground with a water table close to the surface, *Guibourtia* forest merges with evergreen rain forest.

Wetland Fauna: Some vagrant species of fish enter the lake from the Zaire River during high floods but do not develop populations in the lake. Altogether 111 resident species have been identified in the lake, together with about a dozen vagrants. Open waters support populations of small, plankton feeding, shoaling fish, belonging to the genera *Barbus*, *Clupeopetersius* and *Microthrissa*, together with their predators, such as *Hydrocynus vittatus*, *Mormyrops deliciosus* and *Odaxothrissa losera*. There are numerous mudsucking, detrivores or insectivores, which fall prey to other carnivorous species of *Chrysichthys*, *Malapterus*, *Mormyrops* and *Polypterus*. The plant communities of the quiet coves, with their abundant invertebrate faunas, attract many species feeding on vegetation, insects, freshwater crabs and detritus. Another spectrum of predatory fish occurs here. An unusual group of predators, well represented in the lake, are those feeding almost exclusively on fins torn off other fish. These include species of *Belonophago*, *Eugnathichthys* and *Phago*. Endemism is low, and only *Clarias cangicus*, *Clupeopetersius schoutedeni*, *Congolensis tumbanus*, *Eutropius tumbanus*, *Lamprologus congolensis* and *Tylochromis lateralis microdon* have distributions restricted to the lake and its immediate environs.

Amphibians and their tadpole stages are abundant in the aquatic prairies near the banks. *Crocodylus cataphractus* is common, and *C. niloticus* is present though far less common. A tortoise, *Amyda* sp., varanid lizards, and some terrapins also occur here, together with numerous snakes, including *Boulengerina annulata*, *Python sebae* and various tree snakes. Most snakes associated with the lake are piscivorous. The birds and mammals are similar to those described in the previous section, 4a.

Human Impact & Utilisation: The human population is comparatively high on the eastern side of the lake, above average for the Zaire Depression, and reaches a density of 15 persons/km^2. Here the principal town, Bikoro, has over 1000 inhabitants. By contrast the west bank is very sparsely populated, with a density of less than 3 persons/km^2. The lake is fished commercially and the annual catch varied between 2000-3500 tonnes between 1964-1983 and most of the local people are engaged in, or associated with, the fishing industry, but there is some local agriculture. The principal species fished belong to the genera *Chrysichthys*, *Citharinus*, *Clarias*, *Eutropius*, *Mormyrops* and *Xenomystus*. There is a cargo and passenger boat service between Bikoro and Mbandaka which takes 21 days for the return trip, and carries on average 400-1200 tonnes of cargo upstream, returning with 1300-1800 tonnes.

Conservation Status: No part of the lake is protected, but it is proposed that the bays and channels of Bituka, Lobambo and Nganga on the sparsely populated southern and western shores should become an integral nature reserve. It is thought that the creation of such a reserve would not interfere with profitable fishing on the lake.

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(C) LAKE MAI NDOMBE

Location: 1°32'-2°43'S/18°03'-18°36'E
Area: c. 230 000 ha (open water area)
Altitude: c. 310 m asl
Nearest Towns: Bolobo (225 km W); Kinshasa (375 km SE)

General: The lake is entirely surrounded by equatorial forest and measures 135 km in length, with a mean width of 17 km. It is oriented N-S and reaches a maximum width of 55 km in the north, but tapers to a point where it discharges into the Fimi River in the south. The lake occupies an alluvial depression. It forms the lowest point of a shallow swampy basin and around most of its perimeter its banks shelve gently into the water and are densely forested. The water is shallow with a mean depth of perhaps 3 m. On the east and southwest the beds are of Pleistocene, or even Pliocene age, dating from the time when the entire depression was flooded, but in the northwest the beds are very recent.

Climate: The lake enjoys about 2100 hours of sunshine a year, with monthly receipts ranging from 140-185 hours, with maxima in May-June and a minimum in November. The mean annual incident radiation receipt is 127 Kcal/cm^2 and evaporation from the lake has been estimated as 1356 mm/yr. Relative humidity varies between 80-90% throughout the year, but with the lowest values, c. 80% being recorded at the southern extremity in August. The mean annual temperatures are close to 25.3°C all over the lake, with a mean figure of 25.9°C in March, and mean monthly maxima and minima of 30.9 and 22.4°C respectively, while the corresponding figures for November are 24.7, 29.4 and 21.1°C. Wind speeds are similar to those reported for Lake Tumba, but violent gusts are uncommon. Mean annual rainfall increases from 1700 mm in the south to 1900 mm in the north. Maximum falls of up to 225 mm occur in October, and minimum falls in July range from 10-50 mm. There is a short but distinct dry season, lasting 50 days in the north but nearly 80 days in the south over the June-August period.

Hydrology & Water Quality: Lake Mai Ndombe has 14 major affluents draining some 6 768 000 ha of very wet swampy land, the most important of which are the Lokoro and Lotoi which enter the northeastern arm of the lake and the Olongo Lule which enters the northwestern arm. The lake spills over into the Lukenie River, draining another huge area to the east, which is thereafter known as the Fimi River. This eventually discharges into the Kasai River. The black humic waters of Lake Mai Ndombe do not immediately mix with the clear waters of the Lukenie, so that after the confluence, the Fimi River has a ribbon of black water along the north bank and a ribbon of clear water along the south bank. Following the confluence with the Kasai, the brown Fimi waters also remain separate from the reddish Kasai waters for a long distance. Low water in the lake is reached in September and high water is from January-April, and there is an annual fluctuation of about 2 m in water level. The variation of mean water level also fluctuates by about 2 m from year to year. The rise of water levels during October-November is due in part to water entering from the Lukenie, with water flooding across country from this river 50 km upstream of the point where it picks up the effluent from Lake Mai Ndombe. It has been estimated that the water content of the lake varies from 4-10 billion m^3 over the course of a year.

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The temperature is quite high, but there are no reliable figures. However, judging from the incident radiation regime and its shallowness, and drawing parallels with Lake Tumba, it is probably in the range of 28-30°C. The waters are dark and transparency is low, c. 80 cm. The pH range is 4.0-4.5. The water column is oxygenated throughout, but never saturated, and the level of mineralisation is very low.

Wetland Flora: Most of the lake is still completely enclosed by virgin equatorial forest, except in the immediate vicinity of a few small villages and in the far south where, between the banks of the Lukenie and Fimi Rivers and the southern tip of the lake, much seasonal swamp forest has been cleared for agriculture. Virtually all the surrounding forest is subject to periodic inundation, but permanent swamp forest is concentrated in the north, along the courses of the rivers entering there. The most extensive area is from the NE arm of the lake southeastwards along the Lokoro River, where the main block extends for 153 km upstream and in places spreads for over 40 km on either side of the river. Patches of permanent swamp forest also occur farther upstream on the Lokoro and its tributaries, the Lole and Lula Rivers, and this is the case on all the affluent streams. *Raphia* swamps occur around the shores in the wettest sites, made impenetrable by the presence of spiny climbing palms, principally *Eremospatha* spp. These grade into *Oubanguia africana* and *Guibourtia demeusei* forests in less permanently inundated places, and these in turn to terrestrial evergreen rain forest on unflooded land. There have been no proper botanical surveys of Lake Mai Ndombe.

Wetland Fauna: There have been no zoological surveys of Lake Mai Ndombe, and what is known stems from travellers reports. Among invertebrates, the medusa of *Limnocnida congoensis* has been found there, and freshwater crabs, *Potamonautes* spp., are plentiful. As far as the fish fauna is concerned, some inventories were made at the beginning of this century. By 1918 some 40 species were known from the lake including *Alestes bimaculatus*, *Gnathonemus leopoldianus*, *Marcusenius nigropinnis* and *Notopterus afer*. *Alestopetersius leopoldianus*, *A. nigropterus* and *Nannothrissa stewartii* are endemic. The lake contains terrapins, *Pelusios* spp., and three crocodiles, *Crocodylus cataphractus*, *C. niloticus* and *Osteolaemus tetraspis* (de Bondt, 1969); also *Boulengerina annulata* together with several semi-aquatic snakes.

The avifauna appears to be rich, and most of the Central African aquatic birds are found there, although there are no official lists. A comparatively rare species is the small kingfisher, *Corythornis leucogaster leopoldi*. Mammals associated with the lake are similar to those found along rivers in the central depression dealt with earlier in section 4a.

Human Impact & Utilisation: Population density around the lake is low, about 4 persons/km^2, but falling to 2 persons/km^2 in the south. The two centres of population are Kutu at the confluence with the Lukenie River in the extreme south and Inongo on the east bank. There is some small scale agriculture and oil palm, *Elaeis guineensis*, is grown locally around the lake, also on a small scale. In the SW, between the lake and the banks of the Lukenie and Fimi Rivers, rice is cultivated, and there have been extensive clearances for this, the rice being grown in what were formerly seasonal swamp forest areas. Some millions of hectares of forest have succumbed in an area extending 15-20 km from the lake and river banks. Fishing on the lake produces an annual catch of about 1000 tonnes, but the maximum sustainable

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yield has been estimated as 10 000 tonnes in 1983. There are boat services between the lake and Kinshasa, carrying up to 5000 tonnes of merchandise/yr in both directions.

Conservation Status: Unprotected.

5. Wetlands of the Eastern Highlands

Co-ordinates of Region: 4°41'N-8°27'S/28°00'-30°32'E
Area of Region: c. 267 345 km^2
Altitudinal Range: 650-4507 m asl

General: The region under consideration lies between longitude 28°E and the mountainous watershed along the eastern border which separates the Central Zaire Basin from the basins of the Rift Valley Lakes. In altitude it rises from about 650 m asl in the west to over 3000 m asl at several points in the Mitumba Mountains. Along the eastern border there are 6 principal massifs, all with great plateau-like tops 1500-2000 m asl, all also surmounted by higher peaks. It is the elevated plateaux at the feet of the mountains that are important for their wetlands. These plateaux, from north to south, cover more than 937 500 ha above the western shore of Lake Albert, more than 900 000 ha above the western shore of Lake Edward, more than 600 000 ha above Lake Kivu, and in three blocks, more than 2 750 000 ha along the western shores of Lake Tanganyika. Streams from the summits meander over the plateau, with innumerable swamps along their courses, in valleys which are little incised, but then plunge down the steep and deeply dissected western slopes, with waterfalls and rapids, before their beds again flatten below the 1000 m contour, en route to the Zaire River. Drainage to the east is by short torrential streams, descending by serried steps to the floor of the Western Rift Valley.

Climate: Climate throughout the region varies greatly with altitude. In general there is a tight correlation between altitude and the temperature of the coldest month. Below 1000 m this is in the vicinity of 23°C, but 19°C at 1500 m, and below 15°C at 2000 m asl. There is little seasonal variation in mean monthly temperature near the equator, but it becomes apparent over the Marunga Massif at the southern end of Lake Tanganyika. The permanent snow line is close to 4500 m asl, and although this height is attained at Mt. Karisimbi (4507 m) and Mt. Stanley (5110 m), a snowfield exists only around the latter. Mean annual rainfall exceeds 2200 mm between 1000-1300 m on the western slopes of the plateaux in the equatorial zone, and exceeds 2800 mm on some of the higher slopes. However, it appears to be less great in an intermediate zone between 1500-1800 m asl. Here it seldom exceeds 2000 mm/yr. Precipitation decreases progressively in moving north or south away from the equator, reaching maxima close to 1500 mm/yr on the Marunga Massif in the far south.

Wetland Flora: There are two principal phytogeographic regions, one Soudano-Zambezian, and the other Guinean. The former occurs above 1300 m on the plateaux, on the eastern slopes, and on parts of the western slopes. The lower western slopes are the province of dense wet rainforest or semi-deciduous forest of Guinean affinity.

Vast swamps occur on the summit plateaux in the headwater regions of the myriad streams, and there are wet formations of lesser extent on some of the eastern and western slopes. On the plateaux human activities have influenced the marshy vegetation, locally

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tending to make it very uniform, as discussed in the appropriate subsection. For this reason a small number of discrete associations can be recognised.

Cyperus papyrus dominates large deeply inundated areas around lakes and ponds, e.g. around the 4 Mokoto Lakes NW of Lake Kivu, and in the Kabare (2°28'S/28°47'E) district. Small deeply inundated permanent swamps along streams are generally covered by *Typha domingensis*, or by this species together with *Cyperus latifolius*. *Miscanthidium violaceum* dominates huge areas of swamp on flat wet surfaces away from the main watercourses, though small streams may traverse them, when they are generally fringed by *Typha*. *Miscanthidium* forms tall coarse tufts, 4–5 m high, with a lower storey of *Scleria* spp., and with *Nymphaea mildbraedii* on water or mud between tufts. *Phragmites mauritianus* seems to be almost completely confined to the eastern slopes where it fringes deeply furrowed watercourses on the steep slopes, and spreads out into the small deltas which streams build into the lakes. However, *Cyperus latifolius* is the most widespread plateau species. It covers great areas, in almost pure stands, reaching 1.5 m in height, but around the edges other heliophilic species become abundant and chief among these are *Alchemilla mildbraedii*, *Polygonum strigosum* and *Thelypteris squamigera*. This association tends to be colonised by woody species, producing a canopy around 3 m high, and the most common species involved are *Hypericum lanceolatum*, *Maytenus acuminatus* and *Myrica kandtiana*.

At lower altitudes periodically flooded forests along rivers are similar to those of the central depression. *Uapaca guineensis* often forms pure stands, but possibly these are secondary in nature. Nevertheless, this species is dominant in much of the higher riverside forest, especially away from the equator. In the far north and south it is joined by *Ficus mucuso*, *Irvingia smithii*, *Klainedoxa* sp., *Mitragyna stipulosa* and *Syzygium* cf. *cordatum* in gallery forest, sometimes also by *Chlorophora excelsa* and, in the north, by *Khaya senegalensis*. Below 1000 m, galleries of *Gilbertiodendron dewevrei* and *Staudtia stipitata* occur along watercourses, but with *Mitragyna stipulosa* forest in any semi-permanently swampy areas. *Gilbertiodendron* forest interdigitates with another type of ombrophilous evergreen forest, comprising almost monospecific stands of *Michelsonia microphylla* in the equatorial region. This forest occurs under the very wet climate along the lower western slopes of the massifs between altitudes of 650-1200 m, on soils that are always wet, if not swampy.

In some of the savanna regions, in places of great seasonal pluviosity, where the soil is poorly drained, *Kotschya africana* and *Setaria sphacelata* often form a mosaic vegetation.

Wetland Fauna: At the lower elevations the gallery forest, swamp forest and riverine forest faunas include *Cephalophus nigrifrons*, *C. sylvicultor*, *Cercocebus albigena* (N only), *Cercopithecus aethiops*, *C. albogularis* (N only), *C. ascanius*, *C. mitis stuhlmanni* (N only), *C. mitis kandti* (Kivu region), *Colobus badius*, *C. guereza* (N only), *Felis aurata*, *Genetta tigrina*, *Herpestes ichneumon*, *H. sanguineus*, *Kobus ellipsiprymnus*, *K. kob*, *Leptailurus serval*, *Neotragus batesi* (NE only), *Osbornictis piscivora*, *Panthera pardus*, *Phacochoerus aethiopicus*, *Potamochoerus porcus*, and *Syncerus caffer*. *Hylochoerus meinertzhageni* occurs in montane forests, and *Phacochoerus* is more common towards the east. A cline is evident from west to east, along which elephant populations increase in size from the small forest elephant, *Loxodonta africana cyclotis*,

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to the bush elephant, *Loxodonta africana africana*. The usual small semi-aquatic mammals, *Aonyx capensis*, *Atilax paludinosus*, *Dasymys* sp., *Lutra maculicollis*, *Pelomys* sp. and *Potamogale velox* extend upward into the higher forests, and most occur in the plateau herb swamps. Here, at least in the south, *Thryonomys swinderianus* is also present. *Aonyx capensis* has been recorded above 3000 m, while *Atilax* and *Lutra* have been observed 2000 m asl. *Aonyx congica* is uncommon above 650 m.

Human Impact & Utilisation: Large areas of this region are very sparsely populated, but close to small centres of population the herbaceous wetland vegetation is heavily exploited for thatch and fibre for basketry and fish traps, and it is cut regularly over large areas, limiting the dominant vegetation to those species which survive this treatment. The rivers are fished throughout the region, illegally in the national parks, where there is also some poaching of elephant and antelope.

Conservation Status: There are 3 national parks in this region. The Garamba National Park is situated on the border with Sudan in the far north, and here poaching has been intense in recent years. For example, elephant numbers in the park fell from 22 000 in 1976 to 8000 in 1983, and recurrent civil unrest in neighbouring countries does not improve the situation. In this park, in a predominantly savanna area, gallery forest and papyrus swamps are protected. To the south, in the Maiko National Park, strips of swampy riverine forest are protected, and in the Kahuzi-Biega National Park all the wetland types of the plateaux and mountainsides are protected.

6. Lake Tanganyika & the Ruzizi Plain

(A) LAKE TANGANYIKA

Location: 3°21'-8°51'S/29°04'-31°12'E
Area: 3 290 000 ha (c. 1 502 200 ha in Zaire)
Altitude: 773 m asl
Nearest Towns: Kabalo (255 km W); Lubumbashi (500 km SW)

General: Lake Tanganyika is 659 km long with a maximum width of 85 km at the parallel 5°55'S. It is slightly brackish and the second deepest lake in the world (1470 m). It lies in the western arm of the Great Rift Valley and down most of its western side the escarpment plunges straight into the water, and in the south basin it continues underwater to the maximum depth of 1470 m, which is reached just 4 km offshore. Only at the northern and southern ends is the underwater slope moderate, and even in these places the 100 m contour is reached inside 10 km. The adjacent mountain ranges exceed 3000 m asl at the northern end of the lake, which is fed by several large rivers, and countless small streams which enter all round its periphery, in Zambia, Tanzania, Burundi and Zaire. The Ruzizi River, draining Lake Kivu, descends the Panzi Falls before entering Lake Tanganyika so that the two lakes are faunally isolated. The Ruzizi has formed a substantial delta at the north end of Lake Tanganyika. The other principal affluent is the Malagarasi River, which drains much swampy land to the south of Lake Victoria. The lake drains from the middle western section via the Lukuga River to the Lualaba, but water levels fluctuate over long time periods, much as they do in Lake Malawi to the south, and these are discussed by Canus (1965). The flora, fauna,

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hydrology, water chemistry and geological history of the lake proper are dealt with in detail in section 2.9.4b, Lake Tanganyika. However, brief account of the fish fauna, and the lake and delta floras are given here. The flora and fauna of the Fizi Plain, at the head of the large bay near Fizi (4°18'S/28°56'E), is quite similar to that of the Ruzizi Plain described in the next section.

Wetland Flora: *Ceratophyllum demersum* is abundant in the vicinities of affluent river mouths, while in the deltas of several rivers *Azolla pinnata* may form immense floating mats, green or red-brown in colour, and there are great submerged beds of *Myriophyllum spicatum*, *Najas marina*, *N. pectinata*, *Ottelia ulvifolia*, *Potamogeton pectinatus* and *P. schweinfurthii*. *Potamogeton* spp. are the predominant macrophytes around much of the shoreline, with occasional rafts of *Nymphaea caerulea* and *N. capensis* in shallow sheltered bays. *Cyperus papyrus*, *Phragmites mauritianus* and *Typha domingensis* dominate the delta swamps, with *Vossia cuspidata* as principal low growing associate.

Wetland Fauna: The lake contains a large fish fauna, comprising some 193 species from 13 families, an analysis of which suggests that the lake is ancient and has been isolated for a long time. Although 98% of the cichlids and 57% of the non-cichlid species are endemic, similar proportions to those found in the faunas of Lakes Malawi and Victoria, it is the degree of speciation here, which distinguishes Lake Tanganyika from the others. It contains no less than 8 endemic genera, and some endemic species reveal distinct subspecific forms between the north and south ends of the lake. Comparatively recently Zaire Basin species have invaded the lake, presumably by way of the Lukuga River, the most recent effluent. These include *Distichodus fasciatus*, *Hydrocynus goliath* and *Labeo lineatus*. Other interesting species include *Protopterus aethiopicus*, *Polypterus congicus* and *P. ornatipinnis*, also Zaire Basin species which live in lagoons and deltas around the lake, especially the Malagarasi Delta. These are ancient fish and their presence has probably been continuous from the time when the Malagarasi flowed directly into the Zaire Basin, before the faulting which led to the development of the Rift Valley and its lakes. There are two fully aquatic piscivorous snakes in the lake. *Boulengerina annulata* lies up in the rocks during the day and fishes nocturnally, while *Glypholycus bicolor* hunts pelagic fish, chiefly shoals of *Stolothrissa tanganicae*.

Human Impact & Utilisation: The lake is fished intensively from several ports including Uvira, Kalémié (Albertville) and Moba (Baudouinville) in Zaire.

Conservation Status: Unprotected.

(B) THE RUZIZI PLAIN

Location: 2°32'-3°21'S/28°56'-29°35'E
Area: 184 000 ha (total lower plain)
Altitude: 773-810 m asl
Nearest Towns: Bukavu (47 km N); Kongolo (350 km SW)

General: The Ruzizi Plain occupies the floor of the Western Rift Valley at the northern end of Lake Tanganyika, and has been transgressed by lake water in the past. The lower plain slopes very gently southwards to the lake, and the Ruzizi River meanders across the centre of the plain, roughly from north to south, forming the national border with Burundi. On either side of the plain the land rises steeply into the mountains. Precipitation over the lower plain is 800-900 mm/yr, while on the slopes of the valley it is

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1200-1300 mm/yr. April is the wettest month with mean falls of 140-160 mm in the plain and 180-200 mm in the hills, depending upon site. The dry season usually begins in the second half of May and persists until the end of September, but is longer in the south than the north. Winds are generally light in the morning, increasing to peak velocities at midday, when they may attain 20 km/hr in the wet season and 28 km/hr in the dry season. Mean monthly temperatures range from 22.5-25°C, while mean monthly maxima and minima are 30.5-32.5°C and 14.5-17°C respectively. There are extensive wetlands on the plain, chiefly associated with the Ruzizi River and its tributaries.

Wetland Flora: *Phragmites mauritianus* swamps accompany the Ruzizi River, in a belt up to 3 km wide along the lower half of its 135 km course between Lake Kivu and Lake Tanganyika and into its delta, but along its tributaries these swamps are reduced to much narrower strips, e.g. on the Sange and Kiliba Rivers. The swamps are broader in the south than the north, and it is estimated that the area of reedbeds may exceed 20 000 ha. Where inundation is permanent the reeds reach 4 m in height, but where it is seasonal they are little more than 2 m high. The most important associate species are *Ipomoea fragrans*, *Panicum meyerianum*, *Paspalidium geminatum* and *Polygonum pulchrum*, the last three species being especially well represented where the surface waters are ever only superficial.

On the sides of lakes, on meander bends and around small islands in the river, one finds sandy beaches, subject to periodic inundation, but with groundwater always near the surface. These places are covered by a *Cyperus laevigatus-Pluchea bequaertii* association. There is generally a distinct upper stratum, reaching 1.5-2 m, comprising suffrutescent species, dominated by *Pluchea bequaertii*, with *P. dioscoridis* and *P. ovalis*, and a ground cover of *Cyperus laevigatus* and *Fimbristylis ferruginea* reaching 30-125 cm.

The country adjacent to the floodplain is *Themeda-Bulbine* grassland, but throughout this there are small ponds which provide waterholes for domestic cattle. They are flooded to depths of over 1 m in the rainy season but are transformed into quagmires during the dry season, and support a flora of *Oryza barthii*, with *Asteracantha longifolia* and *Burnatia enneandra* on the fringes, and sometimes central patches of *Nymphaea lotus* and *Utricularia thonningii*. From place to place the *Themeda-Bulbine* association is interrupted, in periodically inundated depressions on the lowest terraces, by swards of *Sporobolus spicatus* which are heavily grazed by local cattle in the dry season. This is the most halophilic association on the valley floor, under which the soil water contains salts to a total concentration of 8‰. Elsewhere, in large shallow depressions in the *Themeda-Bulbine* savanna, where the gradient is virtually nil, water collects semi-permanently. The ground surface is always muddy, particularly where trampled by cattle, but surface water is seldom more than a few centimetres deep. These areas support a cover of *Panicum ruziziense*, with some *Ammania senegalensis*, *Cyperus platycaulis*, *Desmodium hirtum*, *Ilysanthes parviflora*, *Lindernia boutiqueana* and *Ophioglossum costatum*.

Another very local hydromorphic association in this large wide valley is that of *Setaria holstii* and *Botriochloa insculpta*. This occupies depressions along the valley floor that were once the beds of lakes. They have clay floors and are inundated for most of the wet season, but dry completely during the dry season, when the clay hardens and cracks.

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Other species found here include *Digitaria scaentae*, *Glycine borianii* and *Paraknoxia ruziziensis*, together with vagrants from the surrounding savanna.

Where the rivers traverse the metamorphic terrain at the feet of the mountains they flow in very steep sided valleys, and throughout these regions the narrow banks carry gallery forest dominated by *Baphia descampsii* 10-12 m high, with *Craibia grandiflora*, *Cissus araliodes* and *Sterculia tragacantha* as typical associates.

Wetland Fauna: Some reptiles are present, including various swamp snakes, *Dromophis lineatus*, *Limnophis bicolor* and *Philothamnus irregularis*, together with varanid lizards and occasional crocodiles. Among the notable birds of the flood plain and permanent herb swamps, *Actitis hypoleucos*, *Acrocephalus schoenobaenus*, *A. scirpaceus*, *Calidris ferruginea*, *C. minuta*, *Chlidonias leucoptera*, *Cuculus canorus*, *Delican urbica*, *Falco subbuteo*, *Glareola nordmanni*, *Hippolais pallida*, *Hirundo rustica*, *Motacilla flava*, *M. feldegg*, *Pandion haliaetus*, *Phylloscopus trochilus*, *Porzana porzana*, *Riparia riparia*, *Tringa glareola* and *T. nebularia* may be cited. Mammalian wildlife has been largely displaced by domestic cattle, and in numbers, the wetlands now support only small mammals, otters, mongooses and water rats.

Human Impact & Utilisation: Both the Ruzizi Valley and the Fizi Plain are intensively cultivated, and the wet areas are frequented by domestic cattle in the dry season when large areas of wetland are burned.

Conservation Status: Unprotected.

7. Lake Kivu

Location: 1°35'-2°31'S/28°49'-29°20'E
Area: c. 260 000 ha (excluding islands; c. 165 000 ha in Zaire)
Altitude: 1460 m asl
Nearest Towns: Bukavu (at S end); Kongolo (460 km SW)

General: Lake Kivu lies in the western trough of the Great Rift Valley, enclosed on three sides by land which rises steeply from the lake to over 2000 m, and to 4507 m just to the north. The lake is 100 km long, and has a maximum width of 50 km almost exactly along the parallel 2°S. There are several islands in the lake, most small, and most in Rwanda, but Idjwi Island, 40 km long and with an area of 30 000 ha, is in Zaire.

Hydrology & Water Quality: The lake receives run-off from the surrounding mountains, and it is believed that warm water is injected into the lake from submerged hot springs. Further, effluents from the small group of Mokoto Lakes, to the northwest, disappear into the volcanic ash, but are believed to reach Lake Kivu. Rainfall in the catchments exceeds 2400 mm and is not markedly seasonal. The lake is deep, c. 480 m, meromictic, and the most firmly stratified lake in Africa. Water density increases towards the bottom, but not as a steady gradient; there are a series of discrete layers. The surface water has a salinity of 1‰, and the top 70 metres are mixed, but it seems that below this the hypolimnion is completely stagnant, highly saline, and very rich in nitrogen and phosphorus. The pH of the surface waters is about 9.1. It appears that natural phenomena, other than earth movements and the pouring of hot lava into the lake, do not cause upwellings of the bottom water, which is highly nutritive but contains much dissolved

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sulphide and methane. The temperature at the surface is close to 25°C, decreasing with depth to about 22°C at 70 m, but then increasing again to 25°C at 375 m depth. The 70 m contour is very close to the shore, and since only the upper 70 m of the water column is oxygenated, it has been estimated that only 12% of the lake floor receives any oxygen. This is the most saline lake in the Western Rift Valley.

Wetland Flora: There is little information regarding the phytoplankton, but it is neither diverse nor abundant. The macrophyte flora, which extends down to a depth of 8 m, is extremely poor, and there is only a narrow fringe of lake bottom above this depth. The deep lake floor is covered by an organic ooze, but towards the shores the bottom is quite sandy, with an encrusting calcareous scale. Here *Cladophora* sp. is the dominant plant. Higher up there are beds of *Ceratophyllum demersum*, *Najas marina* and *Potamogeton pectinatus*, the latter species being most abundant. Around the shallowest margins there are beds of *Phragmites mauritianus* and species of *Cyperus* and *Scirpus*.

Wetland Fauna: The fish fauna is poor, comprising just 16 species. Of these, 3 also occur in Lake Tanganyika, namely *Barbus serrifer*, *Barilius moori* and *Clarias mossambicus*. The first and last have wide distributions, but *Barilius moori* is found only in these two lakes. There are 6 species of *Haplochromis*, all endemic, and a distinct subspecies of *Oreochromis niloticus* ssp. *regani*, which suggests that speciation has occurred in the lake over the last 20 000 years. There is no large predatory species in the lake. Birds and otters are the principal piscivores, and the lake supports many birds of passage.

Human Impact & Utilisation: *Limnothrissa miodon* was introduced some years ago, and a small sardine fishery has developed, but prior to this there was no commercial fishery of significance.

Conservation Status: Unprotected. The high mountain catchments to the north however, are protected in the Virunga National Park.

8. Lake Edward

Location: 0°05'-0°56'S/29°16'-29°56'E
Area: c. 234 200 ha (170 450 ha in Zaire)
Altitude: 912 m asl
Nearest Towns: Lubero (28 km W); Bukavu (225 km SSW)

General: Lake Edward is 76 km long with a maximum width of 39 km. It is connected to Lake George, effectively a bay of Lake Edward, by the Kazinga Channel, 40 km long and less than 1 km wide. Lake Edward reaches a maximum depth of 112 m, just 5 km from the western shore, above which the land rises precipitously to a high plateau over 2000 m asl carrying mountain peaks over 3000 m. By contrast the lake floor slopes up gradually to the Uganda shore.

Hydrology & Water Quality: Lake Edward has numerous affluent streams, the most important being the Nyamugasani River from the Ruwenzori Mountains and the Ishasha, Rutshuru and Rwindi Rivers from the Virunga Volcanoes and the Rwanda Highlands. Further inflow comes from Lake George, which also drains the Ruwenzori Range and to the east shares a watershed with Lake Victoria. However, flow through the Kazinga Channel is very sluggish, along a remarkably gentle gradient of 1:80 000 over the first

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24 km. The junction of the waters between Lakes Edward and George, indicated by a change in colour, but also in chemistry, can usually be seen in the Kazinga Channel. The position of this boundary oscillates up and down the channel over a distance of about 3 km seasonally. Lake George is fresh, and its water chemistry is known to have remained fairly constant over the last 40 years, suggesting that the residence time of water in the lake is short, and that evaporation does not lead to the concentration of solutes. However, no subterranean outlets are known, yet the flow into Lake Edward appears minimal. Precipitation over Lake Edward is only 500-650 mm/yr, the lowest in Zaire, but is much higher in the adjacent mountains, e.g. approaching 3000 mm/yr on the western slopes of the Ruwenzori Massif, the highest in Zaire. Lake Edward discharges into the Semliki River, and thence to Lake Albert and the Nile. Water spills over a rock shelf at the northern extremity of the lake, which functions as a natural weir. Water leaving the lake has a temperature of 25-26°C and a pH close to 9.1. The lake is more saline than Lake Albert and less saline than Lake Kivu.

Wetland Flora: *Potamogeton pectinatus* is the dominant submerged macrophyte, in association with *Najas marina* and *Vallisneria aethiopica*. Some *Potamogeton schweinfurthii* and *Najas pectinata* occur along the eastern shores. *Vallisneria* and *Najas* are best developed in the vicinity of river mouths where waters are better aerated. *Cyperus papyrus* and *Phragmites mauritianus* form swamps at the mouths of effluent streams, which are especially well developed along the southern shore. Riverine swamps extend back from the lake up all three principal rivers entering the southern end of the lake for distances of several kilometres.

Wetland Fauna: The present fish fauna comprises about 23 cichlids and 30 non-cichlid species. However, the fauna is impoverished, with certain widespread families being entirely absent, e.g. Centropomidae, Characidae, Malapteruridae, Mastacembalidae, Mochokidae and Schilbeidae. Further, *Citharinus*, *Distichodus*, *Hydrocynus*, *Polypterus* and *Lates*, which are found in Lake Albert and the Nile, are also absent, although both *Hydrocynus* and *Lates* are known to have been present in the middle Pleistocene. From palaeontological studies a picture emerges of Lake Edward being in a phase of recolonisation, its fauna having been partially eliminated at least twice during the late Pleistocene. Although the lake once contained crocodiles, as well as the Nile fish cited, they are also now absent. The rapids prevented their re-introduction from the lower Semliki where they persisted until the middle of this century before they were finally eliminated by hunters. However, it appears that fish have entered from the east, where there is now a watershed with Lake Victoria, and have begun speciating. In the cichlid fauna there are several species with close relatives in Lake Victoria, e.g. *Haplochromis guiarti*, *H. ishmaeli* and *H. macrops* and two common species, *Astatoreochromis alluaudi* and *Haplochromis nubilis*. Two species present in the Nile have either re-entered or survived, *Bagrus docmac* and *Oreochromis niloticus*. *Oreochromis leucostictus* is confined to Lakes Edward and Albert, perhaps having originated in Lake Edward, and passed downstream. Considering the history of the lake the invertebrate fauna is surprisingly rich.

The avifauna of the lake and associated river valleys and swamps is very diverse and includes herons, ibises, egrets, bitterns, ducks, geese, darters, cormorants, skimmers, shoebills, openbills, ospreys, gulls, francolins, warblers and weavers. Large numbers of

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pelicans frequent the lower Rutshuru River. Species of interest include *Acrocephalus schoenobaenus*, *A. scirpaceus*, *Anas querquedula*, *Ardeola ralloides*, *Calidris ferruginea*, *C. minuta*, *Charadrius hiaticula*, *Chlidonias leucoptera*, *Gelochelidon nilotica*, *Hirundo rustica*, *Philomachus pugnax*, *Riparia riparia*, *Tringa glareola*, *T. nebularia* and *T. stagnatilis*.

Human Impact & Utilisation: Relatively little since the proclamation of the national park in 1969, but illegal fishing and poaching on the lower Rutshuru are chronic problems. Growing tourism could prove a threat, and the proposal to dam the Rutshuru River would almost certainly have a major, and adverse, impact upon the riverine wetland ecosystem.

Conservation Status: The entire Zairean section of the lake is protected in the Virungas National Park, as is the lower course of the Rutshuru and several other tributary rivers.

9. The Semliki River Valley

Location: 1°20'N-0°11'S/29°30'-30°30'E
Area: c. 375 000 ha
Altitude: 619-912 m asl
Nearest Towns: Bunia (25 km N); Bukavu (300 km SSW)

General: The Semliki loses 293 m of altitude over its 150 km course from Lake Edward to Lake Albert. The upper course is swift, rocky and boulder strewn, 30–40 m wide, and enclosed by the dense Ituri Forest. Most of the descent is made over two rapids sections in this part of the river. In places the river is confined to a narrow channel, 10 m wide, between sheer rock walls. On emerging onto the savanna covered, lower Semliki Plain, the river flows slowly, eventually meandering to its delta in Lake Albert. A chain of oxbow lakes to the west of the present lower course, and deltaic deposits in Lake Albert, indicates that the river bed has been moving eastwards over the lower plain. Swamps occupy an area 15 km wide and 3.5 km deep along the southern shore of Lake Albert astride the delta of the Semliki, which projects a further 3 km into the lake. Upstream, seasonally inundated land extends back from these swamps in a belt 3-7 km wide for many kilometres, and a large area, centred upon the oxbows of the abandoned river course, is poorly drained and comprises hydromorphic soils. Farther back upstream, smaller swamps occur along the Semliki at numerous isolated sites, mostly where tributaries enter the mainstream.

Wetland Flora: *Cyperus papyrus* and *Phragmites mauritianus* dominate the riverine and delta swamps, reaching heights of 5 m. Much of the unflooded lower valley floor is covered by *Themeda* savanna, and in this, saline hydromorphic soils support vast swards of *Sporobolus spicatus*. Elsewhere, seasonally inundated soils are covered by species of *Hyparrhenia*, *Loudetia* and *Pennisetum*, with *Pennisetum purpureum* and *Imperata cylindrica* representing post-cultivation grasses. The former occurs on the wettest soils, the latter on drier fringes subject to fires. Gallery forests contain a spectrum of typical Zaire species, together with some of more East African affinity.

Wetland Fauna: The fish fauna is alluded to in sections 8 and 10. Among the reptiles, crocodiles are believed to have become extinct in the region as a consequence of intensive hunting, but varanid lizards are common, as are snakes. These include *Drom-*

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phis lineatus, Limnophis bicolor, Naja sp., *Natriciteres olivacea, Philothamnus irregularis* and *Psammophis olivacea* in the swamps, and various arborescent species, including *Dasypeltis scabra, Dispholidus typus, Dendroaspis angusticeps* and *Thelotornis kirtlandii*.

Birds are prolific and diverse, the spectrum changing abruptly at the transition from tropical closed forest to savanna, and finally to marshland at the delta. The range of piscivores from the latter sites includes pelicans, herons, ibises, egrets, gulls, fishing eagles, ospreys, skimmers, darters, cormorants and kingfishers, while the rare yellow papyrus warbler, *Chloropeta gracilirostris*, has been recorded from the lower Semliki, together with ducks, geese, moorhens, weavers and a variety of other warblers. Species of interest include *Buteo buteo, Chlidonias leucoptera, Ciconia ciconia, Crex crex, Cuculus canorus, Falco subbuteo, Gallinago media, Gelochelidon nilotica, Lanius collurio, L. minor, Lymnocryptes minimus, Merops apiaster, Pernis aprivorus, Phylloscopus trochilus, Porzana porzana, P. pusilla, Riparia riparia, Tringa glareola* and *T. ochropus*.

Mammalian populations along the Semliki River are large and species found in these areas include *Aonyx capensis, Atilax paludinosus, Cephalophus* sp., *Damaliscus lunatus, Dasymys* sp., *Herpestes ichneumon, Hippopotamus amphibius, Kobus ellipsiprymnus, K. kob, Loxodonta africana, Lutra maculicollis, Osbornictis piscivora, Phacochoerus aethiopicus* and *Syncerus caffer*.

Human Impact & Utilisation: Of recent years this has been slight, but poaching of elephants continues, and fishing and tourism are potential threats. The proposal to dam the Semliki River will, if implemented, have a major adverse impact upon the riverine ecosystems, possibly compounding damage done by impounding the Rutshuru above Lake Edward.

Conservation Status: A great deal of the Zairean part of the Semliki Valley, including the entire upper forested section, is protected in the Virungas National Park. This was established in 1925 as Albert National Park, and became the Virungas National Park in 1969. It was designated a World Heritage Site in 1979. The park is contiguous with national parks and wildlife sanctuaries in Uganda and Rwanda.

10. Lake Albert

Location: 1°01'-2°07'N/30°23'-31°26'E
Area: 565 915 ha (247 345 ha in Zaire)
Altitude: 619 m asl
Nearest Towns: Kisangani (575 km WSW); Bukavu (450 km SSW)

General: Lake Albert lies between two parallel escarpments in the Western Rift Valley, at an altitude of 619 m, with an extreme length of 180 km and a maximum width of 43 km. Just under 44% of its surface is in Zaire. Its deepest point, 56 m, lies 7 km off the western shore, from where the land rises steeply to a high plateau more than 2000 m asl. The lake floor slopes gently upwards towards the east, but the eastern escarpment rises abruptly just a few km from the east bank in Uganda. The lake is subject to violent windstorms which cause the upwelling of bottom waters, but even without these happenings, the lake is generally well mixed. During calm periods, which frequently

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occur between November and February, a degree of stratification develops and dissolved oxygen levels fall, but not deleteriously for the fauna.

Hydrology & Water Quality: The principal affluent streams are the Semliki, which enters at the southern end, and the Victoria Nile, which enters very close to the northern end. Both rivers have built deltas into the lake. While the Nile carries more water than the Semliki, it has little influence on the ecology of the lake, other than to maintain water levels. The Nile water is fresh, with a salinity of 0.1‰, while the main body of lake water, up to 10 km from the delta which the Victoria Nile has built into the lake, has a salinity of 6‰ and a pH close to 9.0. Lesser streams entering the lake from Zaire are, from south to north, the Kisege, Ndrigge, Muita, Nyamusiki, Kilowir and Mboge Rivers. However, all these, and other small rivers entering from the Ugandan side, are highly seasonal and of only secondary importance to the two major rivers. Some periodically inundated land occurs around the southern margin of the lake in the vicinity of the Semliki River Delta, and also along the eastern shore at some isolated spots, notably the Victoria Nile Delta. The results of detailed hydrobiological surveys were published by the Institut Royal des Sciences Naturelles de Belgique (Brussels) between 1957-1962. General information is provided by Bishop (1965; 1969) and Livingstone (1976).

Wetland Flora: *Potamogeton schweinfurthii* is the dominant submerged macrophyte over most of the lake, by contrast with Lakes Kivu and Edward where *P. pectinatus* is most common. However, this latter species is also present in Lake Albert. The principal associate species are *Najas marina* and *Vallisneria aethiopica*, and as in the other lakes, they are most abundant in the vicinities of river mouths, but this phenomenon is not so pronounced as it is in the two other lakes, possibly because Lake Albert is shallower and its waters are generally well oxygenated. In the river deltas, there are extensive stands of *Cyperus papyrus* and *Phragmites mauritianus*, the flowering culms of which reach 4.5 m in height, with aquatic meadows of *Vossia cuspidata* on the lakeward side, and twining thickets of *Cyclosorus striatus* on the landward side. In ponds in the swamps, and in sheltered coves around the lake, there are floating-leaved and free-floating associations, notably a *Lemna paucicosta-Pistia stratiotes-Azolla nilotica* association, and a *Nymphaea calliandra* association. In the latter, *Najas marina*, *Nymphaea lotus* and *Vallisneria aethiopica* are usually to be found, together with free-floating plants of *Ceratophyllum demersum* and *Utricularia thoningii*. Species of *Nitzschia* and *Stephanotis* are the chief planktonic diatoms, undergoing periodic fluctuations in density. Blooms of the blue-green alga, *Anabaena* sp., occur locally from time to time, and lead to the mass mortality of fish, especially *Lates niloticus*.

Wetland Fauna: The fish fauna comprises 46 species, of which 22 are also found in the Nile. Some genera, e.g. *Bagrus*, *Heterobranchus* and *Lates*, have long histories in the lake, having been recognised from mid-Pleistocene sediments, while *Clarotes*, which was present in the Pleistocene, is no longer there. *Alestes baremose*, *Citharinus citharus*, *Lates niloticus* and *Oreochromis niloticus* form the basis of the present fishery. Two distinct populations of *Lates niloticus* are present, one which breeds in the lake, and another which migrates into rivers to spawn. In Lake Albert this species is an inshore form and is largely piscivorous, whereas another species, *Lates microphthalmus*, is pelagic and feeds mainly on *Caridina* (a freshwater prawn). Among the other piscivores both *Hydrocynus vittatus* and the smaller *H. forskalii* occur in the lake, but the latter,

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here, tends to be pelagic and also feeds very largely upon *Caridina*. Of 36 non-cichlid species, 3 are endemic, while of 10 cichlids, 4 are endemic. These are all species of *Haplochromis*. The cichlid fauna is poor compared with that of most other East African Lakes, including some other 'nilotic' lakes, such as Lake Edward. Accounts of the fish fauna are given by Worthington (1929) and Holden (1967; 1970). The invertebrate fauna is discussed by Green (1967a,b; 1971) and Verbeke (1957a,b).

Birds of interest found along the lakeshore are *Buteo buteo*, *Chlidonias leucoptera*, *Ciconia ciconia*, *Crex crex*, *Cuculus canorus*, *Gallinago media*, *Gelochelidon nilotica*, *Lanius collurio*, *L. minor*, *Lymnocryptes minimus*, *Merops apiaster*, *Muscicapa striata*, *Pernis apivorus*, *Phylloscopus trochilus*, *Porzana parzana*, *Riparia riparia*, *Tringa glareola* and *T. ochropus*.

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REGION 5

SOUTHERN AFRICA

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Introduction

This region has a total area of 5 900 296 km^2 and comprises the ten countries which lie, at least in major part, to the south of the watershed separating the Zaire and Zambezi Basins. The watershed follows an irregular course across the southern part of the continent, wandering between the parallels 10° and 13°S, from the Huambo Mountains in Angola to the Nyika Mountains in Malawi. Physiographically the region consists of a high triangular plateau with an elevated rim. Internally the land dips gently away from the rim, to a lower lying interior, but externally it falls by stepped scarps, often very abruptly. The coastal plain, along both eastern and western sides of the plateau, is backed by these scarps. In the west and south this plain is narrow, less than 20 km wide in places, but it opens out towards the northeast and, in parts of Mozambique, reaches 130 km in width. The high rim of the plateau attains maximum elevations of 2620 m asl in Angola on the western side, and 3482 m asl in Lesotho on the eastern side.

Climate

The climate of the region is primarily determined by the warm southward flowing Agulhas Current on the east coast, and the cold northward flowing Benguela Current on the west coast, and by the regular alternation of high (winter) and low (summer) pressure cells over the plateau. Precipitation is highly seasonal over most of the region. During winter, dry winds tend to blow offshore, away from the central plateau, which is then virtually rainless except for the extreme south.

Wet weather in the far southern interior occurs sporadically in winter. It is due to cold air from the Southern Ocean moving eastwards or northeastwards across the tip of the continent and temporarily displacing the high pressure cell. These 'cold fronts' seldom, if ever, reach farther north than South Africa, and manifest their greatest influence over the southern part of that country.

Along the west coast the prevailing winds are from the south. They blow parallel to the coast, almost throughout the year, and are cool and desiccating. Thus the west coast is extremely arid. The narrow band of the Namib Desert, between 80-160 km wide, occupies the coastal strip for some 1700 km from Mocamedes in Angola to a position

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south of the Orange River mouth in South Africa. On this coast the sand desert reaches the sea in places, and sand dunes approach 350 m in height. Some localities are perennially rainless, and over most of the area precipitation seldom exceeds 50 mm in more than two months of any one year.

Moisture laden winds blow onshore along the southeastern and eastern coasts in summer, leading to moderate levels of precipitation at the coast, and relatively high levels on the mountains which provide a continuous backdrop to the coastal plain. During summer the high eastern edge of the Drakensberg Escarpment in Lesotho is almost perpetually covered by cloud, and in parts of northern Natal and western Swaziland a summer mist belt forms on seaward facing scarp slopes above 1200 m. Precipitation in these areas exceeds 2000 mm locally and is possibly higher on the plateau rim in Lesotho. Thunderstorms are frequent along the full length of the great eastern escarpment, usually occurring on more than 100 days per summer season in parts of Natal and Swaziland. However, areas of great local aridity occur in the hinterland of the east coast. For example, the Tugela River has eroded a deep wide valley through the seaward slopes of the plateau in Natal, and while mean annual precipitation at the edges of the valley is in the vicinity of 1200 mm, some stations deep in the valley receive less than half of this. Similarly, parts of the lower Usutu Valley in Swaziland are very arid, and in such sites high levels of insolation and evapo-transpiration exacerbate the ecological impact of poor local rainfall.

In addition to the warm and humid southeasterly and northeasterly winds from the Indian Ocean, which primarily influence the eastern side of the region, moist air from the Zaire Basin moves south in summer, causing heavy precipitation on the mountainous Zaire-Zambezi watershed. Here, along the northern boundary of the region, mean annual rainfall may reach 1700 mm. Nevertheless, the influence of the Zaire airmass wanes quickly in passing southwards to lower ground, and the south of Zambia is consequently drier than the north.

Seasonal and regional extremes of temperature occur throughout the interior plateau. Daytime temperatures frequently exceed 40°C in the north in summer, while by contrast, frosts are common in the south in winter. Readings as low as -18°C have been recorded at the top of the Drakensberg Escarpment in Lesotho, and widespread frosts are common on the southern and central parts of the interior plateau. Mild frosts occur on the coastal slopes of the plateau, e.g. above the 400 m contour in Natal. In South Africa, snow frequently covers the peaks of the mountains in winter, and in some years briefly covers the higher parts of the plateau. Very rarely it reaches the southern Transvaal, and has been known to fall on the higher coastal slopes of Natal.

Drainage

All the principal rivers of the region have their sources in the mountains of the high rim of the central plateau. Drainage is accomplished either by short steep streams which descend the scarp slopes directly to the sea, or by long streams which at first flow down the more gentle slopes to the interior of the plateau. Here, like the Okavango River, they may dissipate their waters in endorheic wetlands, or like the Zambezi and Orange Rivers, they may traverse deep gorges through the rim of the plateau. Both these latter rivers reach the sea on the side of the continent opposite to that on which they rise.

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Coastal, or scarp, streams have small drainage basins compared to those of the rivers which cross the plateau, but this is not to say that all scarp streams are unimportant. For example, the Save River drains an area of 92 100 km^2 in Zimbabwe and Mozambique, and the Tugela River drains an area of 29 008 km^2 in South Africa. This latter drainage basin is approximately the same size as Belgium and it is larger than some small African states. On the west coast, south of Benguela, all scarp streams are ephemeral, and even the Cunene River ceases to flow at the surface near its mouth in dry seasons. On the south and east coasts only the smallest streams cease to discharge to the sea during dry seasons, at which time their mouths become choked by sand-spits so that their lower reaches invariably form brackish lagoons filled by reeds and/or trees.

The principal drainage basins of the region, which include two of the largest in Africa, are those of the Cuanza and Cunene (Kunene) Rivers which flow into the Atlantic Ocean in Angola, the Cubango (Okavango) River which discharges internally into the Okavango Swamps in Botswana, the Orange River (1 020 000 km^2) which reaches the Atlantic Ocean in South Africa, and the Limpopo and Zambezi (1 330 000 km^2) Rivers which reach the Indian Ocean in Mozambique.

Wetlands

Tidal wetlands have a sporadic distribution around the entire coast, but mangrove vegetation reaches a southern limit on the west coast at Benguela in Angola (12°35'S), and on the east coast, at the Nahoon River mouth (32°59'S) in South Africa. At latitudes higher than these, herbaceous saltmarsh vegetation prevails on sheltered intertidal mudflats. There are numerous small lagoons and estuaries on the east coast and, in northern Natal and Mozambique, lakes and swamps occur along rivers and intermittent streams crossing the coastal plain. Other wetlands occur in depressions between stranded coastal dunes, and at the seaward edges of the lowland plain immediately to landward of the active coastal dune system. Some small marshes and pans occur on ephemeral streams on the west coast. On the high rim of the plateau, seepage from extensive sponge bogs provides the headwaters for the rivers, and in an area where water resources are at a premium, these must be of prime concern in conservation policies. Small basin bogs, or dambos, are scattered on the wetter slopes of many northern catchments, e.g. in Zambia and Malawi, and vast swamps and floodplains occur along the Zambezi and its tributaries where these streams traverse the flatter northern parts of the interior plateau. Elsewhere, in the arid western and central parts of the plateau, seasonally flooded salt pans have a scattered distribution, and there are a few perennial endorheic lakes and ponds.

With the exception of the Cuanza and Cunene, all the principal river systems transgress national boundaries, as do some important wetlands. To set the national accounts in context, overviews of two important physiographic features of the region are given here. These are the Southeast African Coastal Plain and the Zambezi Basin, the latter encompassing parts of Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia and Zimbabwe.

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The Southeast African Coastal Plain

This sandy plain extends for some 2700 km up the southeastern coast of Africa, spanning 15° of latitude from Durban (29°53'S) in South Africa to Mossuril (14°55'S) in Mozambique. It exceeds 160 000 km^2 in area and reaches 130 km in width. It is flat and hot, and riddled with swamps, despite having a comparatively arid climate in southern Mozambique. Thus at Quegulele (24°07'S/32°37'E) for example, where the Limpopo River emerges onto the plain, mean annual rainfall is 500 mm, while mean class A pan evaporation is 1800 mm. At Chókwé, some 20 kilometres nearer the sea, mean annual rainfall is close to 700 mm, but evaporation is also higher at almost 2300 mm/yr. Along the sea the plain is bounded by an almost continuous line of richly forested dunes, rising at Maphelana (28°24'S) to over 180 m in height. The plain extends from the tropics southwards into a warm temperate zone providing a discontinuous series of very similar wetland habitats along its length. Numerous clines, of both plants and animals, occur here. Inland of the dune forest the predominant terrestrial vegetation of the plain is thornveld, or open thornveld in southern Mozambique and northern Natal, reflecting the aridity of those areas.

Enormous quantities of siliceous alluvium are brought down to the coast from the mountainous hinterland each year, and are then swept northwards up the coast by longshore drift. In places, e.g. north of the Tugela River mouth in Natal, the sand is coarse and the beaches and dunes steep. Here the dunes rise with remarkable abruptness from the coastal plain, but where finer sand predominates, e.g. in Inhambane, the dunes are lower and the beaches flatter. The coast has been tilting seawards along a monocline for millions of years, but lateral shifts of the hinge line have led to alternate phases of coastal emergence and submergence. As a consequence of the former process, lines of stranded dunes may be found on broader sections of the plain, and a series of terraces appears in many river valleys. The hinterland has been rising since the inception of the monocline and consequently scarp rivers have been in a state of constant rejuvenation and have produced unusually large valleys. It is the material from these valleys which now forms the coastal plain.

Storms of great intensity occur over the mountainous hinterland and plain, during some of which precipitation has been known to exceed 500 mm in 24 hours, and on at least one occasion to exceed 740 mm in 36 hours. Sheet flooding may then occur on the middle plain, leading to huge soil losses, while seaward parts of the plain may be inundated to depths of 10 m or more. Fresh alluvium, 4 m deep, may be deposited over large areas of the coastal plain as a consequence of a single flood, and local landform and drainage patterns may change dramatically; shallow lakes may disappear.

Mean annual rainfall is higher at the coast than it is on the plain, and decreases progressively and quite sharply with increasing distance from the sea. It is for example, about 1000 mm at Sodwana Bay (27°30'S), but barely 600 mm at the western edge of the plain some 40 km inland. However, rainfall rises again on the series of scarps and interspersed plateaux which lead upwards to the rim of the central plateau. In passing northwards along the coast mean annual rainfall is about 1250 mm at Durban, decreasing to 1000 mm or less in northern Natal and southern Mozambique. It falls to some 800 mm at the Limpopo River mouth, but thereafter increases through Inhambane, to 1300 mm at Beira and to 1400 mm on the Zambezi Delta. Locally, in northern Mozambique, it

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may reach 1500 mm. Precipitation is highly seasonal throughout the plain and varies considerably from one year to the next. In a normal year the five months from May to September, at least, are virtually rainless. Severe droughts, lasting for several years, are not uncommon.

The entire east coast is strongly influenced by the Mozambique (Agulhas) Current which flows southwards at the edge of the continental shelf. Core temperatures in this stream reach 26°C and it lies close inshore in southern Mozambique and northern Natal. At Sodwana Bay (27°30'S) it is scarcely 3 km from the beach. The current flows most strongly in the immediate vicinity of its convergence with the continental shelf and the cooler inshore water, reaching surface velocities of 5 knots when northeast winds are behind it. Eddies are generated at the boundary with the cooler water over the continental shelf, and these cause tongues of warm surface water to circle landwards where they are deflected northwards alongshore. In consequence, in summer, inshore waters are maintained at temperatures exceeding 21°C as far south as Port Elizabeth (33°58'S). The great latitudinal extension of mangroves on this coast, compared to the west coast, is due to the Agulhas Current. This produces both warm coastal water, and an abundance of alluvium as a consequence of the cooling of warm moist air over the mountainous hinterland.

The prevailing wave attack is from the southeast. It is powerful and oblique to most of the coast, consequently driving a river of sand northwards along shore. Typically, northward pointing spits develop from promontories which then shelter quiet bays, and most river mouths (except for some in the Bay of Maputo, where wave attack is frontal) are diverted northwards behind dune covered spits. Mangroves are confined to the southern shores of bays, and to estuaries and lagoons. The mouths of rivers with low winter discharge rates tend to be occluded by the development of sand-bars so that brackish lagoons develop behind or between the dunes. Such lagoons may be tidal in summer, or they may open to the sea only for a few days each year following heavy rain in the catchments. Where coastal emergence has occurred small streams have often changed course, abandoning their estuaries and finding new routes to the sea. In this way lagoons of varying sizes become isolated as lakes on the landward side of the plain immediately adjacent to the active dunes. Lake Sibaya in northern Natal was almost certainly formed in this way and appears to represent an estuary abandoned when the Pongolo River turned north. Only a few kilometres distant, at Kosi Bay, the abandoned estuary of the Ingwavuma River reveals an earlier stage in the process. Although the lake system is still tidal its connection with the sea is tenuous, and the mouth of the system has been closed by sand-bars several times this century. It seems likely that the remnants of this estuary will eventually be isolated from the sea. Numerous lakes with an apparently similar heritage are found along the entire length of the coastal plain. Both the Pongolo and Ingwavuma Rivers have been captured by the Usutu River, which has itself been turned northwards and now occupies a swampy depression between lines of old stranded dunes. The swales between stranded dunes on low-lying parts of the plain are often extensive, invariably swampy, and the type of wetland they support occurs throughout the plain.

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All rivers crossing the plain are liable to overtop their banks following storms in their catchments, but some, such as the Pongolo, Pungue and Changane, regularly inundate broad floodplains during the rainy season. The courses of these rivers are marked by a succession of pans, pools, swamps and lagoons adjacent to the river bed. Some of these are perennial, while others hold shallow water for but a few months each year.

The Zambezi Basin

The Zambezi River rises 1585 m asl in a sponge near Kalene Hill (11°10'S/24°12'E) on the northern rim of the plateau in the extreme northwest of Zambia. It first flows north, then west into Angola, then south receiving eleven major tributaries in a 280 km stretch across the high plateau, during which distance it loses 300 m of altitude before re-entering Zambia at Caripande. Above this point the river is bridged five times. Immediately across the border in Zambia the stream widens and descends two falls near Chavuma, then the Nyamboma Rapids, and then receives two major tributaries, the Kabompo on the east bank and the Lungue-Bungo on the west, having then descended to an altitude of 1000 m. The first major wetland of the system occurs on the Lungue-Bungo which rises in Angola. This river descends comparatively steeply from its source in the northern highlands to the Zambian border, but thereafter it traverses a plain which becomes progressively more swampy as it approaches a confluence with two subsidiary streams, about 60 km above the Zambezi. The floodplains of all three tributary rivers merge in a permanent swamp which extends to 75 km in length and 25 km in width at high water and then covers an area approaching 100 000 ha. This swamp, which is sometimes referred to as the Nyamboma Swamp, is situated in a sparsely populated, tetse fly infested area which has few communications and is poorly known.

Below its confluence with the Lungue-Bungo the Zambezi begins to flow more slowly and has developed a seasonal floodplain in a shallow marshy valley throughout Barotseland. The floodplain first develops on the west bank above Likulu, and on the east bank some 15 km farther south. It extends for over 250 km to the south of Senanga, reaching widths of 40 km and maximum areas approaching 770 000 ha at high water. Inundation is highly seasonal and areas of permanent swamp are comparatively small. In traversing the Barotseland Plain the river meanders so much that its length exceeds 590 km. However, the river is bridged at Lealui, in the middle of the plain, close to the confluences of two other tributaries, each of which also drains an important wetland system. The first tributary, the Luena, flows for 100 km through the Luena Flats, towards the lower end of which it loses its integrity and breaks up into many shifting streams in an area of permanent swampland. In total some 90 000 ha of land is flooded at the height of the rainy season, although rather less than 50% of this is permanent swampland. At the lower end of the flats, 60 km above the confluence with the Zambezi on the east bank, the Luena again emerges as a single stream. The second tributary, the Luanginga, rises in Angola and is itself swollen by eight subsidiary streams before it reaches the Zambezi on the west bank. About 100 km above its confluence with the Zambezi one of its subsidiary streams, the Luate, drains the permanent Nyengo Swamp which has a maximum high water area of 70 000 ha.

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At the southern extremity of the Barotse Floodplain, just south of Senanga, the Zambezi is joined on the west bank by the Lueti which drains several large plateau lakes near Chiume in Angola. Some few kilometres downstream the Lui enters on the east bank, having drained substantial areas of permanent swamp near its headwaters, and a seasonal floodplain in its lower course, prior to the confluence with the Zambezi. Then, at an altitude still close to 980 m, near Sioma, the Zambezi enters a long faulted trough in Karoo sediments. In this it plunges over the Ngony (Sioma) Falls and enters a 110 km stretch of rapids, ending in the Katima (Mulilo) Rapids, above which it forms the border between Zambia and Namibia along the northern tip of the Caprivi Strip. Here it flows over a sandy plain, on which it again meanders, and its flood waters spread southwards mingling with those of its next major tributary the Chobe. This latter stream forms the southern border of the Caprivi Strip, between Namibia and Botswana.

The Chobe rises in Angola as the Cuando (Kwando) and in common with its principal tributary, the Utembo, has a source in a sponge on the eastern side of the Lunda Divide (plateau rim) in Angola. Both streams flow southeastwards, out of the hills and inland across the plateau, and together drain a catchment of 96 778 km^2. There are no important wetlands along the upper courses of these rivers, which are boulder strewn and full of rapids, although small reed swamps occur on some of their tributaries and parts of their upper courses carry thin fringes of *Phragmites*. However, in its lower reaches, the Cuando develops an intricately braided course for over 320 km along the border between Angola and Zambia as it approaches the Caprivi Strip. This it crosses, traversing the Linyanti Swamp en route, but emerging from the swamp, after a name-change, as the Chobe River. Much of the eastern extremity of the Caprivi Strip between the Zambezi and Chobe Rivers is flooded during the rainy season, with semi-permanent swampland occupying more than 150 000 ha, and the total area of inundation reaching 380 000 ha when the rivers are in spate. This latter area is often also considered part of the Linyanti Swamp, and at times of highest water it extends outside the Caprivi Strip into both Botswana and Zambia. The Chobe and Zambezi Rivers meet between Kasane and Kazungula, at an elevation of 880 m, after which, as it approaches the Victoria Falls and the end of its upper course, the Zambezi has a mean width of 1350 m.

To the west of the Linyanti Swamp, in Botswana, is the Okavango Delta. This is fed principally by the Cubango or Okavango River. At times of high flood however, some of the water from the major eastern distributary of the Okavango River, the Bonga River, passes eastwards from the neck of the delta through swampy land to the so-called Selinda Spillway. This leads to the Linyanti Swamp. Thus from here some Okavango water may find its way to the Zambezi via the Chobe River. The prospect of the Chobe eventually capturing the waters of the Okavango by backward erosion of the head of the Selinda Spillway clearly exists. The Linyanti Swamp also receives water from Botswana via the Savuti Channel. At times water in this flows northwestwards, entering the Linyanti Swamp at its southeastern extremity, thus at times, the Zambezi drains a small part of Botswana.

The middle course of the Zambezi extends for almost 1000 km, from the Victoria falls eastwards, through Lake Kariba, to Lake Cahora Bassa. The river marks the

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border between Zambia and Zimbabwe until it enters the western end of Lake Cahora Bassa at the twin towns of Luangwa (Feira) and Zumbo, which lie astride the Zambia-Mozambique border. Lakes Kariba (563 100 ha at upper storage level) and Cahora Bassa (266 500 ha at upper storage level) are currently the third and fifth largest impoundments in Africa. In its middle course the Zambezi receives two of its most important tributaries, the Kafue and Luangwa Rivers, on the Zambian bank, and the Gwai (Shangani), Sanyati and Hunyani on the Zimbabwean bank. The southern tributaries rise high on the eastern watershed of the plateau near Bulawayo, Gweru (Gwelo) and Harare respectively. The Sanyati now discharges into Lake Kariba, while the Hunyani enters Lake Cahora Bassa.

Further important wetlands are situated in the Kafue Basin in Zambia. Here the Kafue River drains an area of 155 000 km^2 and has several sources high on the central northern rim of the plateau, at elevations between 1370 and 1560 m asl. Upstream the Kafue receives first the Lushwishi and then the Lukanga Rivers as tributaries. The course of the latter stream disappears in the Lukanga Swamp which occupies a shallow depression of 259 000 ha, from which it reappears as a discrete stream just prior to its confluence with the Kafue River. Subsequently, on the other (west) bank the Kafue receives its largest tributary, the Lunga, and then a few kilometres downstream, the Lufupa, the latter draining Busanga Swamp. This swamp is only slightly smaller than that at Lukanga. From the Lufupa confluence the river flows due south, traversing the Mpatamatu Gorge to an impoundment at Itezhitezhi. From here it swings eastwards and meanders, with a broad floodplain, across the 256 km length of the Kafue Flats to another impoundment at Kafue Gorge. The hydrological regime of this important floodplain is now controlled by the two dams at its western and eastern extremities. Open water now covers some 85 000 ha behind the Itezhitezhi Dam, while the permanent lake at Kafue Gorge may shrink to 120 000 ha at low water and expand to 435 000 ha at high water, making it currently the fourth largest impoundment in Africa. The total area of the Kafue Flats has been estimated as 705 000 ha, of which, prior to control, over 500 000 ha could be inundated in a wet year. However, with the advent of regulation, the area flooded each year is now always less than this. From the Kafue Gorge Dam the river descends a series of steep rapids, losing 610 m in altitude over 24 km, before discharging into the Zambezi opposite the town of Chirundu in Zimbabwe.

The high, wetter, regions of the Kafue catchment, and indeed the higher parts of all other catchments tributary to the Zambezi, are riddled with 'dambos'. These are isolated, shallow, seasonally or semi-permanently waterlogged depressions, generally saucer-shaped in section. Locally they cover as much as 10% of the total land surface and are then the most conspicuous feature of the landscape. Drainage from dambos is diffuse, and collectively they excercise a profound influence on the surface hydrology of a basin and thus merit consideration as important wetlands. Further they harbour several species uncommon in other habitats. Numerous small marshes occur on the southern tributaries in the highlands of Zimbabwe, and on the Luangwa in the far north of Zambia as it traverses the upper part of the plateau. The Luangwa rises at an elevation of 1600 m asl, in the far north of Zambia, just south of Chitipa, at a latitude of 9°45'S. It flows south, and then southwest across the upper plateau, before descending comparatively steeply and flowing along the line of the Muchinga Escarpment to the Zambezi, which it joins at the town of Luangwa, at the head of Lake Cahora Bassa.

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From Cahora Bassa the Zambezi descends from the plateau, flowing swiftly through a long narrow valley to reach the lowlands of Mozambique which it crosses to its delta on the Indian Ocean. It receives numerous tributaries in this lower section, all of which are streams which descend the scarp slopes along the eastern side of the plateau. The first and most important of these on the south bank is the Mazoe-Luenha, which drains the eastern highlands of Zimbabwe, and reaches the Zambezi some 50 km below the town of Tete. The most important on the north bank is the Shire River, which drains a vast catchment around Lake Malawi.

Three countries border Lake Malawi: Tanzania, Mozambique and Malawi. Mountains surrounding the lake rise to 2035 m in the southwest and 2959 m in the northeast. Numerous short streams feed the lake which drains southward via the Shire River through Lake Malombe and the Shire Marshes to the Zambezi. Lake Malawi, which lies in the southern part of the East African Rift System, is situated along the eastern, seaward, side of the plateau. It has a mean surface height of 474 m asl, a total open water area of 2 975 000 ha, and stretches 558 km from north to south, with a maximum east-west dimension of 89 km. In places it is fringed by swamps and marshes. South of Lake Malawi the Shire Marshes comprise an almost continuous tract of permanent wetland to the confluence with the Zambezi, with a total area in Malawi and Mozambique in the vicinity of 130 000 ha. Seasonal floodplains also occur in a narrow strip along parts of the lower Zambezi, in the Zambezi Delta, and over parts of the coastal plain where ancient distributaries of the Zambezi once flowed.

Vegetation

The vegetation of Region 5 is complex. Much of the southwestern seaboard is occupied by the Namib Desert, inland of which are long parallel zones of thorny bush and scrub. Farther north in Angola, the coastal desert gives way to steppes and these to wooded grasslands, while much of Cabinda is covered by typical West African coastal forest. A strip of East African coastal forest and scrub occupies almost all of the Indian Ocean coast, grading westwards, inland, to *Acacia* savannas and these, at altitude, to Afro-montane vegetation on the eastern rim of the plateau.

A mosaic of different bushy types, mostly evergreen, occupies the far south, but these give way in passing north to highveld grasslands along the interior slopes of the Drakensberg Mountains, and to *Acacia* savanna in the southern central plateau. In proceeding northwards over the central plateau Zambezian woodlands appear. These also contain much *Acacia*, and in their turn grade into mopane (*Colophospermum mopane*) woodlands or into more closed Zambezian forest types. The northern interior is largely covered by miombo woodland, characterised by the dominance of *Brachystegia*, *Isoberlinia* and *Julbernardia* species.

The southern tip of Africa, and in particular the southern Cape Province of South Africa, has been one of the great centres of angiosperm evolution and presently harbours one of the richest regional floras in the world, c. 16 000 spp. Temperate species have migrated northwards from the Cape, while tropical species have moved south so that many species in Africa reach their southerly or northerly limits of distribution in a transitional zone in the middle latitudes of Region 5. However,

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floristically, Southern Africa has been rather isolated since before the beginning of the Tertiary. Unless mediated by migratory birds, plant migrations must have taken place along the coast or overland, where, in both cases, the tropics have constituted a barrier. The temperate species of the Cape Province have probably been speciating separately for a very long time.

Wetland Flora & Fauna

The variety of wetland types in this region, which encompasses such a rich vegetation and range of habitats, does not lend itself to a single brief description. Thus separate accounts are given for each country.

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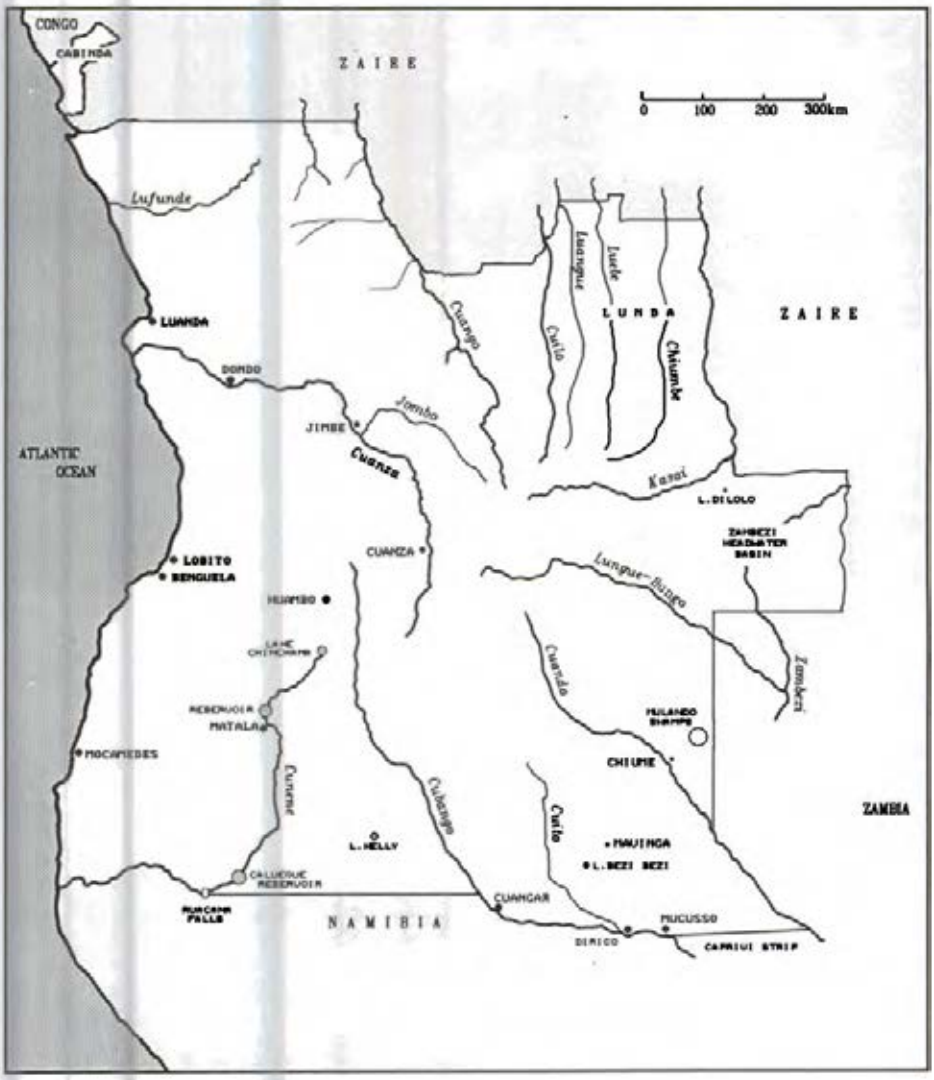

Map of Angola

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5.1 ANGOLA

Introduction

Angola is the largest country in Southern Africa, as that region is defined here, having an area of 1 246 700 km^2. It has a population of 7 108 000 (1983) and hence a mean population density of 5.7 persons/km^2. Excluding Cabinda, Angola stretches approximately 1320 km from N-S, between latitudes 5°52' and 18°00'S, and 1365 km from E-W between longitudes 11°41' and 24°05'E. The Angolan coast, over 1650 km long, occupies the Atlantic seaboard of Africa between latitudes 5°00' and 5°47'S (Cabinda) and 6°05' and 15°17'S (mainland Angola). Thus its entire coastline is tropical.

The small northern enclave of Cabinda (7270 km^2) is a hot, wet, rolling lowland, backed by forested hills on both its northern and eastern borders, but the main body of the country, 60% of the total area, is situated on the great Southern African Plateau and is mostly over 1000 m in altitude. This latter area comprises a great dissymetric bastion, sloping gently to the east, but broken into abrupt steps along the Atlantic coast. The coastal plain is narrow, 10-35 km wide over the southern and central parts. It rises steeply on the landward side, into the serried slopes, deeply gullied escarpments, minor plateaux, and mountains of the western rim of the plateau which reaches a maximum elevation of 2620 m at Mt. Moco in the Huambo District (12°30'S/15°11'E) and 2583 m at Mt. Meco. In this region some 360 000 ha of mountainous country is situated above the 2000 m contour, and a surrounding area of over 7 800 000 ha lies above the 1500 m contour. Four other highland blocks rising above 1500 m lie due west of this principal massif, and the line of these blocks effectively marks the northern rim of the Southern African Plateau. The western rim of the plateau, over 1500 m high, lies parallel to the coast in the southern central part of Angola, approaching to within 125-175 km of the Atlantic Ocean. The great interior plateau provides an immense reserve of water, and here all the major rivers have their sources.

A smaller upland block in the north is separated from the main block by the valley of the Cuanza River. This northern block reaches altitudes of 1000-1600 m asl and is centred on the town of Negage (7°47'S/15°27'E). In total 66% of the Angolan land surface lies between 1000-1600 m asl.

Drainage

Drainage is complex. No less than 26 perennial rivers reach the Angolan coast. Most of these are comparatively short steep streams which descend directly from the plateau. Others, such as the Cunene, which marks part of the southern border, and the Cuanza, drain large interior basins before swinging west to the coast. The Cunene is extremely seasonal in its flow, and in winter its mouth is often dry, the small flow then being concealed beneath the sandy bed. Between the Cunene and Cuanza 21 other rivers drain the highlands directly to the coast. The first 8 of these, immediately north of the Cunene, in the most arid region, are intermittent streams, not even flowing throughout their entire courses in some years, but the remaining 13 are perennial streams, although highly seasonal in the volume of water that they carry. Between the Cuanza and the Zaire Rivers, which marks the northern border, a further 10 perennial rivers reach the sea, flowing directly out of the northern highland block.

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Drainage lines to the interior radiate from the series of highland massifs along the northern rim of the Southern African Plateau. The principal streams are the Cunene, Cubango, Cuando, Lungue-Bungo, Luena, Kasai (Casai), Cuilo, Cuango and Cuanza Rivers. The Cunene flows off the plateau to reach the Atlantic at the southern boundary of Angola. The Cubango discharges into the Okavango Swamps in Botswana, from where its flood water sometimes finds its way to the Zambezi via the Selinda Spillway and Chobe River; the Cuando, Lungue-Bungo and Luena are tributaries of the Zambezi, while the Kasai, Cuilo and Cuango Rivers are all tributaries of the Zaire (Congo) River. Subsidiary streams flowing north to the Zaire River are numerous and most lie in deep straight parallel trench-like valleys. Over a dozen rivers occupy these characteristic valleys, but some of them unite in their lower reaches, to form the three principal Angolan tributaries of the Zaire River just mentioned. The Cuanza sweeps round, through a huge valley in the western plateau rim, to reach the Atlantic Ocean in central Angola. Interior drainage from the smaller northern highland block, is either south to the Cuanza, or east and north to the Zaire River.

Climate

Temperatures over the southern central region are modified by altitude. Mean annual temperatures are lowest over the western highland block, where they are in the vicinity of 16.5°C. Most of the interior and the southern coastsl strip have mean annual temperatures close to 20°C, but this increases in the coastal lowlands, in passing north, to 25°C at Namibe (15°10'S/12°09'E) and to 28°C at Sumbe. From here farther north, mean annual temperatures at the coast approach 30°C. However, the interior is cooler, and in the northern central part of the country, where parallel valleys run down to the Zaire (Congo) River, mean annual temperature is again low, c. 18°C. This is largely the result of heavy cloud cover for several months during the rainy seasons.

There are two seasons, a rainy season, which in the north and central districts may last for 7 months, from October to May, and a dry season. Temperatures do not fluctuate a great deal from wet to dry seasons. Much of the northern interior, on land sloping towards the Zaire River Valley, receives up to 2000 mm rain/yr. Mean annual precipitation also reaches, or even exceeds this figure over some 7 500 000 ha of high land in the Huambo district. From here, on the western rim of the plateau, precipitation decreases progressively towards the coast, falling to 500 mm in central coastal districts. Going east from Huambo into the central interior, rainfall decreases progressively to 1100-850 mm/yr on the Zambian border. The south of the country, along the Namibian border, receives some 750 mm rain/yr, but this decreases abruptly in approaching the coast, where at the mouth of the Cunene River mean annual rainfall is a mere 20 mm/yr. The southern coastal strip is under the influence of the cold, northward flowing Benguela Current, which brings cool arid conditions to much of coastal SW Africa. The influence of this current however, begins to wane in the vicinity of Lobito (12°20'S/13°34'E), north of which the coast is significantly warmer, and the hinterland more humid. However, coastal rainfall does not reach 750 mm/yr until well north of Luanda (8°50'S/13°15'E). It is about 850 mm at the mouth of the Zaire River, rising to 1300 mm on the coast of north Cabinda. In the interior hills of Cabinda it exceeds 1800 mm locally, with rain falling on 120-130 days each year.

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Vegetation

There are arid seaward plains between Sumbe (11°13'S/13°50'E) and the mouth of the Cunene River, surmounting the series of scarps below the great plateau at attitudes of 200-500 m. They support grassy steppes dominated by *Aristida papposa*, *Schmidtia kalahariensis* and *Setaria* sp., but contain large patches of *Acacia heteracantha*, *A. quintanilhae*, *Colophospermum mopane* and *Terminalia prunioides* thornbush, with *Crotalaria* sp., *Indigofera daleoides* and *Cassia italica* in the lower storey. *Acacia albida* and *Combretum imberbe* are found on alluvium along intermittent streams. Savannas of varying density, dominated by *Brachystegia* and *Julbernardia* spp., cover most of the interior plateau in the south and east of the country, while closed forests occur at lower levels in the river valleys tributary to the Zaire River. However, on the higher valley sides these forests are generally backed by savannas. The littoral vegetation of Cabinda is mainly grassy savanna which grades into dense forest on the low hills of the hinterland.

Wetlands

Although the southwest of the country is arid, taken overall, Angola is amongst the wettest of countries in Southern Africa; large areas in the north receive more than 1500 mm of rain/yr, spread over a long wet season. Much of the interior is characterised by gently undulating land between rivers, and in these places drainage is poor. Numerous dambos and some extensive swamps and marshes characterise these areas. Some of these systems include groups of small endorheic lakes. In other places drainage occurs from these swamps to local rivers, but in a rather diffuse fashion. Riparian strip swamps occur along some of the major rivers, or they may have narrow, but often very long, floodplains. These wetlands are dealt with by river systems or regions. Extensive plateau floodplains, such as occur in neighbouring Zambia, are developed only on the Cunene River, and with different character on the Cuanza River. Permanent swamps also occur along the upper reaches of the Cuanza and its tributaries. Strips of tall swampy forest are found along all rivers flowing into the Zaire Basin in North Lunda Province. The coastal plain from Lobito northwards is traversed by many streams with floodplains and dependent lagoonal systems. Mangroves occur on the coast as far south as Lobito, and there are extensive saltmarshes in some sites south of this. Sponges abound in the mountains and provide the sources of many rivers.

Wetland Flora

Riverine Vegetation: Rivers carry thin fringes of *Phragmites mauritianus* at high altitudes in southern and central districts, but once they have descended to the plateau the fringe communities become more extensive and more complex. Plants such as *Commelina microspatha*, *Ethulia conyzoides*, *Floscopa glomerata*, *Kosteletzkya buettneri*, *Mikania cordata*, *Pennisetum glaucocladum* and *Polygonum senegalense* appear in the reed beds here. At lower altitudes *Typha domingensis* enters the association, often forming large stands in and behind the *Phragmites*, and at still lower altitudes *Cyperus papyrus* dominates riversides, growing in front of the *Phragmites*. Papyrus is invariably associated with aquatic grasses at its outer face, notably *Vossia cuspidata* and *Leersia hexandra*.

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The floating species *Aeschynomene fluitans*, *Nymphaea caerulea* and *N. lotus* are common in permanent and semi-permanent ponds along rivers throughout the country, and these plants, together with numerous submerged aquatics, carry a luxuriant epiphyton. *Ceratophyllum demersum* and *Potamogeton* spp. generally dominate the beds of submerged vegetation and are almost always associated with species of *Utricularia*. Around pond margins *Cyperus distans* and *Scirpus muricinus* may be found, together with the swamp fern *Cyclosorus interruptus*, and tall grasses, including *Miscanthidium junceum* and *Pennisetum glaucocladum*. Where pond margins are temporarily expanded by deep flood waters each year, there is usually a zone of *Vetiveria nigritana* and/or other floodplain grasses. *Loudetia simplex* covers large areas where the soil is almost permanently wet but seldom flooded, particularly in the headwater basin of the Zambezi River.

Gallery Forests & Woodlands: In the south these are open woodland associations comprising such species as *Acacia albida*, *A. erubescens*, *A. nigrescens*, *A. sieberana*, *Diospyros mespiliformis*, *Ficus burkei*, *F. capreifolia*, *F. sycomorus*, *Garcinia livingstonei*, *Kigelia pinnata*, *Markhamia acuminata*, *Phoenix reclinata*, *Syzygium cordatum* and *S. guineense*. *Hyphaene benguellensis* is common locally, on sandy banks and islands in rivers. In the north the galleries are taller and more dense, and include a number of Guineo-Congolan species. A forest mosaic occupies the alluvial floors of many valleys in the north, the floristic composition of the different patches being determined by inundation regimes ranging from seldom inundated to permanently inundated. This mixed forest type is known locally as muxito and is characterised by *Anthocleista vogelii*, *Apporrhiza nitida*, *Carapa procera*, *Mitragyna ciliata*, *Nauclea pobeguinii*, *Oxystigma buchholzii*, *Pandanus candelabrum*, *Parinari congensis*, *Phoenix reclinata*, *Raphia gossweileri*, *Spondianthus preussii*, *Symphonia globulifera*, *Uapaca guineensis*, *Ventilago africana*, *Voacanga thouarsii*, *Wildemaniodoxa* (*Chrysophyllum*) *laurentii* and *Xylopia rubescens*, together with the climbers *Chaetocarpus africanus*, *Eremospatha cabrae*, *Terminalia gossweileri* and *Tetrapleura tetraptera*. Often the secondary nature of muxito is betrayed by the presence of species such as *Annona senegalensis*, *Canarium schweinfurthii*, *Chlorophora excelsa*, *Ceiba pentandra*, *Elaeis guineensis*, *Musanga cecropioides*, *Raphia textilis* and *Xylopia aethiopica*. The understorey contains coarse herbs such as *Sarcophrynium* sp. (Marantaceae), *Lycopodium cernuum* and several terrestrial and climbing ferns. Species of *Impatiens* occur here, and *I. gossweileri* is found semi-submerged on the margins of pools.

Tidal Forests: The mangrove flora is richest in Cabinda and species drop out of the association in passing southwards. The coast and hinterland become more arid in this direction, and inshore sea surface temperatures decline, reflecting the strengthening influence of the cold Benguela Current. The progressive loss of mangrove species is well established before Luanda (8°50'S/13°15'E). An abrupt transition from a tropical to a temperate spectrum of marine species is seen in both flora and fauna in the vicinity of Cape Santa Maria (13°27'S/12°31'E) south of Benguela. Tropical species predominate to the north of this, while temperate ones are ascendant to the south.

In rapidly prograding sites the frontal mangrove swamp consists of *Rhizophora racemosa*, size graded from juveniles at the seaward face to a mature forest 20 m high towards the land. The widths of the size graded zone and the mature forest zone varies. The former is seldom more than 200 m wide, and the latter seldom more than 1000 m wide, and these

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widths are reached only in Cabinda and in the estuary of the Zaire River. Behind this zone, on rising ground, there is usually an extensive *Rhizophora harrisonii* zone, with a canopy height of 10-20 m in Cabinda and on the Zaire River. Up estuaries and their affluents in northern Angola these latter forests may grade into *Pandanus-Raphia* swamps and these into pure *Raphia* swamps dominated by *R. hookeri* and *R. palmapinus*. This situation arises where rivers have high discharge rates for much of the year and fresh to brackish tidal conditions prevail for long periods. *Raphia* swamps represent a stage in the transition from tidal to fresh water swamp forest which develops both behind and upstream of the *Rhizophora-Pandanus-Raphia* swamps.

Near to the mouths of some estuaries there are drier sites behind small *Rhizophora* stands, where inundation is shallow and the soil is firm and saline. In these places *Avicennia* zones develop, with open canopies 10-15 m high. *Laguncularia racemosa* is an associate here, and dense swards of *Acrostichum aureum* grow in open glades. Bushes of *Conocarpus erectus* may be found on the fringes of littoral thickets, together with *Dalbergia ecastaphyllum* and *Drepanocarpus lunatus*, the latter pair often growing as scandent shrubs. *Acrostichum* may also appear in the more landward parts of the *Rhizophora* zone, after felling, where it sometimes grows so densely that it may preclude forest regeneration. Raised sandbars are a feature of many river mouths, including the Zaire River, and typically, these are covered by low thickets comprising, among other species, *Caesalpinia bonduc*, *Chrysobalanus icaco*, *Dalbergia ecastaphyllum*, *Drepanocarpus lunatus*, *Hibiscus tiliaceus*, *Rhopalopilia marquesii*, *Syzygium guineense* and *Ximenia americana*.

In the south of Angola tidal swamps are backed by open salinas on the landward sides. These are virtually devoid of vegetation, but are often fringed by narrow strips of saltmarsh vegetation along the inner margins. Here *Sesuvium portulacastrum* is prominent. These saltmarsh strips grade into fringes of halophytic grassland at the tidal limit where *Sporobolus virginicus* is often dominant. Tall grasslands studded with *Hyphaene gossweileri*, or littoral thickets, are found beyond this in the supra-tidal zone.

Chrysobalanus icaco, *Dalbergia ecastaphyllum*, *Drepanocarpus lunatus*, *Hibiscus tiliaceus*, *Pandanus candelabrum* and *Raphia vinifera*, which are found on the margins of tidal swamps in different situations in the north of the country, all reach their southern limits of distribution at or before the Cuanza River mouth (9°20'S), while *Rhizophora racemosa* reaches the mouth of the Cuvo River (10°49'S). *Avicennia africana* forms monospecific stands in Lobito Bay (12°19'S) and at the mouth of the Catumbelo River (12°26'S/13°31'E). In some northern rivers a mixed woodland occurs on levées and sand banks flooded only by the highest tides, but then by saline water, and this is dominated by *Baikiaea insignis*, *Camoensia brevicalyx*, *Carapa procera*, *Chrysobalanus icaco*, *Dalbergia ecastaphyllum*, *Drepanocarpus lunatus*, *Heteropterys leona*, *Hibiscus tiliaceus*, *Pandanus candelabrum* and *Ternstroemia africana*.

Fresh Water Swamp Forests: These occur along lowland rivers and on the fringes of lagoons, where the soil surface is inundated for long periods each year. In such places many Guineo-Congolan species are present and *Anthocleista vogelii*, *Carapa procera*, *Mitragyna ciliata*, *Phoenix reclinata*, *Symphonia globulifera*, *Uapaca guineensis*, *U. heudlotii* and *Voacanga thouarsii* are common.

Floodplains: The most important floodplains are in the SE and these are dominated by grasses typical of the Zambezian region. Depressions which are flooded for long periods

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are covered by *Acrocerum macrum*, *Echinochloa pyramidalis*, *Oryza barthii*, *O. longistaminata* and *Sacciolepis africana*, with *Echinochloa scabra*, *Eriolasia imbricata*, *Hyparrhenia* spp., *Panicum repens*, *Paspalum suborbiculatum*, *Setaria sphacelata* and *Vetiveria nigritana* in more temporarily inundated spots. *Heteropogon contortus* and *Cynodon dactylon* occur where flooding is only brief. On patches near rivers, where inundation is regular but of short duration, *Heteropogon contortus* and *Cynodon dactylon* are dominant if grazing is intense.

Dambos: These occur in southeastern and central eastern Angola and support various hygrophilic grasses and sedges, together with *Xyris anceps* and numerous dicotyledonous herbs.

Wetland Fauna

Fishes: The fish fauna of the Cunene River changes in passing upstream since fish are unable to ascend the waterfalls. The spectrum of species found on the plateau is similar to that found in the Cubango and other tributary streams of the upper Zambezi and Okavango systems, and differs from those found in Atlantic coast streams, suggesting the original Zambezian affinities of the Cunene. Species of Zambezian affinity common in the southern and central rivers include *Clarias gariepinus*, *Hepsetus odoe*, *Hydrocynus vittatus*, *Labeo lunatus*, *Oreochromis macrochir*, *Serranochromis angusticeps*, *S. macrocephalus*, *Synodontis woosnami* and *Tilapia sparrmanii*. *Alestes macrolepidotus*, *Gymnarchus niloticus*, *Malapterus electricus*, *Protopterus annectens*, *Schilbe mystus* and species of *Barbus*, *Labeo*, *Marcusenius*, *Mormyrops*, *Synodontis* and *Tilapia* are also important in central and northern districts.

Reptiles: *Crocodylus niloticus* occurs throughout the country, but is scarce locally, while *C. cataphractus* also occurs in the northern rivers. *Varanus exanthematicus* and *V. niloticus* are both found in Angola. Snakes are plentiful in the wetlands. *Dromophis lineatus*, *Limnophis bicolor*, *Naja mossambica*, *Natriciteres olivacea*, *Philothamnus irregularis*, *P. ornatus*, *Psammophis sibilans* and *Python sebae* are common in swamps or reed beds throughout the country, while *Naja melanoleuca* occurs in swampy situations in central and northeastern districts. Arboreal snakes in the riparian forests include *Dasypeltis scabra*, *Dispholidus typus*, *Philothamnus semivariegatus* and *Thelotornis kirtlandii* (W African form).

Birds: Widespread species from southern rivers, lagoons and reedswamps include *Acrocephalus* spp., *Amandava subflava*, *Amblyospiza albifrons*, *Anas sparsa*, *Anhinga rufa*, *Ardea goliath*, *A. purpurea*, *Ardeola ralloides*, *Asio capensis*, *Balearica pavonina*, *Butorides striatus*, *Centropus cupreicaudatus*, *Ceryle rudis*, *Circus aeruginosus*, *Cisticola brunnescens*, *C. galactotes*, *Corythornis cristata*, *Coturnix chinensis*, *Crex egregia*, *Dendrocygna viduata*, *Egretta garzetta*, *E. intermedia*, *E. vinaceigula*, *Euplectes afer*, *E. axillaris*, *E. macrourus*, *E. orix*, *Gallinago nigripennis*, *Grus carunculatus*, *Halcyon leucocephala*, *H. senegalensis*, *Haliaeetus vocifer*, *Ixobrychus minutus*, *Limnocorax flavirostris*, *Megaceryle maxima*, *Nycticorax nycticorax*, *Ortygospiza gabonensis*, *O. locustella*, *Phalacrocorax africanus*, *Plectropterus gambensis*, *Ploceus cucullatus*, *P. velatus*, *P. xanthops*, *Porzana parzana*, *Quelea erythrops*, *Q. quelea*, *Rynchops* sp., *Sarothrura rufa* and *Schoenicola platyura*. *Euplectes hartlaubii* is virtually confined to small dambos in the upper Zambezi Basin.

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Species identified in the riparian woodlands and swamp forests of central and southern Angola include *Alcedo leucogaster, A. semitorquata, Andropadus virens, Apalis cinerea, A. rufogularis, Artomyias fuliginosa, Baeopogon indicator, Bias musicus, Bleda eximia, B. syndactyla, Bombylonax breweri, Bradypterus cinnamomeus, Bycanistes subcylindricus, Cercococcyx mechowi, Chlorocichla flavicollis, Colius striatus, Columba unicincta, Cossypha bocagei, Estrilda atricapilla, Fraseria cinnerascens, Halcyon albiventris, H. leucocephala, Lamprotornis purpureiceps, L. splendidus, Laniarius leucorhynchus, Lybius bidentatus, L. hirsutulum, L. minor, Macronyx grimwoodi, Malimbus malimbicus, Melichneutes robustus, Mesopicus griseocephalus, Musophaga rossae, Nectarinia batesi, N. bannermani, N. cyanocephala, N. seimundi, Neolestes torquatus, Onchyognathus fulgidus, Pandion haliaetus, Phyllastrephus cabanisi, P. cerviniventris, Pirenestes ostrinus, Platysteira cyanea, P. peltata, Ploceus superciliosus, Pogoniulus atroflavus, Psittacus erithacus, Pteronetta hartlaubii, Pyrticus turdinus, Scotopelia peli, Stizorhina fraseri, Tauraco persa, T. schütti, Terpsiphone rufiventer, Trachyphonus purpuratus, Treron calva, Trochocercus nitens* and *Turdus olivaceus.*

The spectrum of species is different in northern districts where *Alcedo semitorquata, Alethe castanea castanea, Andropadus virens, Anthreptes aurantium, Anthus brachyurus leggei, Apalis cinerea alticola, A. goslingi, Ardeola idae, Aviceda cuculoides, Bias musicus pallidiventris, Bleda syndactyla multicolor, Bostrychia rara, Bycanistes subcylindricus, Caprimulgus climacurus, Cercococcyx mechowi, Ceryle rudis, Chaetura melanopygia, Cisticola lateralis vincenti, Colius striatus congicus, Columba malherbii iriditorques, C. unicincta, Corythornis cristata, Eremomela scotops congicus, Estrilda atricapilla, Francolinus squamatus scheutii, Fraseria cinnerascens, Guttera edouardi schoutedeni, Gymnobucco bonapartei, Halcyon senegalensis, Hirundo nigrita, Lagonosticta rubricata congica, L. senegala ruberrima, Macronyx grimwoodi, Macrosphenus concolor, Megaceryle maxima, Neolestes torquatus, Nicator chloris, Phedina brazzae, Ploceus bicolor, Prinia leucopogon, Psalidoprocne albiceps suffusa, Pteronetta hartlaubii, Pyrticus turdinae, Sylvietta denti, S. virens baraka, Tauraco schütii, Turdus olivaceus stormsi, Uraeginthus bengalus katangae* and *Zosterops senegalensis kaszica* are more characteristic.

Mammals: Small mammals resident in or regularly visiting riverine wetlands include *Aonyx capensis, Atilax paludinosus, Dasymys incomtus, Genetta tigrina, Lutra maculicollis, Otomys angoniensis, Pelomys fallax, Potamogale velox* (N and NE only) and *Thryonomys swinderianus*, while *Ichneumia albicauda, Leptailurus serval* and *Mungos mungo* are occasional visitors.

Large mammals frequenting wetlands include *Aepyceros melampus, Hippapatamus amphibius, Kobus ellipsiprymnus, K. leche, K. vardoni, Loxodonta africana, Potamochoerus porcus, Raphicerus sharpei* (reedbeds, S only), *Redunca arundinum, Tragelaphus spekei* and *Syncerus caffer. Acinonyx jubatus, Alcelaphus buselaphus, Connochaetes taurinus, Crocuta crocuta, Equus burchelli, Hippatragus equinus, Loxodonta africana, Lycaon pictus, Panthera pardus, Sylivicapra grimmia, Syncerus caffer* and *Tragelaphus strepticeros* are often seen on the southern and southeastern floodplains after the floods have subsided. Occasional visitors to riverine reedswamps include *Hippotragus equinus, H. niger* and the principal large predator in swamps, *Panthera*

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pardus. *Trichechus senegalensis*, which travels far upstream from the sea, is known at least as far south as the Cuvo River.

A number of primates occur in the trees of central and northern wetlands. These include *Allenopithecus nigroviridis*, *Cercopithecus ascanius*, *C. mitis*, *Colobus polykomos*, *Galago demidovii* and *Miopithecus talapoin*. *Funisciurus pyrrhops* and *Protoxerus stangeri* are two squirrels which live in seasonally inundated forests.

List of Wetlands Described

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1. Wetlands of the Cunene River System

General: The Cunene (Kunene) River rises from a sponge (12°42'S/15°25'E) some 40 km west of Huambo at about 2350 m asl. It is initially called the Rio Cunhangamua, and the first tributary, known as the Rio Cuando, rises at a point (12°40'S/16°05'E) close by. After the confluence the stream is referred to as the Cunene. Some 50 km south of its source it enters Chinchama Lake (13°09'-13°20'S/15°49'-15°58'E), an impoundment, the water surface of which is above the 1500 m contour. From the lake the river descends swiftly through boulder strewn mountain valleys to a second, but smaller, impoundment at its confluence with the Catape River at Matala (14°45'S/15°02'E). There is an isolated swamp (14°34'S/14°49'E) above the confluence of two ephemeral tributaries to the northwest of Matala. From Matala the river descends to the Southern African Plateau. Here, in parts of its middle course, both above and below Quiteve (16°02'S/15°10'E) and its confluence with the Calonga River, it flows slowly across the southwestern edge of the plateau at elevations between 1110-1120 m asl, and periodically floods the adjacent plain. In this region, known as the Cunene Flats, flooding occurs in most wet seasons. Areas of up to 150 000 ha may be inundated, extending for nearly 150 km along the river, with maximum widths of 15 km. The major perennial tributary, the Caculuvar, and several large ephemeral streams add to the flood, joining the Cunene just below Xangongo (16°43'S/15°01'E).

In the past the Cunene River flowed into a large pan on the flats, the existence of which is revealed by deep and extensive alluvial deposits. The fact that these deposits contain

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palaeolithic tools testifies to their recent age and suggests that this was a centre of early human population. From this region the river used to flow southeastwards to Namibia where it discharged into a great lake in the Etosha district. However, at some time, perhaps during a great flood, it must have overflowed the banks of the old Cunene Pan and found a new course to the sea, its waters being captured by another river. The old courses leading to Etosha remain clear but now contain only intermittent streams, while Etosha Pan is the remnant of the lake. The course of the rejuvenated Cunene River falls steeply to the sea with many cataracts, and a waterfall 124 m high at Ruacaná. The river is dammed again at Calueque above Ruacaná Falls, providing hydroelectric power and water for irrigation purposes. Here the artificial lake (17°02'-17°14'S/14°42'E) has an area close to 15 000 ha.

Some 50 km from its mouth (17°16'S/11°50'E) dunes of the Namib Desert form the south bank of the river and sand from them continuously slides into the river. When the river is in spate the sand is swept to the coast, but during the dry season the lowest reaches are choked by sand banks. Water flow is minimal in the lower course at this time and the river discharges into a lagoon, its mouth having been deflected alongshore behind a sandy spit. By contrast, the opposite northern bank of the river is a rocky platform rising steeply from the water. This is an extremely arid area and average annual rainfall at the Cunene River mouth is less then 20 mm a year.

Hydrology of the Cunene Flats: In this region the plateau experiences hot summers and warm dry winters, with a mean annual precipitation of 950 mm falling over a period of about 100 days. Precipitation is however, very variable from year to year, both over the flats and the catchment. Floods occur following heavy rains in the catchment, but large floods only occur when rains on the plateau are coincidently heavy. In a wet year the catchments receive over 1750 mm and the flats over 1000 mm, but in dry years the catchments may receive less than 1200 mm and the flats a bare 650 mm. Very little flooding occurs in dry years. Peak flows in the Cunene, measured above Ruacaná Falls, normally occur in April, but are occasionally as early as February. A record wet season flow rate of 1069 m^3/sec was measured at Ruacaná in April 1965, but peak flows are usually in the range 350-450 m^3/sec.

Flora & Fauna: There are no important wetlands along the upper course of the Cunene, which is full of minor rapids, although small *Phragmites* swamps occur on some of its tributaries. Much of the upper course carries a thin fringe of *Phragmites* as it flows through *Brachystegia-Julbernardia* woodland above Matala, however, once it reaches the plateau the fringe community becomes more complex. Here individual reed swamps on sandy patches may cover several hectares. The floras and faunas of the floodplain (Cunene Flats) and gallery woodland are essentially as described in the national introduction. The riverbank community includes most of the small mammals cited in the introduction, and many of the large mammals from the savannas move onto the Cunene Flats as the floods subside.

Human Impact & Utilisation: The area was a centre of population in prehistoric times, but has never since been densely populated. Prior to the recent emergency the area was quite popular with trophy hunters, and local people also hunted and fished the river, the pans and the floodplain. However, the recent civil conflict and the frequency of military operations in the area has made it impossible to assess its current state of utilisation.

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Conservation Status: The floodplain is unprotected, but higher stretches of the river and some small swamps and dambos are situated in Bikuar and Mupa National Parks. However, the administration of these parks has long been hampered by military operations.

2. Wetlands of the Cubango River System

General: The Cubango (Okavango) is one of the major rivers of southern Angola. It rises from a sponge (12°34'S/16°12'E) over 1600 m asl on the the main highland massif 49 km east of Huambo. With its tributaries it drains a basin of 151 057 km^2 in Angola and flows south out of the hills, and thereafter southeastwards over the Southern African Plateau to the Caprivi Strip, which it crosses into Botswana where it forms a large inland delta. The principal tributary, the Cuito, rises at an altitude of 1400 m on the southern slopes of Mt. Sacangombe (12°44'S/18°27'E) in the next most easterly highland massif, and flows southeastwards to its confluence with the Cubango at Dirico (17°57'S/20°38'E).

As with the Cunene, there are no important wetlands along the upper courses of the Cubango, which is also full of minor rapids, although small reed swamps fringe some of its tributaries. However, beginning near Cachueca, and extending south between latitudes 15°05'-16°03'S and east between longitudes 16°35'-16°50'E, there are four very narrow ephemeral floodplains. The two largest are variously known as Mulola Chioca/Mulola Camonda and Mulola Lueque/Mulola Cunene. They seldom exceed 3 km in width, and are mostly much less than this, and are probably old courses of the Cubango since in their upper reaches they appear to arise from that river. They flood during the rains and drain southwards through several pans, after which they peter out in most years, but the principal stream feeds a group of small lakes. These are located between 16°00'-16°11'S and 16°47'-16°53'E, the largest being Lakes Kelly and Antuima, the former reaching 7.5 km in length and some 2 km in width. In wet years the ephemeral watercourses carry the flood farther south than this, finally anastomosing over the border in Namibia, and eventually contributing to the influx of water to Etosha Pan. This region between the Cunene and Cubango Rivers is one of low and unreliable rainfall. While the mean annual figure is close to 700 mm, several successive dry years may be succeeded by several wet years, and some pans may escape inundation altogether during dry cycles, when rainfall may be as low as 500 mm.

There are no important reed swamps along the upper reaches of the Cuito, but they occur on most of its tributaries, e.g. the Cuanavale, along which they are locally very well developed. However, once the rivers of the Cubango System have reached the plateau, the fringe community becomes better developed and more complex. Here, in places, reed swamps occur on sandy patches and often cover several hectares. Even more extensive patches of semi-permanent swamp border the river once it begins to meander below Cuangar (17°34'S/18°50'E) at the Namibian border, and a fringe of riverine trees and bushes becomes established, and is progressively better developed and floristically richer towards the east.

Flora & Fauna: In the upper reaches, stunted *Phragmites mauritianus* forms monospecific fringes along the river, but the associates mentioned in the national introduction are

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common where more extensive swamps occur on sandy patches. Below Cuangar, *Phragmites* fringes the water almost continuously, but the reedbeds are interspersed with clumps of *Typha domingensis*. To landward, semi-permanent ponds contain waterlilies, and are fringed by low swards of *Cynodon dactylon* where inundation is brief and shallow. Water levels in these ponds fluctuate by up to 3.5 m a year.

There are sparse gallery woodlands along the banks in suitable sites below Cuangar and *Hyphaene benguellensis* is common locally. *Cyperus papyrus* occurs in some permanent swamps in the lower Cuito valley, and near the confluence with this major tributary, papyrus also appears along the banks of the Cubango. From here, in continuing downstream, *Phragmites* and papyrus alternately dominate the banks.

Fish and frogs abound in the permanent pools and are hunted by many birds. Juvenile fish are common in the reedbeds all along the river during the wet seasons. *Crocodylus niloticus* occurs in the lower reaches of the river, but becomes scarce with increasing elevation. The avifauna includes most of the species cited as being riverine birds of the SE in the national introduction.

Human Impact & Utilisation: The upper parts of the drainage basin are sparsely populated, but there are numerous small centres of population along the 420 km stretch of river which forms the border with Namibia. The river is fished continuously, using lines, and traps, and the floodplains and terraces are cultivated on a shifting basis. The riverine fringes are frequently burnt to encourage the growth of new grasses for cattle to graze. Military operations have been frequent in the area, and banditry has been rife.

Conservation Status: No part of the system is protected.

3. Wetlands of the Southeastern Interior

(A) THE CUANDO RIVER SYSTEM

General: The Cuando rises on the slopes of Mt. Tembo to the west of the Cuito, 1460 m asl. It drains an area of 95 591 km^2 in Angola and its upper course is swift and boulder strewn, as are those of its major tributaries. Extensive reed swamps first appear on the Cuando below the confluence with the Lomba River (15°35'S/21°31'E), from where they are fairly continuous downstream to Neriquinha (15°45'S/21°32'E). Thereafter, below Uamanda (16°30'S/22°06'E), for over 180 km as the river forms the border with Zambia, it has a vast and intricately braided course, flowing in several major and many minor channels between myriad islands, and with numerous lagoons along its banks. When flood waters rise each year the whole of this lower area and the adjacent river terraces are inundated in a belt locally exceeding 15 km in width. At peak flood over 200 000 ha is covered by moving water up to 3 m deep.

Almost the entire plateau area between the Cuito and Cuando Rivers drains sluggishly eastwards to the Cuando which receives four major westbank tributaries, the Cueio, Lomba, Cubia and Luiana, of which the latter is by far the most important. Locally all these streams carry extensive riparian swamps and the plains between them are very marshy with several permanent lakes. A broad but discontinuous crescent of swampy land, oriented SW-NE, stretches across the plateau from the vicinity of Lake Bezi Bezi

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(16°15'S/19°45'E) to the vicinity of Malundo (14°51'S/22°00'E) on the Zambian border. This is dealt with separately in the next section, Interior Regions of Impeded Drainage.

Immediately prior to its confluence with the Cuando, at an altitude of approximately 971 m, the Luiana traverses a substantial swamp (17°23'S/22°40'E) 40 km long and up to 16 km wide, with a wet season area of 40 000 ha. Shortly thereafter, across the Namibian border in the Caprivi Strip, the Cuando becomes known as the Linyanti/Chobe River, and its waters pass down the Zambezi to the Indian Ocean. Mean annual rainfall in the upper catchments of the Cuando is over 1500 mm, but this decreases downstream to about 800 mm over the lower floodplain.

Flora & Fauna: In its upper reaches the Cuando and some of its headwater tributaries, e.g. the Quembo, carry well developed fringes of *Phragmites* swamp. Rheophytic vegetation dominates the lower Cuando river bed, along the border with Zambia. This is predominantly sandy and most 'island' surfaces are covered with stunted trees or bushy thickets, or by perennial sedges and grasses, and annual herbs, depending upon the annual flood conditions to which they are subject. Woody vegetation is confined to the most stable sand banks at the least frequently inundated levels. Thin fringing forest occurs on the banks comprising many of the species cited in the introduction.

Malaria is a common disease in the lower floodplain areas, caused by the parasites *Plasmodium falciparum* and *Plasmodium malariae*, both of which may be transmitted by either of the local vectors *Anopheles gambiae* and *Anopheles funestus*. Other species of *Anopheles* have been recorded from the Cuando Valley but are not proven vectors of *Plasmodium*. A snail vector of schistosomiasis, *Bulinus* sp., is known in the river and interior swamps. *Glossinia morsitans*, which transmits sleeping sickness, occurs in the area. The fish fauna of the river is typical of the upper Zambezi Basin and the avifauna includes species associated with the river, its sand banks, lagoons, reed swamps and gallery forest. The spectrum of mammals present is as described in the introduction.

Human Impact & Utilisation: The human population in the region is sparse, but the river is fished and some shifting agriculture takes place on its floodplain. The present situation is difficult to assess because of current unrest.

Conservation Status: The large swamp on the lower reaches of the Luiana, and some smaller ones on its tributaries, are situated in the Luiana Partial Reserve and are, at least ostensibly, protected.

(B) INTERIOR REGIONS OF IMPEDED DRAINAGE

General: There are extensive swamps on the plateau in the southeast of the country between river systems. The more southerly of these plateau swamps are separated by the valleys of streams flowing almost due east, either directly to the Cuando or to one of its tributaries. In the southwest of the swamp belt Lake Bezi Bezi (16°15'S/19°45'E) measures less than 5x5 km, but lies in very swampy land distributed in a crescent around the upper shallow catchments of the Luiana and its 6 tributaries which drain the Mucusso region.

To the northeast of Mavinga (15°44'S/20°21'E) the plain crossed by the Cueio, Lomba and Cubia Rivers carries another large, but discontinuous tract of swamp land. This is situated at altitudes of 1050-1200 m in a region where mean annual precipitation is close

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to 830 mm, and is received over approximately 90 days. Mean annual temperatures are close to 20.6°C, with an October maximum of 24.2°C and a July minimum of 14.5°C.

Proceeding northeastwards from here, to the east of the Cuando River, drainage is directly to the Zambezi. Between the Cuando and Ninda Rivers a second group of lakes is situated between 14°56'-15°15'S and 21°18'-21°50'E in the Chiume region. There are 7 major lakes and several minor ones in an 800 mm rainfall zone. Some of these lakes are endorheic systems surrounded by swamplands, but others drain to river systems. Water from the northern three lakes ultimately finds its way into the Ninda River and thence to the Nyengo Swamp in Zambia, while that from the largest of the southern group, which measures 16x4 km, is the source of the Lueti River, which flows southeastwards into Zambia and is a direct tributary of the Zambezi.

The Malundo Lakes (14°32'-14°41'S/21°49'-21°57'E) lie on the plateau north of the Luate River, adjacent to the Zambian border. They comprise four principal lakes, two exceeding 5x5 km, and several small ponds, situated in an area of extensive swampland which drains via the Luate River to the Nyengo Swamp in Zambia.

Flora & Fauna: *Ceratophyllum demersum* is the principal submerged macrophyte in the lakes. Numerous sedges, waterlilies and aquatic grasses occur along the deep water fringes of extensive papyrus beds. These latter are backed by *Phragmites* and *Typha* on the landward sides. The seasonally inundated landward fringes are dominated by typical floodplain grasses.

The mammal and bird faunas are very similar to those encountered in the reed swamps along the lower Cuando River and described in the national introduction, but faunistically the area is improperly known. Details of the fish, amphibian and reptile faunas are not available.

Human Impact & Utilisation: The area is sparsely populated with small centres of population scattered along the northern margin of the swampy belt, but with no centres of population in it, or between it and the Cuando River. The swamps proper are relatively undisturbed, but some shifting agriculture occurs on the seasonally flooded areas bordering many swamps and lakes.

Conservation Status: A large part of the swampland in the Mavinga district, traversed by the Cubia, Lomba and Cuelo Rivers, is protected by legislation in the Mavinga Partial Reserve, although due to recent unrest satisfactory management of this has been virtually impossible.

4. Wetlands of the Central Eastern Interior

General: A WSW-ENE watershed runs from Munhango (12°10'S/18°36'E) to Mucussueje (10°58'S/21°58'E) and then almost due east along the Zaire border to the northwestern tip of Zambia. Swampy areas occur along the eastern part of the watershed, and below it large expanses of wetland exist in the broad and shallow headwater basin of the Zambezi. This is drained in a dendritic fashion by some 25 major streams. Between two of these, the Chefumgage and Luena Rivers, Lakes Cauamba, Calundo and Chaluvanda occur in an extensive swampland system in the Cameia National Park, while to the NW, in a similar inter-riverine situation, Lake Dilolo (11°30'S/22°04'E) occurs in

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another swampland area. There are floodplains on many of the rivers, narrow reed-beds fringe them in other places, and patches of moist riparian forest are well developed in others. Innumerable dambos cover the landscape, and island patches of moist evergreen forest occur as islands in some of these. Mean annual precipitation over this upper basin is close to 1300 mm, received over about 140 days each year. Mean annual temperatures are close to 20.6°C. October is the warmest month, with a mean temperature of about 22.6°C, and June the coldest month, with a corresponding figure of about 17.5°C. Wetlands in the basin occur at altitudes of 1060-1400 m. In total, together with all its upper tributaries including the Lungue-Bungo and Luanginga, the Zambezi drains 148 417 km^2 of Angola.

Flora & Fauna: *Phragmites mauritianus* dominates reed-swamps, although *Cyperus papyrus* occurs in some of them. Wide reedbeds cover the lake margins, with carpets of waterlilies on their deep water faces and submerged meadows of *Ceratophyllum demersum* where the lake surface is not occluded. *Echinochloa stagnina*, *Leersia hexandra*, *Panicum repens* and *Vossia cuspidata* occur in the water in open patches around the lake margins and amongst the culms of the *Phragmites* where the reed-bed is not too dense. *Loudetia simplex* is dominant over large areas of seasonally wet, but moderately well drained land. The floras of the numerous dambos is as described in the national introduction. *Syzygium guineense* is particularly common in the fringing forests.

Frogs and toads are abundant, and there are several species of snakes in the wetlands, including *Naja melanoleuca* and *Philothamnus ornatus*. Arboreal species in the galleries include *Dispholidus typus*. The avifauna is rich with many birds characteristic of reedswamps and wet grasslands as detailed in the introduction, while the floodplains are visited by large numbers of ducks, geese, herons, ibises and storks.

Hippopotamus amphibius, *Kobus leche*, *Potamochoerus porcus*, *Redunca arundinum* and *Tragelaphus spekei* are the commonest large mammals associated with the wetlands, while *Alcelaphus lichtensteinei* is among the regular visitors. *Aonyx capensis* and *Leptailurus serval* have also been recorded from reed beds in this area.

Human Impact & Utilisation: The headwater basin is only sparsely populated, but much of it is burnt each year and the lakes support local fisheries. There are no major roads in the western part of the basin.

Conservation Status: A substantial area, 1 445 000 ha, in the west of the Zambezi headwater basin, is protected in the Cameia National Park, and this contains representative areas of all the regional wetland types. However, there are several centres of population in the park, and recent civil unrest has made it difficult to manage the park properly. Poaching has always been a problem.

5. Wetlands of the Upper Cuanza System

General: The Cuanza River drains a basin of 145 917 km^2, and rises on a small highland massif to the east of the main massif centred on Huambo. The principal spring (13°40'S/17°30'E) is at Quissuala near Mumbué, over 1500 m asl. From here the river flows north for 220 km before veering northwest for a further 275 km. At this point, just south of Melanje (9°23'S/16°20'E), it swings due west to Dondo (9°41'S/14°25'E), a

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distance of some 230 km, finally flowing northwestwards to the Atlantic Ocean through a lowland valley and across the coastal plain for a further 220 km.

In its upper reaches, on the high plateau, the Cuanza and its tributaries carry very little fringing reed swamp, but these become well developed below the town of Cuanza (16°00'S/17°40'E), and a series of extensive swamps begins just after the river descends below the 1000 m contour. Here it first flows in a comparatively deep and narrow valley, c. 15 km wide, but this widens to 50 km above Jimbe (10°19'S/16°39'E), where it receives its largest tibutary, the Luando. Immediately above their confluence both rivers have extensive floodplains, and these merge at Jimbe and continue downstream. Large tracts of permanent swamp and many lagoons occur on the floodplain margins in this region, particularly along the Luando. There is no meteorological station on the floodplain, but judging from readings at the nearest stations, rainfall here is close to 1300 mm/yr, and is received over about 90 days. Relative humidity is always high, with a mean annual figure close to 75%. September is the warmest month, with a mean temperature of 22.5°C, and June the coolest month, with a corresponding figure of 19.7°C.

Other wetlands occur farther upstream on the Luando system, particularly along its tributary the Jombo. There are extensive swamps and a series of quite large lakes (10°22'-10°28'S/17°44'-17°54'E) between the Luando and Jombo prior to their confluence. This is a more humid region than the preceding one, with mean annual rainfalls close to 1500 mm, but rather similar temperature regimes.

The Cuanza Floodplain reappears sporadically all the way between Jimbe and Dondo, a few kilometres downstream of which latter place a lowland floodplain becomes established on both banks, and the river begins to meander northwestwards. Over this next section of some 160 km the river descends with a mean gradient of 1:1600, and is flanked by numerous lakes and lagoons. In the final 50 km before the sea, which it reaches at Barra do Cuanza (9°20'S/13°10'E), slopes are rather steeper, with a mean gradient of 1:500, but the river is still flanked by a floodplain, and there is a large lagoon just behind the mouth.

Some 30 km downsteam of Dondo, at an altitude of about 150 m, the Cuanza receives its last major tributary, the Lucala, on the northern bank. This river rises near Negage in the northern highland block, and its upper course is marked by rapids and slow flowing stretches, with major falls near Calandula (9°06'S/15°57'E). Both above and below this place the slow flowing stretches have densely forested banks backed either by savanna woodland, or by swamps and floodplain. Dense forest occurs along the river downstream in the N'dalatando (9°18'S/14°54'E) district.

Flora & Fauna: The valley of the Cuanza is more densely forested than those of the southward flowing rivers, and in the middle reaches riparian forests, with Zambezian species, are well developed. *Echinochloa pyramidalis*, *Hyparrhenia* spp. and *Vetiveria negritana* are floodplain grasses. *Cyperus papyrus*, *Phragmites mauritianus* and *Typha domingensis* fringe lagoons and occupy large swampy depressions.

The pond and riverine fish faunas include *Alestes macrolepidotus*, *Hepsetus odoe*, *Hydrocynus vittatus*, *Malapterus electricus*, *Schilbe mystus* and species of *Barbus*,

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Labeo, *Marcusenius*, *Mormyrops*, *Synodontis* and *Tilapia*. The swamp fishes include *Clarias* spp., *Gymnarchus niloticus* and *Protopterus annectens*.

Frogs and toads are abundant throughout the wetlands, and reptiles include crocodiles, monitors and numerous swamp snakes as well as some more terrestrial species at home in semi-aquatic habitats. The avifauna is rich and contains many of the species cited in the introduction. *Grus carunculatus*, an endangered species, is found on the floodplains.

Resident mammals in the wetlands include *Cercopithecus ascanius*, *Colobus polykomos angolensis*, *Herpestes sanguineus*, *Kobus leche*, *Leptailurus serval*, *Otomys angoniensis*, *Tragelaphus scriptus* and *T. spekei*, while visitors include *Crocuta crocuta*, *Hippotragus niger variani*, *Lycaon pictus* and *Panthera pardus*.

Human Impact & Utilisation: Tourists are not permitted to enter the Luando Nature Reserve, but numerous centres of population occur along the middle and lower courses of the river, and indigenous people cultivate the margins of the floodplains and graze their cattle on them in the dry season. The riverine forest provides fuel for them and has been very largely destroyed along parts of the lower course. Due to recent civil conflict the current situation has not been properly assessed.

Conservation Status: Large areas of upper floodplain, together with some lakes and permanent swamps, are protected in the Luando Integral Nature Reserve. This contains long stretches of the Luando and Cuanza Rivers, including their confluence. The area has been protected since 1938, initially as a hunting reserve, but from 1957 as a nature reserve. However, its present condition is not known.

6. Coastal Lakes and Floodplains

General: All the northern rivers meander in their lowland valleys and in crossing the narrow coastal plain they periodically inundate floodplains, e.g. the M'Bridge and Dande Rivers. However, the most extensive floodplains, which include large lakes or lagoons, are on the Zenza, Cuanza and Longa Rivers in the central coastal section. The Cuanza is by far the largest of these, but all three regularly have very high discharge rates and at these times flood large areas of the coastal plain.

Lagoons, one over 10 km long, occur on the Zenza immediately upstream of its delta (8°42'-8°53'S/13°28'-13°38'E). On the Cuanza there is a large lagoon close to the mouth (9°18'S/13°11'E), another (9°11'S/13°38'E) near Bom Jesus, and yet others on both banks 100 km upstream (9°30'-9°35'S/14°02'-14°14'E). Lake Negolome is the largest of these, again over 10 km long. On the Longa River many lakes occur on the floodplain over a 100 km stretch (10°15'-10°27'S/13°34'-14°08'E).

The southern streams all have lowland floodplains, but do not flood regularly. Indeed the intermittent rivers may not flow in their lower courses in some years.

Flora & Fauna: The lagoons and ponds are invariably fringed by papyrus with its widespread associate species, but many papyrus swamps grade into *Raphia* swamps on affluent streams. In places these contain, or are backed by, patches of lowland swamp forest with *Carapa procera*, *Mitragyna ciliata*, *Phoenix reclinata* and *Symphonia globulifera*. The floodplain areas are covered by the typical grasses, with *Leersia hexandra* common in permanently wet situations.

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The fauna of the rivers and lagoons includes *Trichechus senegalensis*, as far south as the Cuvo River, while *Cercopithecus* spp. are common in the *Raphia* groves and swamp forests. *Atilax paludinosus* occurs in all these wetlands together with otters, swamp and cane rats. There are numerous frogs, toads, terrapins, snakes, monitors and a rich avifauna.

Human Impact & Utilisation: The coastal wetlands of the central region have suffered more disturbance than any other wetland systems in Angola. The coastal plain was extensively deforested during the colonial period and numerous small swamps were drained for health reasons, for plantations, and for small scale agriculture. The indigenous people have always fished the rivers, lagoons and ponds intensively, and have utilised the products of the riparian forests and *Raphia* swamps. The northern wetlands between Luanda and the Zaire Estuary have suffered less because the region is comparatively sparsely populated, but commercial exploitation for timber has been heavier here.

Conservation Status: A substantial area of the coastal plain (996 000 ha), including wetlands along the Cuanza and Longa Rivers, is protected in Kisama National Park, proclaimed in 1957, but formerly protected as a hunting reserve from 1938. The flood plains of two intermittent rivers, the Bero and Dos Flamingos, are protected in the Mocamedes Partial Reserve.

7. Tidal Wetlands (Mangroves & Saltmarshes)

General: Mangrove swamps are well developed in Cabinda, in the deeply indented Bay of Chicamba (5°01'S/12°08'E) and in the estuary of the Chiloango River (5°11'S/12°08'E). They also occur in the little bay behind Pt. Malembo (5°16'S/12°11'E) and near the town of Cabinda (5°33'S/12°15'E), but the most extensive tidal swamps in Angola are on the south bank of the estuary of the Zaire River. The river mouth is sandy, with scattered clumps of mangrove, and the principal stand is 45 km upstream, where there is a continuous block of tidal forest 35 km long and up to 13 km deep (6°00'-6°08'S/12°35'-12°53'E), covering some 27 300 ha.

From the Zaire River mouth the sandy coast runs southeastwards and is devoid of mangroves except in the estuaries of the Lucunga (7°00'S/12°52'E), M'Bridge (7°12'S/12°54'E), Sembo (7°41'S/13°04'E), Loge (7°50'S/13°07'E), Uézo (8°03'S/13°14'E), Onzo (8°13'S/13°18'E), Lifune (8°23'S/13°23'E), Dande (8°29'S/13°22'E) and Zenza or Bengo (8°42'S/13°23'E) Rivers. Among the best developed and most extensive are those in the small delta of the Zenza River in the Bay of Bengo. Thereafter, along the 65 km stretch to the Point of Palmeirinhas (9°08'S/13°00'E), the coast is sheltered behind the long spit and island which together enclose Luanda Lagoon (Bay of Luanda). The city and port of Luanda are situated at the northern end of the lagoon and there has been considerable development and oil exploration in the vicinity. The shores of the lagoon are sandy and largely clad with coconut groves or secondary vegetation. Mangroves however, still occur at some isolated sites towards the head of the lagoon.

To the south of the lagoon, sizeable mangrove stands occur only at the mouths of the Rivers Cuanza (9°20'S/13°09'E), Longa (10°15'S/13°44'E), Cuvo (10°49'S/13°44'E), Cambongo (11°10'S/13°51'E), Cubal (11°16'S/13°52'E), Balombo (11°54'S/13°46'E) and Cubal (12°10'S/13°41'E), but minor associations occur in little bays behind the many

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small spits created by the longshore current. Numerous small rivers, with very seasonal discharges, are barred by the longshore currents and for most of the year saline water does not enter their lagoons. Such little systems do not usually support mangroves; possibly this is because any that get in are destroyed by the prolonged submergence of their root systems at high water before the bar is breached each year. The mangrove formation reaches its southern limit on the West African coast in the mouth of the Catumbelo River (12°26'S/13°31'E) between Lobito and Benguela.

Continuing southwards, sheltered tidal habitats are colonised by herbaceous saltmarsh vegetation, but there are few major sites other than those in the bays at Lucira (13°52'S/12°30'E), Namibe (15°08'S/12°08'E) and Tombua (15°49'S/11°49'E), where salt production occurs, and the Baia dos Tigres, sheltered by its 45 km spit ending at Pt. do Marca (16°31'S/11°44'E). The southernmost saltmarsh is on the border at the mouth of the Cunene River.

The tidal water in the *Rhizophora* forest, 50 km upstream in the Zaire Estuary, is quite fresh at low tide, when salinities below 0.7 ‰ have been recorded, while at high tide, when surface water salinities are maximal, readings seldom exceed 20‰ and may be as low as 15‰. Flow is not markedly seasonal in the lower Zaire River, which has the second highest volumetric discharge of any river in the world, with a mean annual rate of 41 300 m^3/sec, measured above the estuarine section at Brazzaville. On the south bank of the Zaire Estuary mangroves extend inland to the vicinity of Pedra do Feitico (4°58'S/13°01'E).

Upstream, on the Chiloango River in Cabinda and the other northern rivers, in fresh or brackish water sites affected by tides, there is mixed riparian swamp forest. This is generally of low stature. It may follow on directly from *Rhizophora* forest, or there may be transitions through a *Pandanus-Raphia* swamp, or there may be no continuum of arborescent vegetation and the fresh water tidal forest may be quite isolated.

Crocodiles and varanid lizards occur in freshwater tidal situations and the avifauna includes *Alcedo quadribrachys*, *Anhinga rufa*, *Anthreptes gabonicus* (virtually confined to mangroves), *Butorides striatus*, *Byeanistes sharpii*, *Ceryle maxima*, *C. rudis*, *Charadrius pallidus* (S only), *C. tricollaris*, *Egretta garzetta*, *Eurystomus afer*, *Glareola cinerea*, *Halcyon malimbicus*, *Haliaeetus vocifer*, *Hoplopterus armatus* (S only), *Larus* spp., *Phalacrocorax capensis*, *P. carbo*, *P. coronatus* (S only), *Podica senegalensis*, *Psittacus erithacus*, *Rynchops flaviventris* and *Sterna balaenarum* in the seaward zones. Among mammals, *Trichecus senegalensis* frequents channels in the mangroves in Cabinda and ascends the Zaire River for at least 100 km. *Miopithecus talapoin* is common in the mangrove trees of Cabinda and northern Angola, while *Cercopithecus mitis mitis* is known from brackish-water tidal forests and *Raphia* swamps in the same regions. *Cercocebus torquatus* occurs as far south as the Zaire Estuary, where it inhabits palm swamps. Other mammals reported in Angolan brackish-water tidal forests include *Aonyx capensis*, *Hippopotamus amphibius* and *Lutra maculicollis*.

Human Impact & Utilisation: A substantial proportion of the small total area (probably less than 70 000 ha) of tidal forest in Angola has either been cleared over the past 50 years, or is severely disturbed being regularly cut for firewood. *Raphia* leaves are widely used for thatching, and the plants are tapped in various ways for their sap which

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ferments to become palm 'wine' which is often illicitly distilled. *Uapaca* wood is a preferred material for making charcoal.

Conservation Status: Small areas of southern tidal forests at the mouths of the Longa and Cuanza Rivers are protected in Kisama National Park, while saltmarshes in the Baia dos Tigres and at the Cunene River mouth are protected in Iona National Park. Elsewhere little or no protection is afforded to coastal ecosystems.

8. Wetlands of Uige & North Lunda Provinces

General: The alluvial floors of the valleys of the rivers flowing northeast to the Cuango in Uige Province in the extreme north of Angola, and the floors of the valleys of rivers flowing north in North Lunda Province, are wet and frequently flooded. Mean annual precipitation figures for this area range from 1600-2000 mm.

Flora & Fauna: The valleys bottoms are covered by dense riverine forest, with patches of both seasonally inundated and permanent swamp forest. This vegetation is known locally as muxito and its characteristic species are cited in the introduction.

Crocodylus cataphractus and *C. niloticus* occur here, also *Pelosios subniger* and *Varanus exanthematicus*. Snakes are common and are as described in the introduction. The avifauna comprises at least 300 species, some of which are cited for northern riverine vegetation in the introduction. The mammal fauna includes several monkeys. *Allenopithecus nigroviridis* is a guenon which feeds on fish, freshwater crabs, snails and insects and tends to be commonest in the east of the region, along the Kasai River. *Cercopithecus ascanius* occurs in North Lunda, together with *C. mona* and *Miopithecus talapoin*, both of which are also found in mangroves. *Cercopithecus mitis* (blue monkey) is probably not found in Angola outside of Uige Province. The colobus monkey, *Colobus polykomos angolensis*, occurs throughout the area as far south as the Cuanza River. Other notable mammals include *Aonyx congensis*, *Funisciurus pyrrhops*, *Galago demidovii*, *Potamogale velox*, *Protoxerus stangeri* and *Tragelaphus spekei*.

Human Impact & Utilisation: Swamp forest has been relatively undisturbed in the north of Angola, but clearances have begun in recent years, since where swamp forest grows, rice can also be grown.

Conservation Status: Unprotected.

9. Wetlands of Cabinda

General: In the Cabinda enclave there is a densely forested undulating hinterland behind a flat sandy littoral over which grassy savannas predominate. Here rainfall is about 850 mm at the coast, but much higher inland, with an annual mean approaching 1600 mm on the low hills. These are drained by the Chiloango River, along the sluggish lower course of which there are considerable areas of permanent swampland and some extensive lakes. Lake Masabe is the largest of these.

Flora & Fauna: Riverine swamp forests contain most of the species listed in the introduction for northern Angola, together with *Canarium schweinfurthii*, *Mitragyna stipulosa*, *Raphia hookeri*, *R. textilis*, *R. vinifera* and *Uapaca heudlottii*. *Chaetocarpus*

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africanus, and *Tetrapleura tetraptera* are common woody climbers, and species of *Ancistrophyllum* and *Calamus* are climbing palms. *Cyrtosperma senegalense* and *Sarcophrynium* sp. are prominent in the understorey. *Lycopodium cernuum* scrambles here, and several ferns contribute to the diversity, among them *Acrostichum aureum*, *Adiantum vogellii*, *Asplenium diplazisorum*, *Bolbitis auriculata*, *Diplazium proliferum*, *Lonchitis currori*, *Lygodium microphyllum*, *Pteris mildbraedii*, *Schizolegnia ensifolia* and *Tectaria angelicifolia*. *Acrostichum* and *Schizolegnia* also occur in the mangroves. Free floating ferns on open waters include *Azolla africana* and *Salvinia nymphellula*. Waterlilies form extensive carpets, often occluding small ponds and extending out many metres from the fringes of large ones. Sedges found in wet depressions in clearings and at watersides include *Bulbostylis* sp., *Fuirena umbellata* and *Rhynchospora* spp.

Amphibians are abundant, and reptiles include both African species of *Crocodylus*. Aquatic snakes are as cited in the introduction. Birds of the swamp forests include most of those cited in the introduction for northern river valleys while the mammals include *Aonyx capensis*, *Cercocebus torquatus*, *Cephalophus nigrifrons*, *Cercopithecus mitis mitis*, *Colobus polykomos*, *Dasymys incomtus*, *Funisciurus pyrrhops*, *Lutra maculicollis*, *Miopithecus talapoin*, *Otomys angoniensis*, *Pelomys fallax*, *Potamogale velox*, *Protoxerus stangeri* and *Tragelaphus scriptus*.

Human Impact & Utilisation: Locally there has been disturbance and or clearing in the wake of oil exploration and development, and utilisation by indigenous people for various products including firewood, wood for charcoal, and thatch and sap for fermenting (*Raphia*). By and large swamp forests have not been extensively destroyed in Cabinda.

Conservation Status: Unprotected.

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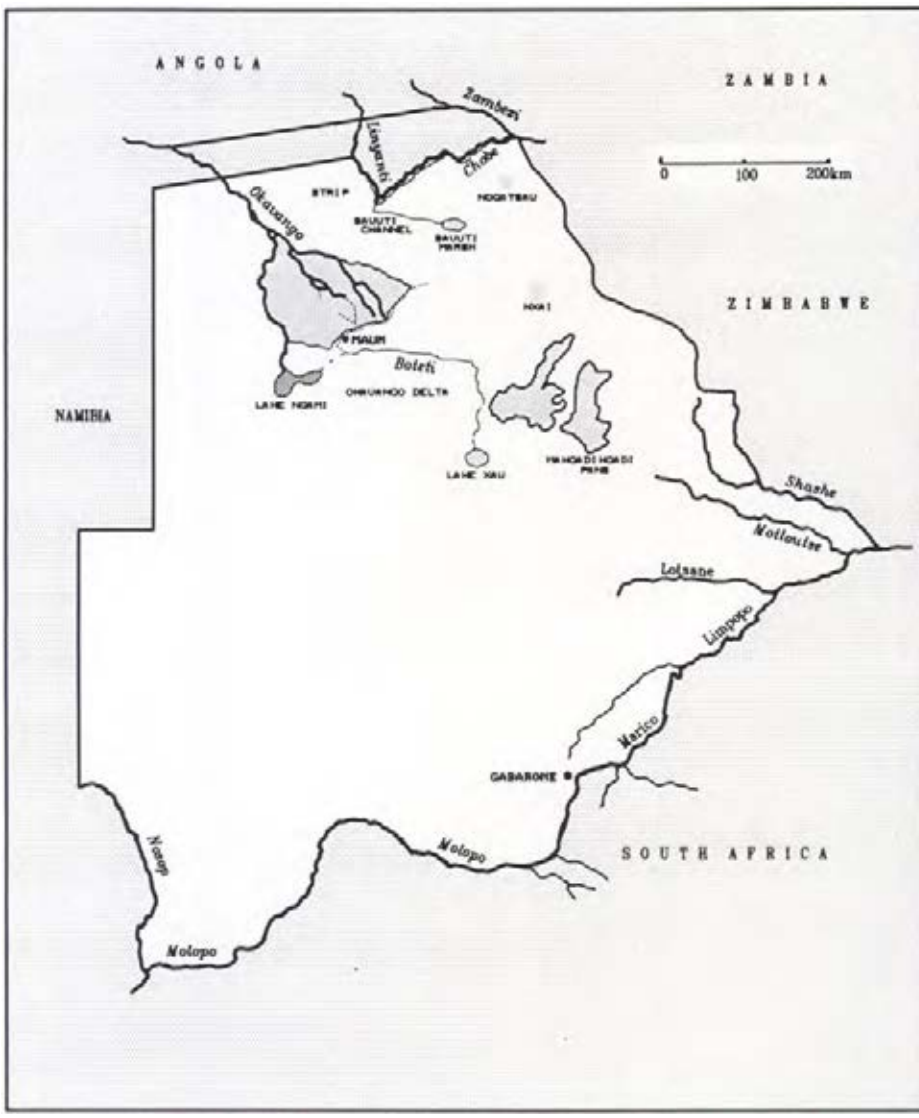

Map of Botswana

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5.2 BOTSWANA

Introduction

Botswana is a land locked republic with a total area of 569 582 km^2 (219 916 square miles: Central Statistical Office, Gaborone). The population at the 1981 census was 1.325 million giving a mean population density of 2.33 persons/km^2. Botswana is bounded by Namibia in the north and west, by Zimbabwe in the northeast, and by South Africa in the south and southeast. Much of the country is situated in the Kalahari, a semi-desert region, and the only reliable water supply is from the Okavango, Chobe and Limpopo Rivers. Most of the country consists of an elevated, flat or undulating plain, at a little less than 1000 m asl. The plain is covered by Kalahari sands overlying Precambrian rock and supports open *Acacia* savanna. There is little surface drainage in the west and south, and in these regions true sand desert is found.

Climate

There are two main seasons. A hot wet 'summer' occurs from November through to March, when much of the rain falls during violent thunderstorms, while cooler dry 'winter' conditions prevail from April to September. Mean annual rainfall ranges from nearly 700 mm at Kasane in the extreme northeast to 250 mm in the extreme southwest. Temperatures can reach 44°C in central districts in March, but can fall to as low as -11°C during a winter night. Insolation is very high; the entire country receives between 3200-3600 hrs sunshine/yr.

Wetlands

In the southeast and east a few ephemeral streams may at times find their way to the Limpopo River, which forms part of the border between Botswana and South Africa. The main drainage system of the country is that of the Okavango River, which rises in Angola as the Cubango, crosses the Caprivi Strip, and flows into the northwest of Botswana, where it forms a delta and drains into a vast endorheic swamp. Evaporation from this swamp is high, and in most years floodwaters do not proceed beyond the southeastern fringes of the delta. However, in years of high floods, water overflows it and forms two continuation rivers, the Nhabe (Lake) River, which drains into Lake Ngami in the southwest, and the Boteti (Botletle) River, which drains first into Lake Xau (Dow) in central Botswana, but may finally spill into the Makgadikgadi (Makarikari) Pans, over 250 km from the delta. Occasionally excess water reaches the Zambezi River via the Selinda Spillway to the north, or the Mababe Depression via the Selinda Spillway and the Savuti Channel. In the north the swamps along the Chobe/Linyanti River extend into the Caprivi Strip region of Namibia.

Wetland Flora

Perennial Swamps: In perennial swamps subject to large seasonal fluctuations in water level, *Cyperus papyrus* is dominant, reaching 4 m in height. This species forms enormous mats, comprising culms, rhizomes and debris, which spread out from steep channel or

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lagoon banks over deep water for distances of 15-20 m. Although *C. papyrus* frequently grows in pure stands, many papyrus swamps contain other species. *Vossia cuspidata* is common among papyrus bases, and along all stream sides. Other species associated with papyrus include low growing forms such as *Polygonum pulchrum*, various Commelinaceae, e.g. *Floscopa glomerata*, and the swamp-fern *Cyclosorus interruptus*. *Miscanthidium junceum*, *Phragmites mauritianus* and *Typha capensis* are also associates of papyrus. These latter species may also grow in pure stands and become dominant locally. *Phragmites mauritianus* grows best in sluggish waters of medium depth and is prominent at channel sides away from the papyrus areas. *Miscanthidium* is widely distributed and usually occurs in pure stands in still less deeply inundated sites. It often occurs behind papyrus, where the channel banks slope comparatively gently, and also on levées. In the Okavango Delta populations of this plant form long 'ribbons' in the swamps, growing on submerged levées. *Typha* flourishes around pools and at channel bends and backwaters, in the shallowest permanent swamps.

On the outer margins of the tall communities, mats of short sedges such as *Cyperus nudicaulis*, *Pycreus nitidus* and *Scirpus cubensis*, or the grass *Leersia hexandra*, often float free on the surface of permanent ponds. Small floating mats are usually monospecific, but large ones generally contain several species. Both floating mats and low emergent mounds of peat tend to be colonised by the insectivorous plants *Drosera madagascarensis* and *Utricularia* spp., and by a species of *Xyris*. Rooted, floating-leaved aquatics also occur around the margins of the tall communities, and may appear between the rafts of floating vegetation. *Brasenia schreberi* and *Nymphaea caerulea* are the commonest of these species. They cover large areas of water, but are almost always associated with *Caldesia reniformis*, *Nymphaea lotus*, *Nymphoides brevipedicellata*, *N. indica*, *Potamogeton schweinfurthii* and *Trapa natans*. In deeper water, or water kept clear of floating species by wind and wave action, submerged aquatics form dense beds. Among these, *Ceratophyllum demersum*, *Lagarosiphon ilicifolius* and *Najas pectinata* are the commonest. Where areas of shallow water occur in permanent ponds there may be a sparse cover of emergent species, including *Eleocharis* spp., *Ericochrysis pallida*, *Phragmites mauritianus*, *Sacciolepis* spp. and *Typha capensis*.

Semi-permanent Ponds: Other rooted emergent species occur on the margins of shallow ponds. They grow in belts up to 50 m wide and also cover shallow patches in the ponds. Perhaps the most important species in these situations are *Leersia hexandra* and *Panicum repens*, together with species of *Eleocharis*, *Fimbristylis*, *Fuirena* and *Rhynchospora*. However, a spectrum of other species also occurs in these sites, but they seldom become dominant. These other herbaceous emergents include *Adenostemma caffrum*, *Alternanthera nodiflora*, *A. sessilis*, *Ammannia baccifera*, *A. prieuriana*, *Caperonia serrata*, *Centella asiatica*, *Commelina diffusa*, *C. fluviatilis*, *C. macrospatha*, *C. zambesica*, *Crassocephalum picridifolium*, *Ethulia conyzoides*, *Eulophia latilabris*, *Floscopa glomerata*, *Hygrophila prunelioides*, *Kosteletzkya buettnen*, *Limnophyton angolense*, *Ludwigia abyssinica*, *L. erecta*, *L. palustris*, *L. stolonifera*, *Melanthera scandens*, *Microlepia speluncae* (a fern), *Oldenlandia lancifolia*, *Pentodon pentandet*, *Polygonum limbatum*, *P. salicifolium*, *Pycnostachys coerulea*, *Senecio strictifolius*, *Torenia thouarsii*, *Thelypteris confluens* (a fern), *Xyris capensis*, *X. rehmannii* and *X. straminea*. Creepers in this vegetation include the parasitic forms *Cassytha filiformis*,

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Cuscuta campestris and *C. australis*, together with *Cissampelos mucronata*, *Cyclosorus interruptus* (a fern), *Ipomoea rubens*, *Mikania cordata* and *Vigna luteola*.

The surfaces of small ponds, which may not dry every year, tend to be totally occluded by a waterlily, *Nymphaea caerulea*, with a small admixture of *Caldesia reniformis*, *Nymphoides indica* and *Potamogeton thunbergii*. In other ponds in the same zone the floating fern *Azolla pinnata* is locally common, together with the duckweeds *Lemna perpusilla* and *Spirodela polyrhiza*. However, in the largest depressions, which are often centred on sections of abandoned river channel where wave motion inhibits the growth of floating-leaved forms, and water is perennial if not permanent, clear surfaces again occupy the centres of the lakes. In these places waterlilies grow around the peripheries inside the tall fringing vegetation. A submerged flora similar to that of the permanent swamps also prevails in these sites, but is possibly more diverse. In addition to the species mentioned previously, *Limnophila ceratophylloides*, *L. indica*, *Najas pectinata*, *Nesaea crassicaulis*, *Ottelia kunenensis*, *O. muricata*, *O. ulvifolia*, *Rotala myriophylloides*, *Vallisneria aethiopica* and *Wiesneria schweinfurthii* are prominent. A fern, *Ceratopteris thalictroides*, grows in shallow water in seasonal ponds, often tolerating total submergence. Under the open water, in mid-lake, small free-floating, but totally submerged species occur, the most important being *Aldrovanda vesiculosa*, *Utricularia benjaminiana*, *U. foliosa*, *U. reflexa* and *U. stellaris*.

Seasonal Swamps: Depressions which normally dry out completely, but which are nevertheless shallowly inundated for many months of the year, tend to be dominated by *Scirpus inclinatus* and *Cyperus articulatus*. These species attain a height of about 2 m, and frequently grow in association with *Cyperus denudatus*, *C. longus* and *Panicum repens*.

Riparian and Fringing Forests: Strips of mixed forest occur along watercourses in sites subject to prolonged inundation, and also around the margins of islands in the Okavango Delta. These are characterised by the presence of *Ekebergia capensis*, *Rhus quartiniana*, *Syzygium guineense* and *Phoenix reclinata*. In seasonal swamp zones a shrubby tree, *Ficus verruculosa*, occurs on levées and forms dense thickets around the edges of many low islands, often spending several months of the year with its trunk bases submerged.

Trees which occur in seasonal swamp forest, at higher levels than the foregoing species, include *Acacia galpinii*, *A. karroo*, *A. nigrescens*, *Albizia harveyi*, *A. versicolor*, *Berchemia discolor*, *Carrisa edulis*, *Cassine transvaalensis*, *Combretum hereroense*, *Croton megalobotrys*, *Diospyros mespiliformis*, *Ficus natalensis*, *Garcinia livingstonei*, *Hyphaene benguellensis* var. *ventricosa*, *Kigelia africana*, *Lonchocarpus capassa* and *Sclerocarya caffra*. In addition to these *Acacia albida*, *A. erubescens*, *A. nigrescens*, *Allaphyllus africanus*, *Combretum imberbe*, *C. zeyheri*, *Croton megalobotrys*, *Erythrophleum africanum*, *Homalium abdessammadii*, *Pteleopsis myrtifolia*, *Strychnos potatorum*, *Syzygium cordatum* and *S. guineense* ssp. *guineense* are found in riverine fringe forest, reaching or exceeding 10 m in height. All are flood tolerant.

Lower growing species found at the waterside or in fringing thicket vegetation are *Clerodendrum glabrum*, *C. myricoides*, *Combretum albopunctatum*, *Cordia sinensis*, *Ehretia amoena*, *Euclea divinorum*, *Friesodielsia obovata* (syn. *Popowia obovata*), *Gardenia jovistonantis*, *G. resiniflua*, *Grewia bicolor*, *G. flavescens*, *G. schinzii*, *Hibiscus diversifolius*, *Markhamia acuminata*, *Maytenus senegalensis*, *Myrica serrata*,

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Oncoba spinosa, *Pappea capensis*, *Premna senensis*, *Rhus quartiniana*, *Salix subserrata*, *Sesbania sesban*, *Tarenna luteola*, *Vangueria randii*, *Vernonia amygdalina*, *Ziziphus abyssinica* and *Z. mucronata*.

The understorey of riparian forests is quite dense, and comprises bushes, scandent shrubs and lianes. In the wettest areas there are a number of bushy species which can tolerate periods of prolonged, if not deep inundation. The most common of these are *Ficus capreifolia*, *F. pygmaea*, *Hibiscus diversifolius* ssp. *rivularius*, *Myrica serrata*, *Rubus exsuccus* and *Tacazzea apiculata*. In slightly drier situations, on the margins of islands and the banks of rivers, *Bauhinia petersiana*, *Boscia mossambicensis*, *Capparis tomentosa*, *Combretum albopunctatum*, *Commiphora africana*, *Cordia ovalis*, *Dichrostachys cinerea*, *Diospyros lycioides*, *Ehretia amoena*, *E. coerulea*, *Flacourtia indica*, *Grewia bicolor*, *G. flava*, *G. flavescens*, *G. schinzii*, *Lantana angolensis*, *Markhamia acuminata*, *Maytenus heterophylla*, *M. senegalensis*, *Paveria lasiopeplus*, *Phyllanthus reticulatus*, *Plumbago zeylonica*, *Rhus pyroides*, *R. tenuinervis*, *Securinega virosa*, *Tricalysia allenii*, *Vangueria infausta*, *Vernonia amygdalina*, *Ximenia caffra* and *X. americana* also grow as bushes or small trees.

Woody climbers or scandent shrubs are locally abundant in periodically flooded riparian forest, and include *Acacia schweinfurthii*, *Artobotrys brachypetalus*, *Byrsocarpus orientalis*, *Canthium huillense*, *Clematis brachiata*, *Clematopsis scabiosifolia*, *Cocculus hirsutus*, *Combretum mossambicense*, *Cynanchum schistoglossum*, *Dalbergia martinii*, *Feretia aeruginescens*, *Gongrothamnus divaricatus*, *Gymnema sylvestre*, *Hippocratea africana*, *Jasminum fluminense*, *Pergularia daemia*, *Phyllanthus reticulatus*, *Rhoicissus tridentata* and *Sarcostemma viminale*.

On the landward sides of the riverine vegetation, on higher grassy floodplains, and on the margins of marshes and pans, there are tall trees such as *Acacia polyacantha*, *A. sieberana*, *Combretum hereroense*, *Peltophorum africanum* and *Terminalia sericea*, all of which can exceed 15 m, and some of which grow to 20 m in height. *Ficus natalensis* and *Parinari curatellifolia* are common on elevated sandy ridges.

Seasonal Floodplains: Areas adjacent to river channels which are flooded only for comparatively short periods, albeit often very deeply, are dominated by grasses. These are zoned according to depth and duration of inundation and include *Acrocerus macrum*, *Andropogon appendiculatus*, *Echinochloa pyramidalis*, *Eulalia* sp., *Leersia hexandra*, *Oryza longistaminata* and *Paspalum polystachyum*. *Oryza* is generally dominant in the deepest water, followed by *Echinochloa* in the middle depths. The fringe areas adjacent to dry land, which are flooded only shallowly and briefly each year, are also covered by grasses. Here *Chloris gayana* and *Setaria anceps* are widespread, but in places the vegetation is terraced, with tall species like *Cymbopogon excavatus*, *Hyparrhenia rufa* and *Imperata cylindrica* occurring in bands at different levels. Sandy soils on the floodplains tend to be dominated by *Eragrostis inamoena*, *E. lappula*, *Setaria angustifolia* and *Trachypogon spicatus*, and saline areas by *Sporobolus spicatus*, *S. tenellus* and a sedge, *Cyperus laevigatus*. The driest and least frequently flooded areas of all are covered by lawns of *Cynodon dactylon*.

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Wetland Fauna

Invertebrates: Little information is available concerning aquatic invertebrates. In both grasslands and woodlands, termites play an important role in the breakdown of litter, nutrient cycling and in soil formation. It is believed that the mounds of *Macrotermes* spp. play an important role in the formation of islands in the delta. *Glossina morsitans*, the vector of sleeping sickness, is present in the Okavango Delta, while two malaria carrying mosquitoes, *Anopheles funestes* and *A. gambiae* are common in all wetlands, as also are snails which carry bilharzia, *Biomphalaria* sp. and *Bulinus* sp.

Fishes: The fish faunas of the wetlands are typical of the upper Zambezi Basin and include such species as *Brycinus lateralis, Clarius gariepinus, C. ngamensis, Hepsetus odoe, Hydrocynus vittatus, Labeo lunanus, Oreochromis andersoni, O. macrochir, Schilbe intermedium, Serranochromis angusticeps, S. macrocephalus, Synodontis woosnami, Tilapia sparrmanii* and *Barbus* spp.

Amphibians: *Hemiscus marmoratum, Hyperolius nasutus, Ptychadena mascariensis* and *P. subpunctata* are representative amphibians in the wetlands of northern Botswana.

Reptiles: *Crocodylus niloticus* is moderately common, having been protected in the Okavango Delta since 1974. *Varanus exanthematicus albigularis* and *V. niloticus* are widespread in wetlands, as are two skinks and a gekko. Several semi-aquatic snakes are to be found in the swamps, including *Crotaphopeltis barotseensis, Dromophis lineatus, Limnophis bicolor, Naje mossambica, Natriciteres olivacea, Philothamnus angolensis, Psammophis sibilans* and *Python sebae*, with *Dasypeltis scabra, Disphlodis typhus, Philothamnus semivariegatus* and *Thelotornis capensis oatesii* in the trees. *Bitis arietans* is found on the wetland fringes in and around the delta.

Birds: More than 400 bird species have been recorded in wetlands in Botswana. Most of these are associated with the forests and herb swamps, but there are some sites for waders. *Aeniginatolimnas marginalis* and *Botaurus stellaris* are rare species confined to wetlands, while *Acrocephalus rufescens, Centropus bengalensis, Lagonosticta nitidula, Laniarius bicolor, Sarothrura rufa* and *Scotopelia peli* are comparatively common species more or less confined to wetlands. Other important species associated with wetlands are *Actophilornis africanus, Amblyospiza albifrons, Anhinga rufa, Ardea goliath, Asio capensis, Balearica regulorum, Bostrychia hagedash, Bradypterus baboecala, Chlorophoneus sulphureopectus, Circaetus cinerascens, Cisticola galactotes, C. pipiens, C. rufilata, Clamator glandarius, Coracias naevia, Cuculus canorus, C. clamosus, Dendrocygna viduata, Egretta ardesiaca, E. intermedia, Ephippiorhynchus senegalensis, Euplectes axillaris, Falco dickinsoni, Gallinula angulata, Glaucidium capense, Grus carunculata, Haliaeetus vocifer, Hieraaetus spilogaster, Kaupifalco monogrammicus, Laphaëtus occipitalis, Merops bullockoides, M. nubicoides, Microparra capensis, Motacilla flava, Mycteria ibis, Necrosyrtes monachus, Nettapus auritus, Pelecanus rufescens, Phalacrocorax africanus, Platalea alba, Plectropterus gambensis, Ploceus ocularis, P. rubiginosus, Pluvialis squatarola, Poicephalus meyeri, Polyboroides typhus, Porphyrula alleni, Riparia riparia, Rynchaps flavirostris, Thalassornis leuconatus, Tockus bradfieldi, T. erythrorynchus, Upupa africana* and *Vanellus senegallus*. Several enormous permanent heronries exist, e.g. at Cakanaca, Geobega and Geodikwe. Here *Ardea melanocephala, Ardeola ralloides, A. rufivenris, Butorides striatus, Egretta garzetta, E. intermedia, E. vinaceigula, Ibis ibis, Leptoptilos crumenife-*

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rus, Nycticorax nycticorax, Plegadis falcinellus and *Threskiornis aethiopicus* may be found nesting in the trees. From September onwards vast flocks of *Merops nubicus, M. superciliosus, Ploceus cucullatus, P. xanthops* and *P. xanthopterus* come to breed in the reed beds. The wetlands of Botswana are important conservation sites, in an international context, for *Anastomus lamelligerus, Botaurus stellaris, Butorides rufiventris, Caprimulgus natalensis, Ciconia episcopus, Egretta vinaceigula, Ephippiorhynchus senegalensis, Grus carunculata, Pelecanus onocrotalus, P. rufescens, Turdoides leucopygius* and *Vanellus crassirostris.*

Mammals: *Hippopotamus amphibius, Kobus leche* and *Tragelaphus spekei* are resident in the permanent swamps while *Loxodonta africana, Panthera pardus* and *Syncerus caffer* visit them. Large populations of small mammals live in the wetlands, including *Aonyx capensis, Atilax paludinosus, Dasymys incomtus, Dendrodromus mesomelas, Lutra maculicollis, Mus minutoides, Otomys angoniensis, Pelomys fallax, Praomys shortridgei* and *Saccostomus campestris. Cercopithecus pygerythrus* and *Paraxerus cepapi* live in swamp forests, and *Papio ursinus* and several fruit bats feed in riparian trees in large numbers in the dry seasons. *Aethomys chrysophilus* is common at the edges of pans.

As the floodwaters recede many species move onto the floodplains and pans, including *Aepyceros melampus, Alcelaphus buselophus, Antidorcas marsupialis, Connochaetes taurinus, Damaliscus lunatus, Equus burchelli, Giraffa camelopardalis, Kobus leche, Manis temminckii, Oryx gazella, Papio ursinus, Phacochoerus aethiopicus, Redunca arundinum, Rhaphicerus campestris, Taurotragus oryx, Tragelaphus scriptus* and *T. strepsiceros.* Predators which follow them include *Acinonyx jubatus, Canis adustus, C. mesomelas, Crocuta crocuta, Felis caracal, Hyaena brunnea, Lycaon pictus, Panthera leo, P. pardus* and *Vulpes chama.*

List of Wetlands Described

1. The Okavango Delta
2. Lake Ngami
3. The Makgadikgadi Pans
4. Savuti Marsh & the Mababe Depression
5. Wetlands of the Linyanti/Chobe Rivers
6. The Nogatsau Pans
7. Lake Xau
8. Nxai and Kgama Kgama Pans
9. Artificial Impoundments

1. The Okavango Delta

Location: 18°29'-20°12'S/22°12'-23°45'E
Area: c. 1 000 000 ha (wetland) + 400 000 ha (dryland in delta)
Altitude: 930-1000 m asl
Nearest Towns: Gaborone (580 km SE); Maun (at SE edge of delta)

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General: The Okavango Delta has developed in a depression in the Kalahari bedrock in northwest Botswana. It comprises a panhandle (95 km long) and a typical delta section (170 km from base to apex). The system slopes from an elevation of 1000 m asl at Mohembo, at the beginning of the panhandle, to 980 m at the apex of the delta and to 930 m at Maun, at the base of the delta. There is very little suspended matter in the incoming river water, but a considerable bed load. The Okavango River bed consists of sand with a median grain diameter of 0.2-0.4 mm. Preliminary calculations by Wilson and Dincer (1976) show that sand discharge at the top of the panhandle may exceed 2 million tonnes annually, while in the lower swamps it is considerably less than this, with a smaller median grain diameter. This continued deposition has given rise to the present complex of islands, ridges, pools, and permanent and seasonal swamps.

The delta landscape is dynamic; channel switching is the result of aggradation within a channel accompanied by the new growth of new vegetation. This process can quickly close a large channel, and new channels are easily created by the feeding activities of a hippopotamus herd. But peat fires play a major part in the dynamics of the delta. Initially new channels are erosive but, with time, both channel bed and adjacent peat swamp begin to aggrade. The channel then becomes moribund, and if abandoned, the adjacent peat swamp dries. Subsequent burning of the dry peat completes a cycle of channel evolution which takes up to 100 years under present flow conditions. After a fire and the collapse of the peat, the old sandy channel beds are left elevated about a metre above the burnt out peat, and the old peat area becomes available for re-flooding (Stanistreet *et al.*, 1988).

The delta is subject to seismic shocks which are believed to have a marked effect on the general topography and the pattern of flooding, and especially upon the amount of water exiting from the base of the delta into the Boteti River. The delta is crossed by a number of faults. There are two major ones at right angles to the long axis of the delta, parallel to the base of the delta, and these tend to favour the transverse spread of floodwaters across the delta rather than their continued progression to the base of the delta. These are the Gumare Fault which crosses the northern tip of Chief's Island, and the Kunyere Fault along the present base of the delta. Another complex fault system trends WNW-ESE across the southeast corner of the delta and continues through to the Makgadikgadi Depression.

Estimates of the total area occupied by wetlands in the system vary widely, (between 1-2 million ha), but the most reliable figures seem to be those of Wilson & Dincer (1976), who, using satellite imagery, determined the following areas within the delta complex: panhandle 100 000 ha, central swamp 150 000 ha, Thaoghe System 70 000 ha, Boro-Kiri-Kunyere System 350 000 ha, Maunachira-Santantadibe System 300 000 ha, and the Magwegqana (Selinda Spillway) System 30 000 ha, giving a total area of 1 000 000 ha.

Mean monthly temperatures over the delta range from 26.9°C in October to 15.6°C in June, with a mean annual figure of 22.2°C. Insolation averages 9.2 hrs/day over the year (September 10.6; December 8.3), while mean monthly humidity varies from 68.9% in February to 30.8% in September, reflecting the pattern of precipitation. Mean monthly rainfall is 120 mm in January and 0 mm in June, with a mean annual average close to 500 mm. Wind speeds are low (annual mean 4.4 km/hour) and evaporation high (class A pan 2826 mm/year, open water 1860 mm/year).

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Perennial swamps cover 45% of the total area, with the rest of the delta being subject to seasonal inundation. The permanent swamp extends from approximately half way down the panhandle to cover large areas to the northwest of the delta, penetrating further down the eastern drainage system of the Nghoka, Maunachira and Santantadibe Rivers than the others. It is characterised by deep permanent channels and lagoons containing extensive beds of *Cyperus papyrus* and *Phragmites mauritianus*. Islands occur throughout the delta with increasing frequency to the south. Channels occur between some islands, but the majority are separated by melapo, which are shallow, grass and sedge-covered floodplains up to 500 m wide. Melapo, or the lowest parts of them, which are inundated every year, are referred to as primary melapo. They are characterised by the presence of sedges, at least 75 cm high, and are flooded to depths of 50 cm or so. Secondary melapo are not flooded every year, but only when the flood is higher than average. Even then inundation may not exceed 10 cm in depth. They are characterised by the presence of grasses over 1 m tall and are often situated in strips between primary melapo and the islands. Large permanent pools are referred to as lediba, plural madiba. The largest concentrations of madiba are along the upper course of the Thaoge River in the west and along the Nqoga/Maunachira River on the eastern side. The two largest pools are Xakanaxa Lediba, 3.04 km long and 800 m wide, through which the Maunachira flows, and Jerejere Lediba, which is circular, 1 km in diameter, contains an island, and is completely isolated from any distributary stream.

Conspicuous features of the delta are the numerous small islands formed from large termite mounds, which reach elevations above maximum high water mark and have a characteristic vegetation. These mounds often occur close together in groups and provide refuges for even quite large animals during the floods. A number of long sandy ridges form islands in the delta, oriented roughly from NW to SE along the long axis of the delta, and these tend to favour the spread of the flood down the long axis of the delta, in opposition to the influence exerted by the fault lines. The largest and highest of these long sand islands is Chief's Island in the east of the delta.

Hydrology & Water Quality: The Okavango River is derived from two rivers which rise in the highlands of Angola, the Cubango and Cuito, which both flow in an approximately southerly direction across Angola, before uniting to form the Okavango River. This then crosses the Caprivi Strip and then enters northwestern Botswana. This river then flows in a southeasterly direction for a short distance before forming a typical delta with anastomosing distributaries. The heaviest rains fall in Angola in January and February, but the floodwaters which develop do not reach the beginning of the delta, at Mohembo, before March. The delta has a comparatively gentle slope (1:3600) and the floodwaters spread slowly and thinly over it, not reaching the eastern limits, near Maun, until August. Rain falls on the delta from November to March, and therefore, except at the upper end, direct precipitation is completely out of phase with the annual flood. However, such rainfall has little impact on the principal flood wave which moves through the delta, from Mohembo to Maun, at an average speed of 3.2 cm/second (2.74 km/day). The depth of the floodwater varies from place to place, and from season to season, but the average depth, at high water, is thought to be of the order of one metre. Maximum depths of 10 m have been recorded in the distributaries. The bulk of the floodwater passes over the delta face as a widening shallow sheet of water. It is not principally carried by the river channels. Water spills out of the river in the panhandle and at the top of the

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delta, and where channels traverse the delta they may be perched above the level of the flood between levées. As water overtops a levée it is lost to the river forever, not being able to rejoin the channel, unless it be at a lower level in the delta miles farther on.

Wilson & Dincer (1976) have estimated the catchment area of the Cubango River to be 115 000 km^2 with a mean rainfall of 983 mm (range 605-1125 mm), and that of the Cuito to be 65 000 km^2 with a mean rainfall of 876 mm (range 476-1100 mm). They suggest that riverine inflow amounts to 11 billion m^3/yr, while direct precipitation accounts for a further 5 billion m^3/yr. Rain falling on land adjacent to the delta quickly penetrates the sands of the Kalahari and produces no surface run-off, but there is no information on peripheral seepage into the delta. The mean active storage capacity of the delta has been estimated at between 1 and 7 billion m^3. Evapo-transpiration from the delta is colossal, amounting to some 15.4 billion m^3/yr. The delta surface is warm when the floodwaters spill over it in a very thin sheet, and this exacerbates evaporation. Thus outflow to the Boteti River at the base of the delta is only a fraction of the inflow, but even then it amounts to 300 million m^3/yr. Losses to ground water are considered to account for an equivalent amount. That the delta was once much wetter than at present is suggested by the fact that the Boteti River has a conveyance capacity much in excess of its present needs; it seems likely that during fairly recent pluvial phases it carried the waters of the Okavango River onwards. Further, there is good evidence that the Thaoghe System drained into Lake Ngami, only 100 years ago, but it presently runs dry long before reaching there.

Little information is available concerning the water chemistry of the delta, but salinity of the ground water increases steadily from the panhandle to the base of the delta, and doubtless water quality varies from deep permanent swamp areas to the mainly dry, seasonal swamps. It has been estimated that approximately 370 000 tonnes of dissolved solids are left in the delta each year, equivalent to 37 g/m^2. Conductivity of ground water may exceed 5000 μmhos/cm locally. These extreme values are a consequence of high evapo-transpiration rates. However, flowing water in the channels seldom carries more than 250 mg/l total dissolved solids. Dissolved oxygen levels in flowing water is generally high, c. 7.5 mg/l, but in lakes and pools it declines after the flood, and many small pools become anoxic. A number of soda pools occur on the delta. Water temperatures rise to 40°C in the shallows when the waters are receding, but the temperature spectrum in flowing channels ranges from 21-27°C, and in lakes and ponds from 18-35°C.

Flora & Fauna: The delta supports a rich and varied flora since it encompasses all the vegetational types discussed in the introduction. Plant communities range from submerged aquatic, through swamp grassland, to riparian forest and seasonally inundated savanna woodland. In common with many other seasonal herb swamps, fire plays an important role in its ecology. Fires are started on the periphery by farmers during the dry season to promote the growth of new grass for their cattle, and others are started by hunters, deeper in the swamps, to flush out game. Up to 75% of the sedge and grassland of the delta may be burnt in some years. The principal vegetational zones are the perennial and seasonal herbaceous swamps, the riparian or levée forests, the island fringes, and the pools (often called lagoons), both permanent and semi-permanent.

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Although essentially floating, the papyrus mats are so dense and so deep that they often rest on the substratum and become firmly wedged in the channels in which they grow. They frequently form blockages, even in principal channels, and play a significant rôle in determining the morphology of the delta, diverting stream flow and producing islands. Papyrus develops best where there is little variation between minimum and maximum water levels, and is therefore a useful indicator of perennial swamplands which become progressively less common towards the lower end of the delta. A comprehensive account of the vegetation of the delta is given by Smith (1976).

More than 65 fish species have been recorded in the delta. Herbivorous species include *Tilapia rendalli*, while detrivorous ones include *Oreochromis andersoni* and *O. macrochir*. Together these contribute 18% of the total fish biomass of the delta. Species which are largely insectivorous include some Characidae, Cyprinidae and Schilbeidae. Species of Mormyridae and Mochokidae feed mainly on invertebrates, while the catfishes *Clarias gariepinus* and *C. ngamensis* have a broader diet and feed on fish, invertebrates and detritus. Purely piscivorous fish include *Hepsetus odoe* and *Hydrocynus vittatus* and various representatives of *Serranochromis*. The shallow floodplains provide breeding grounds for cichlid and clariid species at high flood. An account of the fishes of the Delta is given by Merron (1991).

The amphibian, reptile and bird faunas include most, if not all of the species cited in the introduction. The Delta is the most diverse wetland in Botswana in terms of habitat and consequently has the most diverse faunas. Over 400 species of birds have been recorded there including *Turdoides melanops*, an uncommon localised resident found along the western borders. The most numerous large mammal is *Syncerus caffer* which may number 20 000 at any one time. There are also populations of *Connochaetes*, *Loxodonta* and *Equus* estimated as 14 000, 12 000 and 4 000 respectively.

Human Impact: Ngamiland (essentially the delta region) has a population of 94 322 (1991 census), 28% of which lives in the town of Maun (26 569), with most of the remainder distributed along the southern and western fringes of the delta. Some villages occur on islands of high land in the delta, but these have only sparse populations which consist primarily of women and children, the menfolk being employed in larger centres further away. Some fishing occurs from these villages, but not on a commercial scale; most fish caught are consumed locally. Some trading occurs between villages, by canoe. Population density is currently 1.06 persons /km^2. Infant mortality is high and life expectancy short.

The majority of people in the delta area live by subsistence farming and cattle rearing. The principal arable crops, produced on the delta fringes, are sorghum, maize and millet, grown when the floodwaters have receded. There were some 300 000 head of cattle in Ngamiland in 1990. Cattle invade the fringes of the delta in increasing numbers each year, possibly as many as 70 000 each dry season. Extensive spraying campaigns, to try to eradicate tsetse fly to open up more delta land for cattle, have been in operation for some years, and pesticide residues are now present in the food chain over most of the delta. Fences have been erected to inhibit the movement of wild animals, particularly buffalo, out of the delta, with a view to preventing infection of domestic herds with foot and mouth disease. This practice interferes with the natural migrations of several mammal species, but on the positive side prevents the incursion of cattle into the Delta during drought periods.

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Income is also derived from making curios, hunting, and manufacturing processed skins and other wildlife products, and from conducting hunting and photographic safaris. In the past crocodiles (*Crocodylus niloticus*) were hunted for commercial gain, no less than 50 000 being taken between 1953-1968. That the numbers had declined seriously is evident from the fact that in 1973 a concessional quota given to a game industry company for 500 crocodiles went unfulfilled. A ban on crocodile hunting was imposed in 1974. Hunting of other animals still occurs in the delta; some 8000 animals were killed in 1974, 83% by local hunters and 17% by visiting licensed hunters.

In 1977 FAO/UNDP published the findings of an exhaustive investigation into the use of the Okavango Delta as a primary water resource (Ag. Dept. Gaborone, Botswana. Bot/71/506 Tech. Rep. 2 Vols. 361 pp. 1977). This reviews the hydrology of the delta and its biota and makes proposals for the artificial manipulation of water flow through the delta. Following this a detailed feasibility study of water extraction from the delta was carried out in the early 1980s (SMEC, 1991). However, in the face of national and international concern as to the possible impact of such action, the Southern Okavango Integrated Water Development Project was suspended pending review by an independent IUCN team during 1991-92.

Conservation Status: 390 000 ha of the delta is protected in the Moremi Wildlife Reserve. This was first created by the baTwana tribe in the 1950s, and Chief's Island was added to it at a later date. Possibly this was the first time that an African people set aside part of their land to be protected. The reserve is centred about 19°30'S/23°30'E in the Ngamiland district at the eastern side of the delta. International visitors are presently encouraged (although the FAO report previously mentioned did not regard this as desirable). There are several tourist camps in the reserve, although no camps or human habitations are permitted on Chief's Island. A potential threat to the reserve arises from the possibility of the introduction of more cattle as a consequence of the tsetse fly eradication campaign. However, this is small in comparison to the possible impact of alterations to the water regime, whether through action in Angola, Botswana or Namibia. It is possible that the delta may cease to function as a wetland if demands for irrigation are met. The delta is in a natural long term dry phase, being significantly drier than it was 100 years ago.

The Department of Wildlife and National Parks issues hunting licences for defined areas, specifying quotas and species, but enforcement is difficult and poaching and illegal fishing still occurs. The education unit of the Department attempts to promote public awareness, and the Botswana Wildlife Training Institute at Maun trains game scouts in conservation and management matters.

Tinley (1973), on the ecology of the protected part of the delta, and the proceedings of a Symposium on the Okavango Delta and its Future Utilisation, published by the National Museum of Botswana, Gaborone, in 1976, are useful references.

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2. Lake Ngami

Location: 20°37'S/22°40'E
Area: 67 250 ha (entire system)
Altitude: 932 m asl
Nearest Towns: Gaborone (560 km SE); Toteng (on NE edge of the lake)

General: Lake Ngami is an ephemeral endorheic lake to the south of the Okavango Delta. When Livingstone, Oswell and Murray first saw it in 1849 its diameter was thought to be 170 miles (275 km). Since then the lake has become progressively smaller, and has, on several occasions, not only dried up completely, but has remained dry for years on end. It was dry in 1800 and 1865, for the decade 1900-1910, again in 1930 and in 1973-1974. It almost dried in the 1960s, then flooded, but was dry again by December 1982. This century its water surface has varied between 0-20 000 ha. Over the past 50 years the mean flooded area has been 12 300 ha. At high water it has had a mean depth of 1 m, a maximum depth of 3.5 m, and a storage capacity of 350 000 000 m^3. That part of the lake bed which is temporarily unflooded is covered by grass, providing rich pasture for domestic cattle. Swampy grasslands frequently cover as much as 55 000 ha around the lake, but principally at the southwestern end of the lake. The overall length of the basin is 59.4 km and the maximum width is 11 km.

Hydrology: Lake Ngami is fed by several rivers carrying overspill from the Okavango Delta. The Thaoge was the main outlet from the delta 100 years ago, and then fed Lake Ngami, but blockages diverted the flow and now ensure that water from this source, on the western side of the delta, no longer reaches the lake. The Thaoge, after leaving the Okavango Delta proper, passes through a series of minor swamps and finally terminates in a small depression at Setsau. Currently, water reaches Lake Ngami from the central and eastern sides of the delta via a number of ephemeral streams, the most important of which are the Kunyere and Nhabe (Lake) Rivers. The Kunyere drains the Xo Flats, a wide, almost treeless, shallowly flooded (40 cm) and island studded region of the lower central delta. Flows in the Kunyere are more reliable than those of the Nhabe River, but do not always reach the lake. The Nhabe carries overspill from the central southern delta, arising at the Thamalakane/Boteti junction. Maximum flow in this stream in recent years has been 11 m^3/sec in its upper course, but even when the river does flow here, water does not necessarily reach the lake. It is said that the lake can go from 'full' to 'dry' in two years and from 'dry' to 'nearly full' in one year, but 'full' is an inappropriate term as the entire lake bed has not been fully inundated this century.

Flora & Fauna: Much of the the lake floor is covered by grasses, but thorn trees and bushes (*Acacia reficiens*) are currently spreading over the river basin and parts of the lake, with the advent of what seems to be an increasingly drier regime.

The principal fish are species which are able to survive the intermittent long periods of drought, chiefly species of *Alestes*, *Barbus*, and *Clarias*. When it contains water, Lake Ngami is an important habitat for water birds. A total of 285 bird species has been recorded at the lake over the years, and numbers vary greatly from year to year with the state of the lake. Most notable are the concentrations of pelicans and flamingoes which are found there periodically. Counts of 65 000 *Phoenicopterus ruber* and 8000 *Pelecanus onocrotalus* were made in 1971. The flamingoes do not normally breed at the lake and

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when seen are usually in transit between their two major breeding sites in southern Africa, Etosha Pan in Namibia, and the Makgadikgadi Pans in Botswana. Counts for the Okavango Wildlife Society in 1981 indicated greatly reduced numbers of flamingoes, with white pelicans, which do breed on the lake, then the most numerous species. When water levels are low cattle enter the nesting colonies and cause great destruction; wet years therefore tend to be good pelican years. Ducks, e.g. *Anas erythrorhyncha* and *Dendrocygna bicolor*, and geese, e.g. *Alopochen aegyptiacus*, arrive in large flocks, sometimes numbering hundreds of thousands. 500 000 *A. erythrorhyncha* were counted on the lake in 1954. Many use the lake as a staging post, particularly if numbers are high. Some migrant waders terminate their journey from the northern hemisphere here, others also stage, before going farther south. Terns, gulls and the pied kingfisher (*Ceryle rudis*) are common. The temporary grasslands support *Anthus novaeseelandiae*, *A. similis*, *A. vaalensis*, *Charadrius asiaticus*, *Eupodotis afra*, *E. ruficrista*, *Glareola nordmanni*, *Grus carunculata*, *Oena capensis*, *Streptopelia capicola*, *S. senegalensis*, *Struthio camelus* and *Vanellus coronatus*. Predatory birds include *Accipiter badius*, *A. minullus*, *A. ovampensis*, *Aquila rapax*, *Haliaeetus vocifer*, *Leptotilos crumeniferus* and *Micronisus gabar*, while *Gyps africanus*, *Necrosyrtes monachus* and *Torgos tracheliotus* are vultures found over the lake.

Human Impact: The ephemeral nature of the lake does not lend itself to large scale exploitation. Even when it is flooded the full fishing potential of the lake is not realised, partly because the people who inhabit the area consider it unacceptable to eat fish, but some small commercial operators have enjoyed a degree of success in producing dried fish for sale in Francistown. Cattle rearing is the main means of subsistence, which is reasonably successful since tsetse fly has largely been eradicated from the lake. Many thousands of cattle graze in the area permanently, and up to three times this number concentrate on the shores in the dry season to feed on the lakeside grasslands and obtain water. High water in the lake is normally attained during the dry season, so that at this time the shores are densely stocked with cattle. They leave behind substantial quantities of manure which is beneficial, contributing to the high productivity of the lake. A program has recently been undertaken to sink boreholes away from the lake to reduce the density of cattle on the lake margins. When the lake waters recede hygrophilous grasses provide excellent grazing in those areas which are not cultivated.

The lake margin is extremely fertile and villagers implement a system of rotational cultivation for a variety of crops on a rather casual basis. Villagers also hunt a variety of game, but take ducks on the lake preferentially. A quota system was implemented, and there is a closed season for duck shooting, but neither is, or was, easily enforceable. The major threat to the ecosystem is that of its drying out permanently. Only 3-5% of the water that enters the Okavango Delta spills out at the southern end, some normally flowing into Lake Ngami and some flowing down the Boteti. With the manipulation of the water balance of the delta, for irrigation farming along the Boteti, the prospect that Lake Ngami will get drier is very real.

Conservation Status: There is no formal protection. The area is administered tribally, and the Department of Wildlife and National Parks is trying to promote concern for conservation issues.

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3. The Makgadikgadi Pans

Location: 20°15'-21°10'S/25°00'-26°15'E
Area: c. 1 000 000 ha
Altitude: 910-915 m asl
Nearest Towns: Gaborone (410 km S); Francistown (130 km SE)

General: The Makgadikgadi Pans are salt pans lying at the end of the vast depression in NE Botswana, which, some 200 km to the west, also contains the Okavango Delta. In the Makgagikgadi region the depression is floored by sandy alkaline lacustrine soils. There are two major pans, Ntwetwe Pan (overall dimensions of 160x96 km) in the west, and Sowa (Sua) Pan (overall dimensions of 112x72 km) in the east, with several smaller pans to the south. The rim of the depression reaches elevations of 960-1000 m asl. The lowest point, 890 m asl is in Sowa Pan. A few densely vegetated islands are isolated in the large pans, and these are so far distant from the shores that they are completely undisturbed. The entire depression once held an enormous lake which probably discharged to the Chobe River. Alluvium from this lake, over 100 m deep, is found in the Makgadikgadi region. Ntwetwe and Sowa Pans are among the largest salt pans in the world. They are partially flooded in most years, to depths of 15-25 cm, and then attract huge numbers of wading birds. The pans provide the end point of the Okavango/Boteti drainage system, with the Boteti River entering the southern tip of Ntwetwe Pan. However, since the river has been dammed at Mopipi, water from this source only reaches the pans during extremely wet years. During the rainy season water enters Sowa Pan from the Nata River which has formed a small delta in the northeastern tip of the pan. This stream rises in Zimbabwe and drains higher land to the northeast. On occasions Sowa Pan may fill from this source. Much later in the year any residual water from the Okavango system enters Ntwetwe via the Boteti River. Direct precipitation contributes very substantially to the water regime of the pans. The total area of the pans, which has often been given as in excess of 2 300 000 ha, is frequently exaggerated. Analysis of satellite images by the authors indicates an area of close to 1 000 000 ha for the two main pans. Subsidiary pans account for a further 250 000 ha.

For most of the year the pans are completely dry, and are covered by greyish salt encrusted sand. When water levels are receding fast, bubbles of oxygen rise from submerged algae and become trapped in the surface scum, giving it a grotesque warty appearance. Some alluvium is brought in by riverine floodwaters, but a proportion of this is removed during the dry season each year by strong easterly winds which produce numerous 'dust devils'. Mists form over the pans on cool nights and develop into dust hazes as the sun rises. Dew may be quite heavy on summer mornings.

The Pans are set in thorn savanna, with the Kanyu Flats immediately to the north. This latter region is an almost perfectly flat grassland covered by myriad minute pans. Almost all of the Kalahari Desert is floored by Kalahari sands, which are white, grey, black or reddish. They are of both aeolian and fluviatile origin and include silicified sands, calcareous limestones and grits, surface limestones, lake limestones, diatomaceous sandy limestones, marls, conglomerates, pan tuffs, gravels, gritty sands and a full lithological range of silcretes and calcretes. Small fresh water pans and springs are found among the occasional limestone outcrops. 'Bushman' wells in the area are perennial and seldom more than 7 m deep.

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The Makgadikgadi region is extremely arid and any rain that falls does so during the summer months between October and March. The mean annual rainfall is 380 mm on Sowa Pan, but it is very unreliable and annual variations are great. In some years total receipts are as low as 75 mm. There is a mean of 40 rainy days/yr. Daytime temperatures may reach 44°C in the summer, but the winters are cool and dry, and there may be frosts at night when temperatures may drop as low as -6°C.

Flora & Fauna: The almost barren pans are situated in typical savanna surroundings. Islands in the pans are covered by dense woodland which includes species able to tolerate brackish soil water, e.g. *Acacia reficiens*. There are extensive saltmarshes close to the edges of the pans, but these give way to grassland, shrub savanna, and finally to tree savanna in moving away from the pan. *Odyssea paucinervis* and *Sporobolus spicatus* fringe the saltmarsh, in which *Portulaca oleracea*, *Sporobolus tenellus*, *Suaeda fruticosa* and *Vernonia fastigiata* are dominant. Isolated swampy patches along pan margins, probably associated with springs, are dominated by *Phragmites australis*, with *Alternanthera nodiflora*, *Dichanthium papilosum*, *Lagarosiphon muscoides*, *Najas marina*, *Potamogeton* sp. and *Scirpus maritimus* in small pools. In moist crevices at the margins of the pans *Amaranthus thunbergii*, *Cyperus aristatus*, *C. compressus*, *Glinus bainesii*, *Pentzia* sp., and *Polygonum limbatum* may be found. The edges of the pans are grass covered, with *Cynodon dactylon* dominant towards the land, yet the regular adherence of mud to the leaf blades of this species suggests that it is frequently inundated during the rains. Sand dunes on the pan margins are colonised by *Cenchrus ciliaris* and *Panicum meyerianum*. Still farther from the pans, grasses which do not suffer inundation, and which grow in the surrounding scrub savanna, include *Aristida meridionalis*, *Heteropogon contortus*, *Odyssea paucinervis* and *Rhynchelytrum* sp.

In the delta of the Nata River *Sesbania mossambicense* and *Sporobolus spicatus* are common. Various algae are found in brackish pools in the river bed in the dry season, including species of *Cosmarium*, *Nostoc*, *Oscillatoria*, *Pediastrum* and *Rivularia*. *Phragmites mauritianus* fringes semi-permanent pools, and in depressions on moist sand *Ammannia prieuriana*, *Blumea caffra*, *Corchorus tridens*, *Cyperus aristatus* and *C. compressus* are present. On drier patches *Argemone mexicana*, *Cerathotheca triloba*, *Courtoisia cyperoides*, *Cucumis metuliferus* and *Ocimum americanum* occur. Typical riverine trees found along the Nata are *Acacia albida*, *A. kirkii*, *Combretum imberbe* and *Lonchocarpus capassa*.

Because the lake often dries completely, only barbels, which overwinter buried in mud, survive to breed when water returns at the start of the summer season. However, a variety of other fish enter with the floodwaters, but they all die when the water evaporates at the end of the season. The sludgy water becomes a nutrient soup which attracts thousands of migrant wading birds and the pans are one of the principal breeding sites for flamingoes in southern Africa. *Phoenicopterus ruber* has been observed in flocks so large that they cover tens of square kilometers. Other avian visitors include ducks, geese, white pelicans and ostriches. *Gypohierax angolensis* and *Terathopius ecaudatus* are notable species found over the pans.

Seasonally the pans provide water for large numbers of immigrant herbivores, as listed in the introduction, and these are then followed by their predators. Large herds of *Connochaetes taurinus* once used to occur in the area, but their numbers have been

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reduced in Central Botswana, possibly by as much as 90%, by the combined effects of drought and veterinary cordon fences, which cut off their migration routes. Other resident species are *Antidorcas marsupialis*, *Manis temminckii*, *Oryx gazella*, *Panthera leo*, *Taurotragus oryx*, *Vulpes chama* and *Papio ursinus*, although the latter is now uncommon. Rats, mice and gerbils live on the fringes of the pans and otters are occasionally present near inlet streams when fish are plentiful.

Human Impact: Farming occurs in the area but the pans are virtually undisturbed. Some bushmen hunt on the pans during the rainy season. Construction of a soda ash plant began at Sowa Pan in 1988. The intention is to produce 300 000 tonnes of soda ash and 650 000 tonnes of table salt per year, sufficient to meet the entire demand of southern Africa, from a resource estimated as virtually inexhaustible (Thomas & Shaw, 1991). This development on Sowa Spit in the north of the pan is expected to have a localised impact on its surroundings.

Conservation Status: The 250 000 ha Makgadikgadi Game Reserve was established in 1970 and includes a small portion of the western section of Ntwetwe Pan. The reserve is centred at 20°25'S/24°55'E, and is mostly savanna. Animals which visit Ntwetwe Pan in the wet season find sanctuary in the reserve during the dry season. Otherwise the pans are unprotected. There is no organised accommodation in the reserve but visitors are permitted to camp. The northern part of Sowa Pan is protected as the Nata Sanctuary, a reserve established by the Nata community to protect bird populations and provide employment for the community.

4. Savuti Marsh & the Mababe Depression

Location: 18°30'-19°10'S/23°58'-24°20'E
Area: c. 3000 ha (Savuti Marsh)
Altitude: c. 920 m asl
Nearest Town: Gaborone (700 km SE)

General: Savuti Marsh lies in the Mababe Depression which is an oval shaped fossil lake bed situated to the northeast of the Okavango Delta, between the delta and the Chobe/Linyanti River. The marsh occupies only a small portion of this grass depression. It lies at the western side of it, and marks the end of the 60-70 km long Savuti Channel which brings water to the Mababe Depression from the Linyanti Swamp. The grassy floor of the depression is situated 920-930 m asl, and its sides, the banks of the fossil lake, rise steeply from it. Along the western and northern boundaries of the depression there is a long wooded sand ridge, the Magikwe Ridge, which is some 200 m wide at the top. In places this ridge rises 30 m above the fossil lake floor, having summit elevations of 936-950 m asl. From October to March, high water in the Linyanti Swamp may spill over into the Mababe Depression via the Savuti Channel which breaches this sand ridge. However, flow in the Savuti Channel is irregular, probably due to adjustments along the Linyanti and Chobe fault lines. Certainly the channel ceased to carry water for long periods, decades or more, in the 1800s and early 1900s, and at these times trees grew in its bed. After a prolonged dry period of at least 50 years, flows began again in 1957, but comprised very variable annual volumes of water.

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Stumps of dead trees then emerged from the water all along the channel as a testament to past dry times. Flows ceased again in the early 1980s (Shaw, 1984).

The Cubango/Okavango system is usually at high water at the same time as the Cuando/Linyanti/Chobe system, since both derive their headwaters from adjacent catchments in Angola. Thus in a year of extreme high water in the Okavango Delta, water escaping via the Magwegqana (Selinda) Spillway to the Linyanti Swamps, could find its way to Savuti Marsh. In the past water may also have reached the Mababe Depression at its southern extremity via the Khwai system. This extends almost 160 km due east from the Nqoga/Maunachira system of the Okavango Delta, in a gradually tapering swampy belt, but flows in it usually peter out long before the Mababe Depression.

Flora & Fauna: The Savuti Channel is lined by an ill-defined riverine fringe comprising *Combretum imberbe, Lonchocarpus nelsii* and other riparian species. Savuti Marsh *per se*, is an open grassland dominated by *Cynodon dactylon*, which is highly nutritious and attracts large numbers of grazers. The marsh is fringed by *Acacia erioloba* woodland, characterised by many dead trees. Where soils are sandy, around the marsh, there are near pure stands of *Colophospermum mopane*, or open woodland dominated by *Burkea africana*. Among the most spectacular of the birds which visit the area are enormous flocks of *Quelea quelea* which sit in the surrounding bushes. *Tockus bradfieldi* and *Pterocles gutturalis*, both rare species, are seen here. Among the large mammals which visit the marsh are *Damaliscus lunatus, Equus burchelli, Hippotragus niger, Kobus ellipsiprymnus, Loxodonta africana* and *Syncerus caffer*. Predators, which abound on the drying marsh, include *Acinonyx jubatus, Leptoptilos crumeniferus, Lycaon pictus, Panthera leo* and *P. pardus*, and many buzzards, eagles and hawks. The Savuti Channel is the home of fish, frogs, toads, crocodiles, monitor lizards, snakes, swamp rats, and hippopotamuses, as indicated in the regional introduction. It is heavily utilised by elephants, and a range of large mammals visit it to drink.

Conservation Status: Part of the Savuti Channel and the entire Savuti Marsh is contained within the Chobe National Park which was established in 1967 and enjoys full protection.

5. Wetlands of the Linyanti/Chobe River

Location: 17°50'-18°28'S/23°25'-25°05'E
Area: c. 120 000 ha (in Botswana)
Altitude: 850-950m asl
Nearest Towns: Gaborone (750 km SE); Kasane (at E end of swamps)

General: A wetland system exists along the Linyanti River on the national boundary between Botswana and Namibia, on the southern side of the Caprivi Strip. The wetland comprises swampy floodplains, reed swamps and meandering and anastomosing waterways, with numerous small islands and backwaters. The entire system is backed by riverine forests. The first, and major part of the system, which is generally marked as the Linyanti Swamp in atlases, is situated in Namibia, in the southern elbow of the Caprivi Strip. However, wetlands also occur to the east of this swamp, extending for 200 km along the Linyanti/Chobe River towards Kasane. The river which enters the Linyanti Swamp from Angola is called the Cuando, but its name is changed to Linyanti in the

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swamp, and then again to Chobe after it leaves the swamp. Wetlands extend on both sides of the Chobe River, but are less extensive on the south bank, in Botswana, except in the vicinity of Kataba where the floodplain reaches some 25 km in width. The Linyanti/Chobe permanent wetlands occupy about 120 000 ha of Botswana at high water, of which some 60 000 ha are situated in the Kataba region, south of Lake Liambezi in the Caprivi Strip. At times of high flood the waters of the Zambezi and Chobe Rivers mingle across a common floodplain at the eastern end of the Caprivi Strip, but if the Zambezi is high and the flood on the Chobe has been delayed, flow may be reversed in the lower Chobe. Rainfall increases from west to east along the Linyanti/Chobe River, reaching a mean annual figure of 700 mm at Kasane. Summer temperatures in the swamps may reach 40°C.

Flora & Fauna: True high forest in Botswana occurs along the banks of the Linyanti/Chobe River, and while the riverine forest shares many species of plants and animals with the Okavango Delta, it is nevertheless, a distinct biome. On some bends the river banks are steep and undercut, if seen at low water, while on the opposite sides, away from the current, there are broad vegetated mudflats. The water fern *Salvinia molesta* occludes many backwaters, and at times of low water, may block the main channel. The river is continuously fringed by dense stands of *Cyperus papyrus* and *Phragmites mauritianus*, behind which are groves of *Phoenix reclinata* set against a backdrop of riverine forest. In places the forest canopy is 18 m high, but it frequently gives way to patches of low riverine thicket only 5-9 m high. The floristic diversity of the riverine vegetation increases downstream, from west to east. Most of the species cited in the introduction are present.

A wealth of animal life is associated with the riverine forests, the reed beds and the river banks, and most of the species cited in the introduction are present. In addition to the resident fauna of the permanent swamps, a range of animals moves seasonally between the wetlands and the adjacent savannas, again as indicated in the introduction. The fish fauna of the Chobe River and its associated pan/swamp system is typical of the upper Zambezi Basin. Altogether 25 snake species have been collected from the wetlands of the eastern Caprivi Strip, and most of these are likely to occur on the Botswanan side of the border.

At least 200 species of birds are associated with the river and its peripheral vegetation, among which *Merops nubicoides* is the most numerous, nesting in holes in the river banks in vast numbers. Other important species are *Ardeola ralloides*, *Cisticola rufilata*, *Cossypha heuglini*, *Ephippiorhynchus senegalensis*, *Glaucidium capense*, *Haliaeetus vocifer*, *Hieraaetus fasciatus*, *Necrosyrtes monachus*, *Nectarinia senegalensis*, *Nettapus auritus*, *Pelecanus onocrotalus*, *Phalacrocorax africanus*, *Scotopelia peli* and *Rhynchops flavirostris*. All the small mammals cited in the introduction are present and *Kobus vardonii* and *Tragelaphus spekei* occur on the floodplains.

Human Impact & Utilisation: The river is fished by local villagers, and some hunting occurs in the unprotected western end near the Linyanti Swamps. However, because of the regular high floods the area has not been developed and is little exploited by the indigenous population. Tourism is on the increase.

Conservation Status: Almost the entire stretch of this wetland, 220 km long, is protected in three contiguous reserves: the Chobe Forest Reserve which borders the river for some

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130 km in the west, the Chobe National Park which borders the river for a further 60 km in the centre, and the Kasane Forest Reserve which borders it for a further 30 km in the east. There are no tourist facilities in the reserves, but there is a safari camp near Linyanti and permits may be granted for camping in the reserves.

6. The Nogatsau Pans

Location: 18°19'S/25°00'E
Area: No reliable information
Altitude: c. 950 m asl
Nearest Towns: Gaborone (700 km S); Kasane (65 km N)

General: A cluster of 8 large depressions and a dam on the Ngwezumba River comprise the 'wetlands' in this area, in the northeastern part of the Chobe National Park some 60 km due south of Kasane. The depressions are essentially fossil pans and although situated on what was once the active floodplain of the river, are now surrounded by forest and mopane savanna. They do not nowadays hold water for any length of time. The largest pans, Cwikampa, Mandabuza and Mapororo, have a resident fauna of amphibians, reptiles, birds and small mammals. They are visited by a spectrum of large mammals throughout the year, but principally during the wet season as indicated in the introduction.

Conservation Status: Protected within the Chobe National Park, and the adjacent Kasane Forest Reserve Extension. There are two campsites for visitors and an airstrip.

7. Lake Xau

Location: 21°14'S/24°50'E
Area: c. 30 000 ha (highly variable)
Altitude: c. 920 m asl
Nearest Towns: Gaborone (400 km SE); Francistown (270 km E)

General: Lake Xau, to the south of the Boteti River and the Makgadikgadi Pans, was once a large shallow lake fed by overspill from the Boteti River. However, since the impoundment at Mopipi, itself a former pan, the lake is usually as dry as the pans in nearby Makgadikgadi Depression. There are still reeds on the lake shore, but they are less extensive and less luxuriant than in former times. Bird life is still abundant on the lake floor, but this is now flooded only sporadically, and to depths of a few centimetres, mainly following local rain. The present lake bed is some 15 km long and 8 km wide, covering some 12 000 ha. It is known to have dried up naturally during past drought periods, e.g. in 1800, when Lake Ngami was also dry. However, in the pluvial past, Lake Xau supported a substantial fish fauna, together with crocodiles and hippopotamuses, waterlilies and submerged aquatic vegetation.

Conservation Status: Unprotected.

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8. Nxai and Kgama Kgama Pans

Location: 19°50'-19°59'S/24°45'-24°47'E
Area: c. 23 000 ha (both pans)
Altitude: c. 930 m asl
Nearest Towns: Gaborone (530 km SSE); Francistown (320 km SE)

General: These two large pans are situated in the Nxai Pan National Park. Nxai Pan, the larger of the two, is a fossil lake bed with a total area of some 15 400 ha. During the rainy season depressions in the pan may fill with water, but the whole pan is never flooded. Kgama Kgama Pan is smaller, but of similar origin and nature. Both pans are set in savanna woodland or open forest which supports large herds of game. Nxai Pan is usually covered by short grass, except for the depressions, and contains many little tree-studded islands which are emergent even if the entire pan is flooded. Common trees on these islands are *Acacia erubescens*, *A. nigrescens*, *A. reficiens*, *Colophospermum mopane*, *Syzygium cordatum*, and *Terminalia sericea*. Many of these species also occur on the pan margins, together with an occasional *Adansonia digitata*.

There are many snakes in the pans, including *Bitis arietans*, *Dasypeltis scabra*, *Dendroaspis polylepis* and various cobras. Birds of interest are *Accipiter badius*, *Gyps africanus*, *Micronisus gabar*, *Necrosyrtes monachus*, *Terathopius ecuadatus* and *Trigonoceps occipitalis*, while noteworthy mammals include *Acinonyx jubatus*, *Connochaetes taurinus*, *Equus burchelli*, *Felis caracal*, *Giraffa camelopardalis*, *Otocyon megalotis*, *Panthera leo* and *Proteles cristatus*.

Human Impact & Utilisation: Virtually none.

Conservation Status: The pans are fully protected in the Nxai National Park. Visitors may enter the park by permit and are permitted to camp at specified campsites.

9. Artificial Impoundments

The largest impoundment is the Shashe Dam (21°20'S/27°22'E) on the Shashe River at an altitude of 1000 m near Francistown. This artificial lake is 15 km long and up to 4.2 km wide in places, with an open water surface close to 3200 ha at capacity. Some way to the south is the Slime Dam (21°57'S/27°50'E) at an altitude of c. 900 m, near the settlement of Selebi-Phikwe. This is much smaller, with maximum dimensions of 1.7 and 0.8 km. In this locality there are a further 18 dams on the Ramokgwebana, Sansukwe and Simukwe Rivers, all tributaries of the Shashe. While these dams are comparatively small they each have more than 60 ha of open water surface. The Gaborone Dam, serving the capital, is one of the largest artificial waterbodies in the country.

The Marico and Limpopo Rivers form the border between Botswana and South Africa over a riverine distance of about 500 km, and in this area there are 55 weirs on the rivers and their tributaries. In this area there are also 4 major impoundments on the tributaries, one at Gaborone serving the capital, and several thousand small farm dams in the country, mostly in the wetter eastern part.

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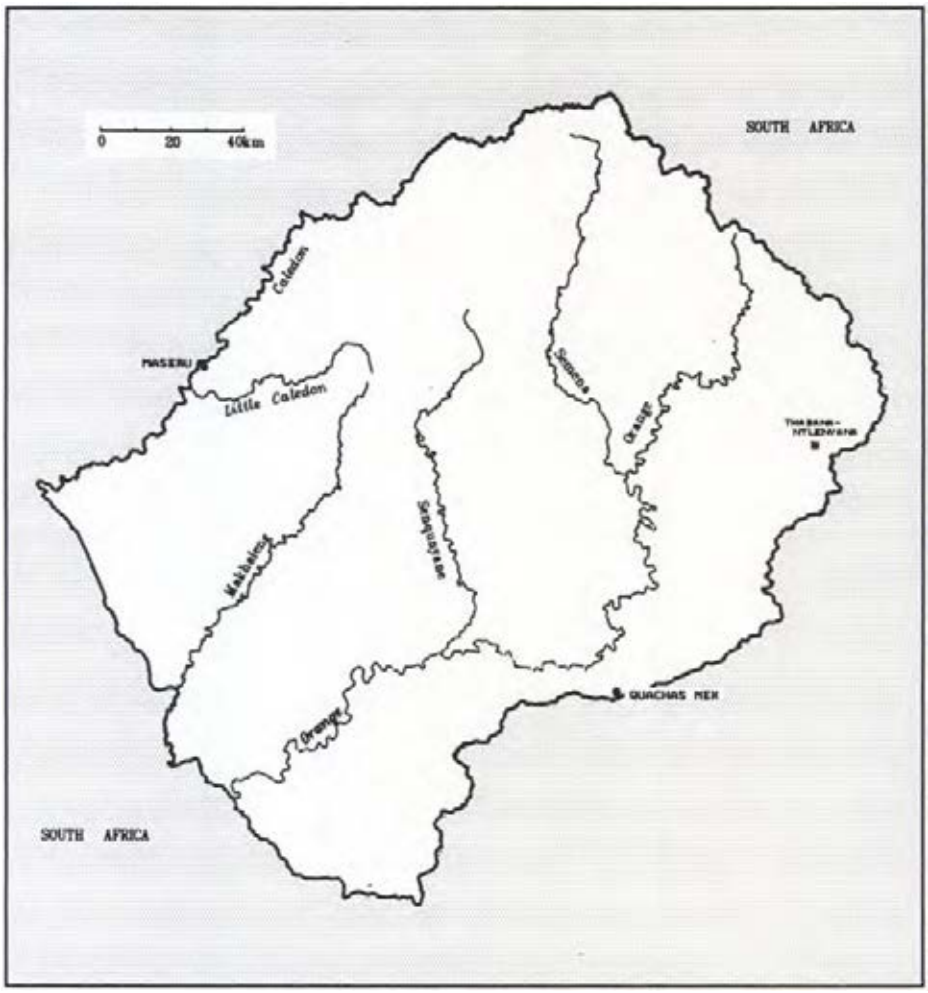

Map of Lesotho

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5.3 LESOTHO

Introduction

Lesotho is situated between longitudes 27°00' and 29°30'E and latitudes 28°35' and 30°40'S, and is completely encompassed by South Africa. It has a population of 1.7 million, a total area of 30 344 km^2, and thus a mean population density of 56 persons/km^2. However, the population is highly concentrated in the western part of the country. Approximately 20% of the total land surface, situated in the west, lies between 1500 and 1850 m asl and is regarded as 'lowland', while the remaining 80% of the country is high, lying between 1850 and 3364 m asl. The land rises comparatively gently from the western boundary with the Orange Free State, towards the eastern boundary with Natal, which is effectively the top of the Drakensberg Escarpment. This, over most of its length in Lesotho, reaches or exceeds an altitude of 3000 m asl and provides a spectacular wall of cliffs with sheer drops of 500-750 m into Natal. The highlands over 2300 m asl comprise horizontally bedded basalts, and this rock forms the peaks and cliffs of the Drakensberg Escarpment. In turn this hard volcanic cap rests upon a horizontally bedded series of sedimentary rocks, several thousand metres thick. The uppermost of these, immediately under the basalt, is a soft sandstone, and the river valleys of Lesotho are principally cut through this stratum on their way to the 'lowlands'. The principal drainage basin is that of the Orange River which rises in the NE of the country as the Senqu. This flows south and then west for 250 km before entering the Orange Free State. The highlands are deeply dissected by many small streams, all of which are headwater tributaries of the Orange River.

Climate

The country experiences warm wet summers and cold dry winters. Temperatures in the lowlands reach maxima of 39°C in summer, but frosts occur throughout the country from April-September. Readings as low as -18°C have been recorded at lowland stations in winter, when, no doubt, the mountain tops are even colder. Rainfall varies locally and annually. Stations in the lowlands have recorded mean annual falls close to 730 mm over the past 50 years, but with substantial oscillations about this figure. Mountain stations receive mean annual falls of 1500 - 1750 mm depending upon their situation, and some temporary research stations recently established on the highest peaks have recorded annual falls of up to 2000 mm. In addition to rain, substantial snowfalls occur in the mountains in autumn and winter. Cloud often forms without giving rain, and early in the afternoon on most days, mists flow back westwards from the Drakensberg Escarpment over the higher slopes of Lesotho.

Wetlands

There are extensive bogs and spongelands in the high rainfall areas of the mountains. These are most common in the northeast of Lesotho and decrease in frequency and individual size towards the south and west. Individual montane bogs are often of small extent, but collectively they cover tens of thousands of hectares. Most are to be found at elevations greater than 2300 m, i.e. above the soft sandstone. From a distance they are

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recognised as splashes of bright green on the brownish background of montane grassland. The summit of Thabana Ntlenyana (29°26'S/29°20'E), the highest point in Southern Africa (3364 m asl), is partly encircled by bogs, and much of the high plateau immediately to the west of the Drakensberg Escarpment is covered by them. Many bogs are situated over springs at the mouths of 'pipes' of diamondiferous gravel which have been intruded into the basalt and sandstone; others have developed at the heads of the broad, shallow, gently sloping valleys that dip west and south into Lesotho, away from the edge of the great escarpment. Yet others occur where water seeps from clefts or discontinuities in the bed rock. Pools develop in depressions on the flat surface of the soft sandstone, e.g. in Sehlabathebe National Park, while other depressions are filled with sodden gravel, providing yet another type of montane wetland. Almost all drainage lines and soaks are fringed by wetland species in the highlands.

Most streams descend swiftly at first, losing 1000 - 1200 m over distances of 60 - 70 km, before reaching the western 'lowlands'. Here their velocities are checked and swamps and small floodplains tend to develop. In the lowlands, streams and river banks are lined by flood tolerant plants, and here farmers have constructed numerous small dams. These latter usually contain aquatic plants and are fringed by reeds or sedges.

Wetland Flora

Bog Vegetation: At the highest altitudes bog vegetation comprises low growing mat-forming species almost exclusively. These give the bogs 'close-cropped', turf-like, appearances. The most important plants involved are *Anagallis huttonii*, *Athrixia fontana*, *Haplocarpha nervosa*, *Limosella capensis*, *L. grandiflora*, *L. longifolia*, *Lobelia aquatica*, *Ranunculus meyeri*, *Scirpus fluitans*, and *Sebaea marlothii*. Towards the edges of the bogs other species show above the mat, usually in clumps but still with very low profiles. These include *Drosera natalensis*, *Eriocaulon baurii* and *Rhodohypoxis rubella*, together with occasional taller clumps of *Kniphofia caulescens*. Tussocks of *Danthonia disticha* and *D. drakensbergensis*, up to 1 m high when in flower, occur around the fringes. Here also, in drier ground, are found other *Kniphofia* species, *Brownleea macroceras*, *Geum capense*, *Helichrysum flanagani*, *Holothrix* sp., *Oxalis depressa*, *Ranunculus baurii*, *Senecio concolor* and *Trifolium burchellianum*. *Eragrostis caesia* and *Poa binata* are common mat-forming grasses on the bog periphery.

Pools are common over springs in these flat open bogs. Water wells up and flushes over the lip of the pond and out through the vegetation, which may be almost totally submerged in clear slow flowing water for large areas around the pools. Several of the mat-forming species are truly aquatic and grow in these bog pools, e.g. *Aponogeton junceus*, *Crassula natans*, *Lagarosiphon muscoides*, *Limosella capensis*, *L. longifolia*, *Lobelia aquatica* and *Utricularia* spp. Usually there is a dense growth of algae in the pools, comprising species of *Lyngbia*, *Nitella*, *Spirogyra* and various diatoms. There is some evidence to suggest that shallow pools become occluded by algae and bryophtes, and that these are then invaded by higher plants leading to the development of hummocks. Once a hummock has formed the displaced water forms a new pool. Thus some of these bogs depart from the 'close-cropped' appearance and appear as a mosaic of vegetated hummocks and moss lined pools. The hummocks are quickly colonised by plants typical of the drier fringes, e.g. *Geranium incanum*, *Oxalis depressa* and *Trifolium*

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burchellianum, and this serves to raise them still higher. However, hummock formation seems to operate only from shallow pools, since the deep ones, with vigorously flowing water, appear to stay open with little change of shape over the years. Although the upwelling of water is invariably quite strong, the steep edges of the pools are seldom breached to form definite outlet channels. This occurs only when sheep or cattle come frequently to drink at the same pool and break down the edges.

Other bogs develop below seepages on the lower mountain sides. These are covered by tussocks of *Aristida* and *Danthonia* spp. which appear to invade the bogs from the periphery, growing over black peat which may occasionally reach 2 m in depth. Tussocks are thus most frequent towards the edges, and although the peat is generally firm, at least during the dry season, it may be semi-liquid over hidden springs towards the centre of a bog. In such places both people and animals sink easily. The central regions around the hidden springs are often yellowish and dominated by mosses, together with some of the mat-forming species cited above, but *Sphagnum*, so common in northern hemisphere bogs, is entirely absent. *Carex cernua*, *Cyrtanthus breviflorus*, *Deschampsia caespitosa*, *Drosera natalensis*, *Haplocarpha nervosa*, *Hesperantha baurii*, *Kniphofia caulescens*, *Limosella* spp., *Scirpus* spp., *Senecio concolor*, *S. speciosus* and some orchids occur between the tussocks. Surprisingly a succulent, *Delosperma* sp., is often found in seepage areas.

If drainage is impeded in a valley wetland, vegetation may spread to form a raised peat bog. Some of these rise 1.5 m above the surrounding grassland, and being covered with vegetation another 1 m tall, are conspicuous dark green features of the mountain slopes. Here again *Danthonia* tussocks fringe the bogs, which are completely covered by tall herbs. Typically these include *Carex cernua*, *C. clavata*, and *C. monotropa*, together with *Juncus glaucus* and *Kniphofia caulescens*. Water from the stream supplying the bog seeps through the peat continuously, but at times of high rainfall it may flow freely over the bog surface between the stem bases. Nevertheless, it usually leaves the bog in distinct streamlets. A wealth of orchids may be found in these bogs, generally recognised when in flower, but passed unnoticed at other times. Among these *Disa versicolor*, *Disperis tysonii*, *Habenaria dives*, *Holothrix incurva*, *Satyrium crisiatum*, and *S. macrophyllum* are locally prominent, with *Brownleea macroceras* on the drier fringes, together with *Geum capense*, *Ranunculus baurii*, *Senecio* spp., and clumps of *Eriocaulon baurii*.

Montane Pools: Pools, ranging from a few centimetres to a metre in depth, occur on the flat surfaces of the horizontally bedded sandstone formations. These support aquatic species such as *Aponogeton ranunculiflorus*, *Ilysanthes confertiflora*, *Limosella* spp. and *Utricularia* spp., while *Crassula galpinii* grows in small gravel-filled hollows soaked with water. In the foothills pools also occur on flat sandstone surfaces, and here *Aponogeton spathaceum*, *Crassula natans* and *Limosella maior* are the dominant species.

Riparian Vegetation: Several tall species characterise drainage lines on the mountainsides, which are therefore conspicuous against the low growing *Themeda-Festuca* grassland. The most important species are *Agrostis bergiana*, *Danthonia drakensbergensis*, *D. macowanii*, *Hyparrhenia glauca* and *Pennisetum sphacelatum*, with clumps of *Anoiganthus breviflorus*, *Corycium nigrescens*, *Gunnera perpensa*, *Kniphofia caulescens* and *Moraea spathulata*. *Anoiganthus* sp. and *Leersia hexandra* grow in the water, with *Lobelia preslii*, *Myosotis sylvatica*, *Ranunculus baurii*, *Senecio concolor* and *S. speciosus* growing at the waterline. Other species which are locally prominent in this

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vegetation include *Phygelius aequalis*, *P. capensis*, *Rubus rigidus*, *Wurmbea angustifolia*, *W. kraussii* and *Zantedeschia albomaculata*.

Mountain streams contain a number of rheophytes, mostly rooted in gravelly patches, and the most conspicuous among these is a straggling, almost trailing bush, *Gomphostigma virgata*. Few submerged species occur in the fast flowing waters, but *Ranunculus aquatilis* is the most widespread.

Riparian vegetation in the lowlands depends very much upon the nature of the river bank, but all species are flood tolerant. On stable banks trees include the indigenous species *Salix mucronata* and *Salix subserrata*, and the now far more common, introduced, *Salix babylonica*. Swards of *Cynodon dactylon* spread under them. Steep shaded banks support bryophytes such as *Anthoceros*, *Fimbriaria*, *Marchantia* and *Riccia*, and the ferns *Asplenium trichomanes* and *Pteris cretica*, with *Selaginella depressa* in clefts. Exposed banks are often colonised by *Equisetum ramosissimum*. In other places *Metzleria depressa* and *Sutera aurantica* form veils of foliage over the banks. Shallow muddy sites attract species such as *Juncus exsertus*, *Mentha aquatica*, *M. longifolia*, *Mimulus gracilis*, *Polygonum salicifolium*, *P. setulosum*, *Ranunculus* sp., *Xyris capensis* and numerous sedges including *Cyperus fastigiatus*, *C. marginatus*, *Eleocharis palustris*, *Fuirena pubescens*, *Pycreus macranthus*, *Scirpus falsus* and *S. macer*. *Nasturtium officinale* and *Leersia hexandra* grow partially submerged at the water's edge, both species being totally inundated during floods. *Phragmites australis* and *Typha capensis* form dense reed beds in backwaters and line the river banks away from the currents. Behind these, in moist sites, but ones which are only flooded irregularly, are the grasses *Arundinella eklonii*, *Imperata cylindrica*, *Pennisetum sphacelatum* and *Phalaris arundinacea*.

Impoundments: Most of the hundreds of dams in the lowlands and foothills are small, but towards their deeper ends many are fringed by *Phragmites*, *Typha* and various sedges. Aquatics such as *Aponogeton spathaceum*, *Lagarosiphon muscoides* and *Potamogeton* spp. occur in fairly deep water, with *Marsilea macrocarpa* rooted on the muddy margins and spreading between the reeds and sedges. *Denekia capensis* and *Lobelia decipiens* are often common around the shallow, frequently dry, inflow ends. Adjacent marshy ground tends to be covered by tussocks of *Agrostis lachnantha*.

Wetland Fauna

Frogs and toads are common in all wetlands in Lesotho. Those whose range is not limited by altitude, even reaching the top of the escarpment, are *Breviceps adspersus*, *Bufo gariepinus*, *B. gutturalis*, *Cacosternum boettgeri*, *Heleophryne natalensis*, *Phrynobatrachus natalensis*, *Pyxicephalus adspersus*, *P. natalensis*, *Rana angolensis*, *R. grayii*, *R. hymenopus*, *R. vertebralis* and *Xenopus laevis*. Common species that seldom ascend above 1800 m asl are *Afrixalus spinifrons*, *Arthroleptella hewitti* and *Rana fasciata*.

A number of frog and rodent eating snakes frequent the wetlands at all altitudes, also reaching the top of the escarpment. The commonest of these are *Amplorhinus multimaculatus*, *Causus rhombeatus*, *Crotaphopeltis hotamboeia*, *Hemachatus haemachatus*, *Psammophis crucifer*, *P. sibilans* and *Psammophylax rhombeatus*.

Birds are uncommon at the edge of the Drakensberg Escarpment, but among those associated with the highest wetlands are *Chalcomitra amethystina*, *Ciconia ciconia*,

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Fringillaria capensis, *Geronticus calvus* and *Neetarinia famosa*. Lower down, on the high slopes and plateaux of the sandstone, where birds are more numerous, these are joined by *Buteo rufofuscus* and *Cinnyris chalybeus*.

Mammals which regularly visit or utilise the wetlands above 2300 m asl include *Atilax paludinosus*, *Canis mesomelax*, *Felis caracal*, *F. lybica*, *Ictonyx striatus*, *Lepus saxatilis*, *Otomys sloggetti*, *Papio ursinus*, *Pronolagus crassicaudatus* and *Redunca fulvorufula*. Lower down on the sandstone *Aonyx capensis*, a few *Connochaetes gnou*, *Lutra maculicollis*, *Ourebia ourebi*, *Panthera pardus*, *Pelea capreolus*, and a few *Taurotragus oryx* may be encountered in wetland areas.

In the lowlands, land adjacent to wetland sites is farmed and thus most large animals visiting these sites are domestic. However, they support a comparatively rich avifauna and contain substantial populations of amphibians and small mammals, and of course there are fish in the rivers.

Human Impact & Utilisation

Ownership of all land in Lesotho is vested in the paramount chief, for the people, and no land is privately owned. In practice, administration of the land is delegated to local chiefs or wardens who grant the right to cultivate to individuals or groups, but all citizens are free to graze cattle on the hillsides.

Apart from Sehlabathebe National Park there are no legally protected areas in the country, and grazing and firing of the highlands, which is becoming progressively more intense, is very deleterious to the ecology of the montane bogs and sponges. Grazing and trampling by domestic animals erodes bogs and sponges. It causes them to dry and reduces their ability to store water and regulate floods. The search for diamonds in the Kimberlite Pipes which underlie many bogs has also resulted in wetland destruction. In the lowlands reed swamps used to be conserved by local practice, since they provided the principal source of thatching material, but with a movement of agriculture into the foothills increased erosion has led to the silting up of many lowland swamps. Today reeds are confined to thin riverine strips in many places, where, only a decade ago, they covered many hectares.

Conservation Status

Representative montane wetlands are conserved in Sehlabathebe National Park which covers 6805 ha in the SE of the country, encompassing the headwaters of the Tsoelike River at elevations between 2300-2550 m asl. The park, which was established in 1970, provides one of the last refuges of a small rare fish, *Oreodaimon quathlambae* (in the Tsoelike River), and a newly described aquatic plant, *Aponogeton ranunculiflorus*. All the animals listed above occur in the park, but most large animals leave the area in winter and are in any case scarce, since the park is above the normal altitudinal range of many.

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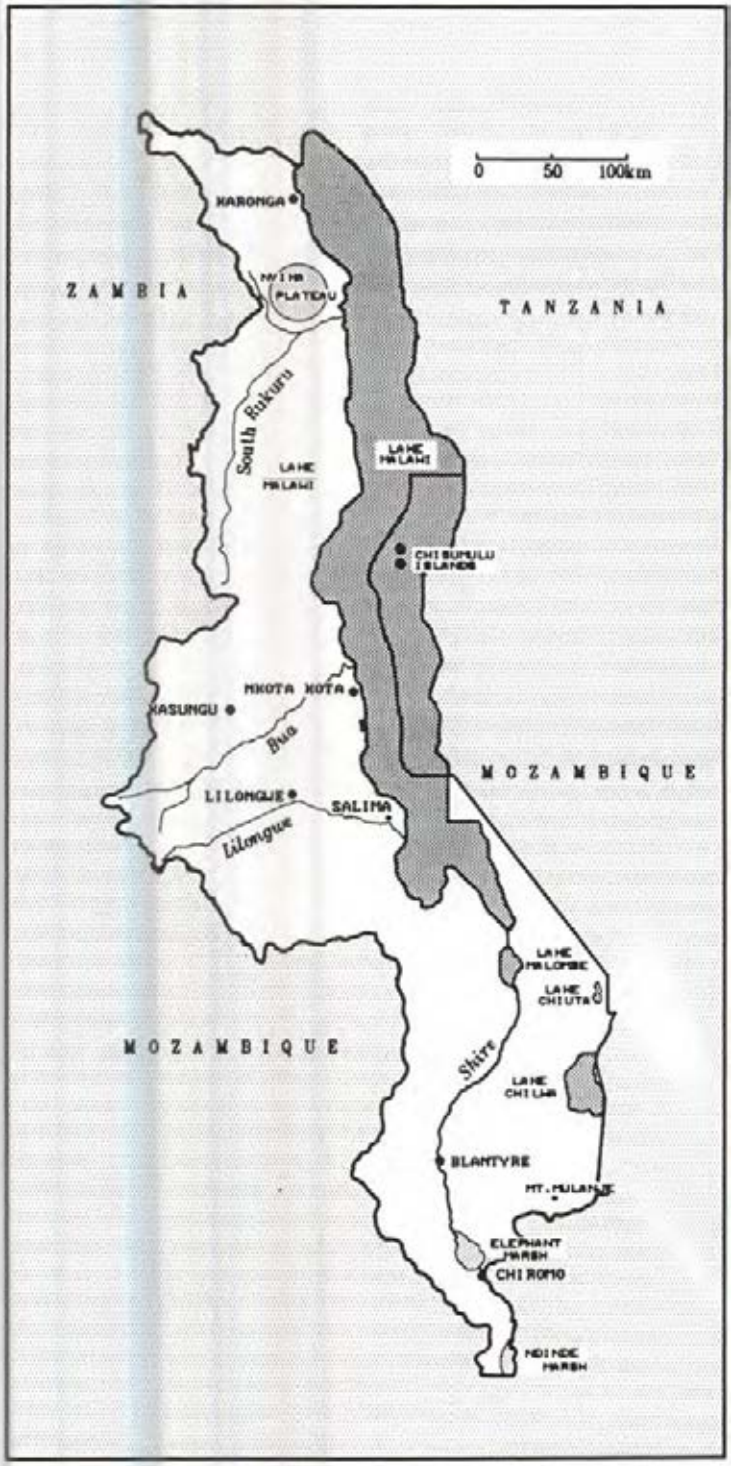

Map of Malawi

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5.4 MALAWI

Introduction

Malawi is a long, narrow country, located at the southern end of the Western Rift Valley. It stretches approximately 870 km from north to south between latitudes 9°30' and 17°00'S, and 350 km from east to west between longitudes 32°44' and 35°55'E. It has a total area of 94 080 km^2 and supports an estimated population of 6 429 000 (1982), giving a mean density of 68 persons/km^2. The highest population density occurs close to the Mozambique border, from Blantyre (15°46'S/35°00'E) down the Shire Valley, with other concentrations around Zomba (15°22'S/35°22'E) and Lilongwe (13°58'S/33°49'E).

Malawi is bordered by Zambia in the west, Tanzania in the north and northeast, and Mozambique in the east, south and southwest. It is a country of dramatic relief, with high mountains and deep lakes. The major physiographic feature is Lake Malawi (Nyasa) which extends from north to south for 557 km along the eastern border. In the central region, to the west of Lake Malawi, a number of plateaux reach elevations of 760 - 1579 m asl, and together cover about three quarters of the total land surface. Mountain ranges, such as the Nyika, Vipya and Dowa Highlands in the northwest, the Dedza-Kirk Range in the west, and the Shire Highlands in the southwest, attain altitudes of the order of 2400 m. In southern Malawi the floor of the Shire Valley lies at an altitude of less than 70 m asl at the Mozambique border, but the adjacent mountain massifs of Mulanje and Zomba reach 2998 and 1976 m respectively.

Climate

Over much of the country there are two seasons, with a hot wet period from November-April, and a cooler drier one from May-October. Although the whole country lies within the tropics the topography is so varied and the range of altitude so great, that climatic conditions are complex with gradations from wet to dry, and hot to cold. During winter the prevailing winds, unless deflected by mountains, are from the southeast, or less often, from the east. These air flows are characterised by a shallow layer of moist air overlain by much drier air. This produces fair-weather cloud which varies in amount according to the depth of the moist layer. After the September equinox the winds tend to become more northerly and the air becomes warmer and more humid. Showers and occasional thunderstorms occur, but heavy rain only becomes general with the arrival of the Intertropical Convergence Zone (ITCZ) in October. This, together with strengthening winds, causes an increase in cloudiness and rainfall until the end of March when the convergence zone is driven farther north by southerly air flows, a process which leads to the cessation of rain throughout the Zambezi Basin. However, in Malawi, the escarpment bordering the lake directly exposed to the southeasterly winds continues to receive rain, partly from off the lake itself, so that in northern parts of the country April may be the wettest month. Weather becomes fair in all parts of Malawi by May.

Much rain is convective, falling in local showers or thunderstorms. It usually occurs in spells of several rainy days followed by several dry days. Periodically, rising pressure to the south results in incursions of cool moist air bringing drizzle known as chiperoni. This can occur at any time of the year, but the effect is striking when it occurs during

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the dry season. When a tropical cyclone moves down the Mozambique channel it tends to distort the ITCZ, so that much moister air from the Zaire Basin is drawn across Zambia into Malawi. Although the winds generated by cyclones moderate rapidly inland, winds speeds can still become high over Lake Malawi, and extremely heavy rain may persist over the country for several days in the wake of a cyclone. Such an event produced a fall of 570 mm in 24 hours at Nkhotakota in 1957.

The southern highlands, and particularly their southeasterly windward slopes, receive 2-3 times as much rain as adjacent low-lying areas, such as the Lower Shire Valley. Here mean annual rainfall varies from 635-762 mm depending upon site. Rainfall is highest on the northern plateaux of Vipya and Nyika, where the mean annual receipt is in excess of 2200 mm. Falls of more than 1500 mm are received along Lake Malawi where the shore is perpendicular to the direction of the prevailing wind. Rainfall along sections of the lake parallel to the wind is much lower. Most valleys, notably those of the Shire and Kasitu Rivers, and the southern end of Lake Malawi, are in rainshadows.

Temperatures in Malawi are greatly influenced by topography, being, for example, much warmer in the lowlands of the Shire Valley than in the highlands. In addition, Lake Malawi has a profound effect upon the weather since it acts as a heat reservoir of sufficient magnitude to set up land and 'sea' breezes. Thus cool air from the lake tends to move over the heated land during the day, but at night cold air from the land tends to drain towards the lake. The onset of lake breezes halts the normal diurnal rise in temperature, and the maximum temperature is several degrees lower than otherwise would be the case. Over most of the country the annual range in temperature is about 12°C, except in the south where it is 15°C. The lowest temperatures occur in June and July (mean monthly minimum at Lilongwe is 5°C), and the highest occur in October and November (mean monthly maximum at Lilongwe 30°C, absolute maximum 40°C). When the rains come there is a fall of about 3°C in maximum temperatures, although the minimum temperatures go on rising until December or January. Thereafter temperatures remain steady until the end of the rains in March or April before decreasing to the winter minima.

Because of the large diurnal variations in temperature, relative humidity varies widely during the day, being highest when the temperature is lowest, and *vice versa*. At dawn, relative humidities of over 90% are common at most weather stations in the country, but by afternoon the figure has fallen to 40-60% depending upon the season. The lowest humidities occur in October, immediately preceding the rains.

Substantial amounts of sunshine are recorded even during the rainy season. The southern and southwestern parts of Lake Malawi are the sunniest parts of the country, while the northern sector is much more often overcast. Lilongwe receives 2665 hours of sunshine/yr, giving a mean daily figure of 7.3 hours, with minimum receipts of 4.6 hr/day in January and maximum ones of 9.9 hr/day in October.

Wetlands

The principal drainage system, covering 158 000 km^2, culminates in Lake Malawi, and extends outside the borders of the country. The lake is fed by the North and South Rukuru, Dwangwa, Lilongwe and Bua Rivers, but the only outlet is the Shire River via Lake

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Malombe. The river emerges from Lake Malombe as the Middle Shire, which loses very little altitude over a distance of 100 km before descending almost 300 m in a series of rapids and waterfalls. Below the last cataract, Kapachira Falls, the river is known as the Lower Shire. Thereafter it flows south, having a broad floodplain and in a number of places expands into extensive marshes and swamps before joining the Zambezi River in Mozambique. The Chilwa Basin is an endorheic system fed by a number of highly seasonal streams flowing into Lake Chilwa which occupies the lowest part of the basin. It is surrounded by permanent swamps and a seasonal floodplain. Other swamps and marshes are found in the Western Highlands near the border with Zambia, e.g. a large marsh surrounds the headwaters of the Bua and Dwangwa Rivers.

Wetland Flora

Riverine and Lacustrine Floodplains: These are dominated by grasses among which *Oryza barthii* and *O. longistaminata* occupy the most deeply inundated sites with *Echinochloa pyramidalis, E. scabra* and *Pennisetum* sp. in sites flooded to intermediate depths. *Acrocerus macrum, Setaria sphacelata* and *Vetiveria nigritana* are common on the margins. In the lowlands these are joined by *Echinochloa haploclada, Eriochloa borumensis* and *Sporobolus robustus. Hyparrhenia* and *Heteropogon* spp. are also locally common on the margins, but where grazing is intense *Cynodon dactylon* is important. On wet grazed margins this latter species is associated with, or gives way to, *Eleusine indica* and *Eragrostis aspera*.

Dambos: Grasses in permanently waterlogged but not deeply flooded, or very temporarily flooded sites, such as dambos, include *Heteropogon contortus, Loudetia simplex* and *Themeda triandra*. In addition species of *Xyris* and various dicotyledonous herbs are also usually present.

Permanent Swamps & Marshes: The permanent swamps are dominated by *Phragmites mauritianus* and *Typha domingensis*, or by *Cyperus papyrus* in permanent water with seasonally fluctuating levels. Papyrus is accompanied by a typical spectrum of low growing, often floating, associates. These include *Aeschynomene nilotica, Echinochloa haploclada, Ipomoea aquatica, Leersia hexandra, Ludwigia stolonifera, Nymphaea caerulea, N. capensis, N. lotus*, and most importantly, *Vossia cuspidata* at the outward waterside faces. A number of free-floating species occur on open water in these swamps, e.g. *Azolla nilotica, Eichhornia crassipes, Pistia stratiotes* and *Salvinia hastata*, while beneath the surface of open water *Ceratophyllum demersum, Ottelia exserta* and *Utricularia* spp. are common. The flora of these swamps may change with the onset of the dry season, since many aquatic plants die back as the water level falls, and other species appear.

Sudds often form in these swamps at high water, the most important sudd-forming species being *Cyperus papyrus, Echinochloa pyramidalis, Ludwigia leptocarpa, L. stolonifera* and *Pycreus mundtii*. Their roots and rhizomes interweave and are bound together by masses of *Nymphaea capensis* and *Trapa natans*. Early in the season when the water is low, new vegetation extends outwards from the *Cyperus-Typha* border of the swamp. This often becomes established in masses of old vegetation which was banked up when the floods subsided at the end of the previous cycle. In the comparatively shallow water of the dry season, the new vegetation is at first rooted, but with increases

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in water levels and the development of flood currents following the onset of fresh rains, it becomes detached from the substratum.

Sedge Marshes: These occur where inundation is neither very deep nor permanent, in sites where the surface dries for a short period each year. Often they are found on the landward side of permanent swamps. *Cyperus articulatus* and *C. digitatus* tend to dominate these areas, reaching 1.5 m in height, with *Echinochloa haploclada, Ipomoea aquatica, Leersia hexandra, Ludwigia stolonifera, Nymphaea caerulea, N. capensis, N. lotus* and *Vossia cuspidata* as common associates. Many of the free-floating species mentioned above are abundant at high water. During the dry season the exposed land between sedge clumps is invaded by annual herbs, e.g. *Cyperus esculentus* and *Hibiscus cannabinus*.

Riverine & Levée Forests: Scattered trees of *Acacia albida, Diospyros mespiliformis, Ficus sycomorus, Ilex mitis, Khaya nyasica, Kigelia pinnata, Rhus longipes, R. tenuinervis* and *Syzygium cordatum* occur on levées in the swamps and along rivers, with lower growing bushes of *Ficus verruculosa* and *Hibiscus diversifolius* at the water's edge.

Wetland Fauna

Fish: The cataracts of the Middle Shire are reputed to act as a total barrier to fish movement, with the result that the fishes above the cataracts belong to the Lake Malawi fish fauna and those below to the Zambezi fish fauna. The extraordinarily rich fish fauna of Lake Malawi is dealt with in section 5.4.6, Lake Malawi, but the Shire system contains some 61 species including *Astatotilapia calliptera, Barbarhinus lucas, Clarias gariepinus, C. ngamensis, Eutropius depressirostris, Hydrocynus vittatus, Labeo altivelis, L. congoro, Marcusenius macrolepidotus, M. livingstonei, Oreochromis mossambicus, O. shiranus, Petrocephalus catostoma, Protopterus annectens and Tilapia rendalli*. The Malawi Plateau fish fauna, described by Tweddle (1982), is also distinct and contains such species as *Barbus kerstenii, B. lineomaculatus, B. paludinosus, B. radiatus, B. trimaculotus, Chiloglanis neumanni, Labeo cylindricus, Leptoglanis* cf. *rotundiceps, Oreochromis shiranus* and *Pseudocrenilabrus philander*. The Chilwa Basin has an impoverished fish fauna dealt with in section 5.4.9, Lake Chilwa.

Reptiles: *Crocodylus niloticus* occurs throughout the country in suitable habitats, and snakes including *Atheris superciliaris, Bitis arietans, Dromophis lineatus, Lycodonomorphus inlanjensis, L. rufulus, Naja mossambica, Natriciteres olivacea, Philothamnus hoplagaster, Psammophis sibilans* and *Python sebae* are ubiquitous in the wetlands.

Birds: Highland floodplains support *Grus carunculatus, Cisticola njombe, Francolinus levaillantii* and *Neotis cafra jacksoni* among many other species. Swamps, lake margins and rivers support *Ardea cinerea, Ceryle rudis, Chlidonias leucoptera, Corythornis cristata, Dendrocygna viduata, Egretta garzetta, Haliaeetus vocifer, Larus cirrocephalus, Megaceryle maxima, Merops nubicus, Phalacrocorax africanus, P. carbo, Plectropterus gambensis, Scopus umbretta* and *Scotopelia peli*.

Mammals: *Aonyx capensis, Hippopotamus amphibius* and *Lutra maculicollis* are found in wetlands throughout the country, while *Alcelaphus lichtensteini, Equus burchelli, Hippotragus equinus, Loxodonta africana, Potamochoerus porcus, Redunca arundinum* and *Syncerus caffer* are frequent visitors to floodplains during the dry seasons.

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Tweddle & Mkoto (1986) provide an extensive bibliography of limnological work carried out in Malawi.

List of Wetlands Described

1. Marshes of the Ruwenya Hills
2. Marshes of Fort Hill Plain
3. Wetlands of the South Rukuru River System
   (a) Northern Tributaries
   (b) Vwaza Marsh
   (c) Southern Tributaries
4. Marshes of Kasungu Plain & the Bua River
5. Marshes of the Lilongwe Plain
6. Lake Malawi
7. Wetlands Associated with Lake Malawi
   (a) Karonga Lakeshore Plain
   (b) Limpasa Dambo
   (c) Nkhotakota Lakeshore Lowlands
   (d) Salima Lakeshore Plain
8. Lake Malombe
9. The Shire Marshes
10. Lake Chilwa
11. Lake Chiuta

1. Marshes of the Ruwenya Hills

General: In the extreme northwest of Malawi the Ruwenya Hills rise from 1220 to 1830 m asl. The mean annual temperatures are from 18-21°C depending upon site, while rainfall varies from 864-1143 mm and winds are predominantly from the east. In this remote, sparsely populated region, small grass and reed swamps occupy the heads of little valleys. One of the largest swamps (9°20'S/32°55'E) covers about 1000 ha. Stunted riparian forests containing *Ilex mitis* and *Syzygium cordatum* are found up to 1700 m asl along stream banks. This area is unprotected.

2. Marshes of Fort Hill Plain

General: This is a gently undulating plain with widely spaced marshy rivers situated south of the Ruwenya Hills. It lies at an altitude of 1250-1400 m asl, has a mean annual temperature of 20°C and mean annual rainfall of 820-1300 mm depending upon location. Easterly winds predominate. There are more than ten marshes of approximately 1000 ha each in an area 9°30'-10°10'S/33°15'-33°20'E, the largest one being on the Mambukiro River. Sandy ferallitic soils supporting *Brachystegia-Julbernardia* wood-

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lands cover the plain with the marshes (dambos) in isolated depressions. The sparse local population practises shifting cultivation, but maintains small patches of permanent cultivation near the rivers. None of this area is protected. The flora and fauna of the wetlands is as indicated in the introduction.

3. Wetlands of the South Rukuru River System

General: This river drains a large basin (10°35'-12°16'S/33°12'-33°50'E) below the watershed on the western border with Zambia. Tributary streams rise on the western slopes of the Nyika Plateau in the north and on Perekezi Hill in the south, and flow to a confluence at a point 11°11'S/32°28'E. Thereafter the river flows east to Jakwa Gorge, traversing Fufu and Wangwe Waterfalls before entering Lake Malawi at Mlowe (10°46'S/34°13'E) on the west bank.

(A) NORTHERN TRIBUTARIES

General: A number of marshes occur on the northern tributaries in a comparatively flat area to the north of Katumbi (10°47'S/33°36'E) beneath the Nyika Massif proper. Most of this upland plain is seasonally very wet. The mean annual temperature is 20°C and the mean annual rainfall is close to 1300 mm.

Flora & Fauna: The wet parts of the plain are covered by short open grassland dominated by *Exotheca abyssinica, Loudetia simplex* and *Themeda triandra*. A comparatively high level of speciation among plants has been recognised here, with at least 15 endemics, including species of *Cardiochilos* and *Holmesia*. The widely spaced rivers are bounded in places by broad riparian marshes, and the surrounding *Brachystegia-Julbernardia* woodland is locally joined by *Cryptosepalum pseudotaxus*. Several streams in the area have been stocked with rainbow trout. Subspecies of reptiles, amphibians and butterflies are endemic to the area, while wetland birds include *Cisticola njombe, Francolinus levaillantii, Grus carunculatus* and *Neotis cafra jacksoni*. Many of the small mammals cited in the introduction are present.

Human Impact & Utilisation: The population is sparse. Shifting cultivation is practised.

Conservation Status: Part of the area is protected within the Nyika National Park, which was created in 1966 and extended in 1978. This park is contiguous with the Nyika National Park in Zambia and wetlands extend across the border. The greatest threat to the marshes, both inside and outside the park, is annual burning carried out by the indigenous population.

(B) VWAZA MARSH

General: South of Katumbi the Hewe River flows into a marshy area known as Vwaza Marsh, from which it emerges as the Luwewe River. This area lies between 1100-1130 m asl and experiences mean maximum temperatures close to 17°C in July and 23.5°C in January, with a mean annual temperature of 21°C. Mean annual precipitation for 1981-83 was 1279 mm, with most rain falling between November and April, and no rain falling between June and September. Most of the wetland is situated west of the Luwewe River where it occupies a shallow depression floored by alluvium. There are

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patches of permanent reed/grass/sedge swamps, seasonally inundated grassy floodplains, abandoned levées and dambos, as well as reed swamps along the active course of the river. In addition an extensive flat area is subject to waterlogging if not to flooding. In total the wetlands occupy an area of about 40 000 ha.

The Luwewe River meanders south from the principal area of permanent 'marsh' in a channel which is 5-10 m wide for most of the year, although, in some years it may be reduced to a series of pools by the end of the dry season. To the southwest of the marsh proper some 7500 ha of grassland covers a seasonally inundated clay pan. This probably represents a former swamp or lake which has been drained by the Luwewe River. Large termitaria are a feature of this pan which is regularly burned during dry seasons.

Flora & Fauna: The floras of the different types of wetland are as indicated in the introduction. The fish fauna is as described for the Malawi Plateau in the introduction. The marsh is an important wildfowl location and many large mammals visit the floodplains during the dry season. However, *Hippopotamus amphibius* is the only large resident. Most of the small mammals cited in the introduction are present.

Human Impact & Utilisation: There has been little impact upon the wetlands. The whole area is infested with tsetse fly and there is endemic sleeping sickness which affects both cattle and people. This has hindered both the development of tourism and the integration of the local people with surrounding communities.

Conservation Status: The full length of the Luwewe River and its floodplains are protected in the Vwaza Marsh Game Reserve, which has a total area of 100 000 ha centred at 11°00'S/33°28'E. However the eastern corner of the 'marsh' is not protected and this locality is utilised intensively by villagers, many of whom were displaced when the reserve was created in 1977 and expanded in 1985.

Hunting occurs in the area, including the illegal hunting of elephants in the reserve. Fishing occurs in all watercourses and, although illegal in the reserve is widespread there. It is especially intense in the south where the river flows close to the reserve boundary. Currently there is pressure from local villagers to have some of the wetland excised from the park for rice cultivation. There is potential for tourism in the reserve and one small camp site, but access is difficult at present. Much of the wetland has been zoned for safari hunting, and game viewing is good during the dry season.

(C) SOUTHERN TRIBUTARIES

General: The southern branch of the South Rukuru River rises in the highlands in the west of Malawi (12°15'S/33°40'E) and makes a steep descent for a short distance to the southwest. It then turns northwards and follows a meandering course, receiving several tributaries, before it reaches the confluence with the Luwewe at Zaro Pool, a swamp fringed widening of the river. From here, for 20 km to Lake Kazuni, another broadening of the river with permanent marshes, the South Rukuru River forms the boundary of the Vwaza Marsh Game Reserve.

The areas of both Zaro Pool and Lake Kazuni fluctuate considerably. Lake Kazuni dried completely in the dry season of 1970, but contained over 80 ha of open water in December of the same year. In September 1979 there were 50 ha of open water (Tweddle, pers. comm.). Lake Kazuni is situated at an altitude of 1082 m asl.

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Along the lower part of its upper course, and throughout its entire middle course between its confluence with the Luwewe and Jakwa Gorge (about 120 km), the South Rukuru River and its tributaries are accompanied by broad grassy marshes/floodplains up to 4 km wide on dark cracking clays or coarse sands. Along the upper course (1250-1050 m asl) the mean annual temperature is 20-21°C and the mean annual rainfall 820-1030 mm. The middle reaches of the river, below 1050 m, experience higher temperatures (mean annual 22°C) and lower rainfall (mostly less than 820 mm/yr).

The Kasitu, the last major tributary of the South Rukuru, rises to the east of the South Rukuru River and flows in a northerly direction to join its south bank. Riparian swamps and a floodplain also occur on this stream, for a distance of 45 km above the confluence, but they are less extensive than those of the South Rukuru.

Flora & Fauna: Scattered trees are found in the marshes, mostly growing on termite mounds. A spectrum of trees grows on the levées, as indicated in the introduction, behind which the river and its pools are fringed by reed swamps and grassy floodplains. Species of *Barbus* and *Clarias* which do not occur elsewhere in Malawi are found in the upper reaches of the river. Many large mammal species visit the floodplains during the dry season, including, along the upper reaches, *Kobus vardoni*. Both Zaro Pool and Lake Kazuni are important for wildfowl, and are visited by buffaloes, elephants and hippopotamuses.

Human Impact & Utilisation: Permanent cultivation is carried out in small patches near the rivers and on interfluves. Population density is generally high.

Conservation Status: Part of this section of the river is protected within the Vwaza Marsh Game Reserve and is important for the maintenance of fish stocks in the river.

4. Marshes of Kasungu Plain & the Bua River

General: The Kasungu Plain (13°20'-13°45'S/32°50'-33°18'E) is situated at altitudes of 975-1220 m asl. The mean annual temperature is 21.7°C. Daily maxima often exceed 29°C between September and May, while daily minima may fall to 4°C between June and August. Annual rainfall over the plain varies between 765-1015 mm. In the southern part of the plain, the Bua River, and its tributary the Busa, both rise in grass swamps, at 14°09'S/33°27'E and 13°31'S/32°55'E respectively. These swamps are dominated by *Hyparrhenia* spp. and are dotted with pools. The headwaters of the Bua carry a marshy floodplain some 70 km long and up to 3 km wide, while the upper Busa carries a similar wetland 48 km long and 1-5 km in width. In addition there are more than 20 marshes and dambos, each exceeding 500 ha, on the plain between the rivers, and 20-30% of this inter-riverine area is subject to periodic inundation. As the rivers gain in size so their riparian swamps widen above their confluence at a point 13°20'S/33°27'E. The Bua is the largest river to enter Lake Malawi from the Malawi side, descending the steep slopes of the Rift Valley escarpment in a series of fault-controlled steps.

Conservation Status: Kasungu Plain has been extensively deforested, and this together with increased ground water extraction threatens to change flood and flow patterns in the rivers draining the plain. Kasungu National Park covers a drier northern part of the plain between the Busa and Dwangwa Rivers. The source of the Busa is situated in the

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extreme southwest corner of the park. Part of the lower Bua is protected in the Nkhotakota Game Reserve, where fishing is prohibited. This is important since the river supports huge breeding runs of the migrating cyprinid fish *Opsaridium microlepis*, which is endemic to Lake Malawi and is one of the major commercial species in its northern and central regions. Protection of the Bua River is considered necessary for the survival of the fishery.

5. Marshes of the Lilongwe Plain

General: More than 70 marshy areas, each greater than 500 ha, lie in a crescent orientated north-west-south on the Lilongwe Plain, at altitudes of 1100-1340 m. Here mean annual temperature is 20.5°C and the mean annual rainfall 890 mm. The surrounding woodlands comprise *Acacia*, *Combretum* and *Piliostigma* spp., and cultivation is largely restricted to the marshy areas.

6. Lake Malawi

Location: 9°30'-14°27'S/33°58'-35°19'E
Area: 2 450 400 ha (1 750 400 ha in Malawi)
Altitude: 475 m asl
Nearest Towns: Lilongwe (90 km W); Blantyre (165 km S)

General: Lake Malawi is situated in the southern part of the Western Rift Valley. It is 557 km long in a north-south direction, has a maximum recorded depth of 706 m, and is the second deepest lake in Africa. In the north, the Livingstone Mountains of Tanzania plunge almost vertically into it and continue into the depths of the northern basin. To the east and west, other escarpments form sheer cliffs at the water's edge. Much of the shoreline is rocky, giving rise in places to sheltered bays, but where the escarpments do not descend directly into the lake, there are coastal plains of varying widths, which are subject to flooding when water levels are high. In the south of the lake the topography is less rugged. The lake is of sufficient size to modify the climate locally, as discussed in the introduction. Annual rainfall varies from 650 mm at Mangochi in the south to 2500 mm at the northern extremity. The lake surface rises 0.7-1.8 m and falls an average of 1.1 m each year. 80-90% of the annual loss is through evaporation with the remaining 10-20% leaving via the Shire River. Below 250 m depth the lake is homothermal at 22.5°C, and is anoxic. Above 250 m there is a seasonal cycle, with the development of a marked thermocline during the warmer months. Reputedly the lake contains the greatest number of endemic fish species of any lake in the world, and fish from it are very important as a source of protein for the people of Malawi.

Hydrology & Water Quality: The principal rivers entering the lake from Malawi are, from north to south, the Lufilya, North Rukuru, South Rukuru, Dwangwa, Bua and Lilongwe, all of which rise in the western highlands of Malawi. The watersheds of these highlands form the boundary between Malawi and Zambia. These rivers have small catchments so that their volumetric flow at any time depends upon the vagaries of local rainfall; they are all subject to sudden flooding and changes of water level over short time periods. Lake Malawi drains to the Indian Ocean via the Shire and Zambezi Rivers.

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Its hydrology is delicately balanced and the level of the lake and the volume of the outflow also react rapidly to short term changes in precipitation over the catchments. However, there have also been long term changes in the patterns of precipitation which have caused the coastal plains to be alternately flooded and exposed for long periods. This has led to demographic changes, and has possibly promoted the great speciation of the fish fauna which characterises the lake. During the past century the level of the lake changed by some 6 m, from 469 m asl in 1915 to its present level of 475 m asl. When Livingstone first saw Elephant Marsh on the Shire River in 1859, it was large, but for the 20 years from 1915 to 1935, Lake Malawi did not overflow into the Shire River, and most of the Shire Swamps became dry land and were cultivated. The re-flooding of the area when the lake level rose again caused serious social disruption to the people of the plains.

The salinity of the lake water is quite low, having a mean conductivity of 200-230 µmhos/cm. Salinity is close to 1.90‰, pH varies between 8.2-8.8, and the following ionic concentrations, in meq/l, are typical: Na 0.16, Ca 0.99, Mg 0.39, carbonate + bicarbonate 2.36, chloride 0.12 and sulphate 0.11.

Flora & Fauna: Throughout the lake there are substantial growths of filamentous algae on the submerged rocks, extending to depths of 5-6 m. This is often dominated by cyanophytes, e.g. *Calothrix* spp. Sheltered sandy shores support *Ceratophyllum demersum*, *Myriophyllum* sp., *Potamogeton* spp. and *Vallisneria* sp., while swampy banks are covered by hygrophilous grasses including *Panicum repens*, *Sacciolepis africana* and *Vossia cuspidata*. Some bays are fringed by reed swamps with carpets of the free-floating *Pistia stratiotes* on quiet shallow water.

The lake supports a very large number of endemic Cichlidae. Almost 300 species of fish have been described from the lake, but the total number is quite possibly in excess of 500 (Tweddle pers. comm.). Many species have limited distributions within the lake, e.g. almost all islands support unique populations of rock-dwelling cichlids. It has been suggested (Beadle, 1981) that the Murchison Rapids on the Middle Shire River prevent the exchange of species between Lake Malawi and the Middle Zambezi system.

Rocky shores harbour a wealth of invertebrates (e.g harpacticoid copepods, chironomid fly larvae, hydrachnid water mites, ostracod crustaceans and larvae and nymphs of various insects). Molluscs are generally only poorly represented, but among those present are the endemic species *Neothauma ecclesi* and *Bulinus nyassanus*. Crevices in rocks hide the crab *Potamonautes lirrangensis* and provide refuges for many fish. Cichlids characteristic of rocky shores are known collectively as mbuna. They tend to be very colourful and are important to the aquarium export trade.

Sandy shores support an almost entirely different fauna. Invertebrates utilising this habitat include copepod and ostracod Crustacea, the prawn *Caridina nilotica*, chironomid larvae, the larvae and nymphs of Odonata and Trichoptera, and a number of gastropod and bivalve Mollusca. A different spectrum of cichlid fishes occupies this niche, e.g. *Haplochromis mola*, *H. similis*, *Lethrinops* spp., *Oreochromis saka* and *Tilapia rendalli*.

In the open waters the zooplankton comprises primarily copepods and cladocerans (e.g. *Diaptomus* spp. and *Mesocyclops* spp.), together with the larvae of chaoborid flies.

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Consumers of the zooplankton include the cyprinid *Engraulicypris sardella*, which is possibly the only pelagic fish to breed in the deep open water, although shoals sometimes swim into shallow waters when they tend to be caught by hand and seine nets. A group of about 16 species of *Haplochromis*, having protusible mouths, are also zooplankton feeders and are known collectively as utaka. The zooplankton feeders are preyed upon by other fish, including *Bagrus meridionalis* and some species of *Ramphochromis* which are fast swimming, thin bodied cichlids with jaws and teeth suitable for predation. These predators are of considerable economic importance.

Species of fish which regularly inhabit depths of 200-300 m include *Bagrus meridionalis* (Bagridae); *Dinotopterus* (= Bathyclarias) *foveolatus, D. felicibarbis, D. rotundifrons, Haplochromis heterotaenia* (Cichlidae); *Synodontis nyassae* (Mochokidae); and *Mormyrus longirostris* (Mormyridae).

Crocodylus niloticus is widespread but uncommon around the lakeshore, except in certain localities. Crocodile hunting is regulated by licence and a strict quota system is in operation. *Cyclodermafrenatum* and *Varanus niloticus* are common all round the lake.

Birdlife is abundant and includes *Ceryle rudis, Chlidonias leucoptera, Corythornis cristata, Dendrocygna viduata, Haliaeetus vocifer, Larus cirrocephalus, Megaceryle maxima, Phalacrocorax africanus, P. carbo, Plectropterus gambensis, Scopus umbretta* and *Scotopelia peli.*

Among mammals, *Hippopotamus amphibius* is fairly common, particularly in peripheral swamps and lagoons, where some may be shot each year for reasons of crop protection. *Aonyx capensis, Atilax paludinosus* and *Lutra maculicollis* are common.

Human Impact & Utilisation: By far the most important activity is fishing. A number of distribution centres have been set up, many of which are close to the shore. There is a continuing improvement in the numbers of these centres and their facilities, and also in the roads which are used to transport the fish to the rest of the country. Most fish are sent to the Blantyre area, but substantial quantities also go to Lilongwe. Over 33 000 tonnes of fish may be landed at Malawian ports in a good year.

Shore seines, long lines and gill nets are used around the lake. Trawling is important at Domira Bay and Salima, and the SE Arm is the most highly developed and productive area of the lake. The principal species taken commercially are *Bagrus meridionalis, Bathyclarias* spp., *Cyrtocara* spp., *Engraulicypris sardella, Labeo mesops, Mormyrus longirostris, Opsaridium microlepis, O. microcephalus, Oreochromis squamipinnis, O. lidole, O. saka* and *O. karongae*. The catch is sold fresh, frozen, smoked and sun dried, depending on size and consumer preferences.

Progressive deforestation and intensifying agriculture in the hinterland may eventually influence climatic patterns over the Lake Malawi Basin, and may be expected to produce increased rainfall because of changes in the land/water temperature balance. The level of the lake is kept fairly high by a barrage on the Shire River. At times of excessive rainfall this has led to damage of installations situated on the lakeshore, because the water has not been released sufficiently quickly.

Conservation Status: Most of the islands and a few sections of the mainland in the SE and SW Arms were gazetted as a national park in 1980. The protected areas include an aquatic zone extending 100 m out from the shore, within which all fishing is prohibited.

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This conserves the rocky shore community, together with those species which move inshore to spawn.

7. Wetlands Associated with Lake Malawi

(A) KARONGA LAKESHORE PLAIN

General: The Karonga Lakeshore Plain extends from the head of the lake in Tanzania, along the northwest shore in a SSW direction into Malawi to a latitude of 10°35'S where it is 8-20 km wide between longitudes 33°55' and 34°15'E. The plain rises from the level of the lake to 502 m asl, and enjoys a mean annual temperature of 24.5°C. Rainfall varies from about 1000 mm/yr in the south to over 2000 mm/yr in the north (Karonga town 1080 mm). The plain is covered by swamps and dambos, with a cluster of 8 sizeable swamps occuping the northern part, and a group of 3 larger swamps occupying the southern part. Here, along the shore of Lake Malawi, long narrow lacustrine sand bars alternate with long strip marshes, all running parallel to the lake. Except for some of the larger marshes, much of the plain is under cultivation and no part is protected.

(B) LIMPASA DAMBO

General: Limpasa Dambo (11°30'-11°45'S/34°15'-34°20'E) is situated in the lowlands near Nkhata Bay. It is approximately 29 km long with widths of 1.5-9 km, and an area of 13 000 ha. It rises from an altitude of 475 m asl at the lakeshore to 518 m asl. The local climate is hot and wet, with a mean annual temperature of 25°C and a rainfall of up to 2290 mm/yr. The dambo floor is clay, and vegetationally it is dominated by grasses. It is uncultivated and unprotected.

(C) NKHOTAKOTA LAKESHORE LOWLANDS

General: Here a strip of lowlands, extending for 125 km along the western shore of Lake Malawi, contains a number of seasonally flooded areas. These include from north to south: Unaka Lagoon, Bana Swamp (c. 15 000 ha, 19x8 km), Dzedza Swamp (c. 2800 ha), Chia Lagoon, and numerous marshy areas, especially to the west of Nkhotakota and to the north of Chia Lagoon. The mean annual temperature here is 24°C and the mean annual rainfall 1275 mm. Nkhotakota Game Reserve lies to the west of the lakeshore, and apart from the Bua and other rivers which flow through it, it contains little wetland. Extensive use is made of water from the Bua for irrigation on the lakeshore plain, and there are fears that too great a use of its waters in low rainfall years may threaten the survival of the fish *Opsaridium microlepis* which breeds in the Bua River.

(D) SALIMA LAKESHORE PLAIN

General: This is a very wet plain about 90 km long, which includes at least 11 sizeable marshes and the swampy delta of the Lilongwe River. This latter is 22 km long and 15 km wide at the lakeshore, with a swamp area of approximately 16 500 ha. Mean annual temperatures over the plain range from 23-24°C while rainfalls range from 1015-270 mm.

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8. Lake Malombe

Location: 14°29'-14°45'S/35°12'-35°20'E
Area: 47 000 ha
Altitude: 470 m asl
Nearest Town: Mangochi (10 km N)

General: This lake lies 15 km to the south of Lake Malawi. It is filled by overflow from Lake Malawi via the Upper Shire River, and discharges downstream to the Middle Shire River. It has a maximum depth of about 4 m, and together with its associated swamps covers an area of some 30 000 ha. The bordering marshes are dominated by *Typha domingensis*, but with considerable areas of *Cyperus papyrus*. During the dry period 1915-1935 water did not enter from Lake Malawi and the system became dry. Part of the swamp and that part of the river between Lake Malombe and Liwonde is protected in the Liwonde National Park, which lies to the southeast of the lake and borders the east bank of the Middle Shire River. The shores of Lake Malombe and the margins of the Shire carry typical riverine and floodplain vegetation, with small areas of gallery forest containing the palm *Hyphaene benguellensis*. The surrounding country is covered by savanna woodland. Here the Shire supports large populations of *Crocodylus niloticus* and *Hippopotamus amphibius*. 207 species of birds have been recorded, including *Agapornis lilianae* and many aquatic species. It is intensively fished but the annual catch fluctuates widely. This is partly related to variations in the size of the lake, and partly to the rebound effect of periodic overfishing. In 1976 the total catch was 6000 tonnes.

9. The Shire Marshes

Location: 16°11'-17°05'S/34°59'-35°19'E
Area: 74 000 ha (maximum wet season inundated area)
Altitude: 70-85 m asl
Nearest Towns: Ngabu (on Elephant Marsh); Blantyre (90 km N)

General: The Shire River drains Lakes Malawi and Malombe and thereafter falls 400 m before reaching the Lower Shire Valley. Barrages near Liwonde regulate the dry season flow of the river to generate hydroelectric power, and influence the passage of the flood waters which pass downstream in the wet season. In its lower course, before discharging into the Zambezi, the Shire flows through an extensive low lying area, which is deeply flooded during the wet season. A series of swamps, or 'marshes' as they are called locally, extends along the river, with two major areas in Malawi. Together these support one of the country's most important fisheries.

The Shire Swamps comprise two tracts of permanent swampland, and some lagoons in the Chikwawa and Bangula areas. After descending the Murchison Falls the river traverses the swampy lagoons at Chikwawa, and then spreads over the larger of the two swamps, Elephant Marsh, which extends some 25 km upstream and downstream of the town of Ngabu (16°47'S/35°15'E). This swamp terminates just above the confluence of the Shire and Ruo Rivers, in the vicinity of Bangula Lagoon, a 1000 ha expanse of open water. Some 40 km downstream of this is Ndinde Marsh, which begins at Nsanje (= Port Herald 16°47'S/35°15'E) and continues south to the southern tip of Malawi. On approaching the marshes the steep sandy banks of the Shire River decline and its waters

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traverse the marshes through a maze of shallow channels, from the almost nonexistent banks of which a flood spills over the intervening land in the rainy season.

In contracted state, at low water between August and November, the 'marshes' occupy respective areas of approximately 30 000 and 6000 ha, but at high water, towards the end of a very wet season, they expand dramatically. Elephant Marsh may then attain a length of 90 km and a maximum width of 30 km with an inundated area of 57 000 ha, while Ndinde Marsh swells to about 20 000 ha. The numerous lakes and lagoons which comprise these marshes, some with areas of nearly 2000 ha, may have connection with the anastomosing river channels only during the wet season. Islands of elevated land are small in extent and mainly peripheral; the marshes are virtually treeless and are dominated by herbaceous vegetation. Local rains between December and April are relatively unimportant in determining the water levels attained in the swamps, by far the most important factor being the flood coming down river from the vast catchments above Lake Malawi. When in spate, the waters of the Shire are dark brown where they enter Elephant Marsh, but quite clear where they leave it, and apparently the swamp traps a great deal of sediment each year. Large areas of the swamps become dry between August and November, and the black soils then become rather saline, but water levels begin to rise again in December and usually peak in May. Some chemical description of the waters of the Shire River are given by Hastings (1973).

Flora & Fauna: The peripheral tree flora which includes *Hyphaene benguellensis*, *Adansonia digitata*, *Lonchocarpus capassa*, and several deciduous trees, is almost exclusively confined to the margins of the swamps and the few scattered islands of elevated land just in from the periphery. Hygrophilous grassland occurs in the outermost zone which is flooded only to very shallow depths in most years. Here the dominant species very from site to site depending upon biotic and edaphic conditions. Where grazing is intense on the dry outer fringes, *Cynodon dactylon* forms an almost monospecific sward, but in wetter areas it is joined by *Eleusine indica* and *Eragrostis aspera*. In less heavily grazed areas the dominant grass is *Sporobolus robustus*, forming clumps up to 1 m high, with *Echinochloa haploclada* and *Eriochloa borumensis* becoming progressively more important as soil wetness increases. Alkaline sites are characterised by the presence of *Sporobolus consimilis*.

Moving deeper into the swamps a sedge marsh is encountered in places where inundation is more prolonged, but exposure still occurs each year. The flora is as described in the national introduction and the width of the zone varies from 20-600 m. Free-floating species are abundant at high water in this zone including *Azolla nilotica*, *Eichhornia crassipes*, *Pistia stratiotes* and *Salvinia hastata*. Beneath the surface *Ceratophyllum demersum* and *Utricularia* spp. are common. Most of these latter species are stranded and die back in the dry season, when sedge clumps are invaded by annuals.

In the broad permanent swamplands which succeed the marshy zone, towards the interior, water depths reach seasonal maxima of about 2 m. Here tall clumps of *Cyperus papyrus* are dominant, often whitened by the guano of roosting birds, and reaching 3-4 m in height. In deep water they are surrounded by more open stands of *Typha domingensis* with many floating-stemmed, floating-leaved and free-floating species about the stem bases. In less deep, but still permanent water, vast, dense, monospecific stands of *Phragmites mauritianus* occur, often isolating the papyrus clumps as islands.

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The central and most deeply inundated areas of the swamps comprise expanses of open water, which are at times covered by enormous carpets of the free-floating species mentioned in the introduction. Beneath clear water, great beds of submerged macrophytes occur, including *Ceratophyllum demersum* and *Ottelia exserta*, all with a prolific algal epiphyton. At the edges of the emergent vegetation of the swamp zone, floating sudds are formed. These eventually become detached and drift away, frequently aggregating on open water, and often causing blockages which lead to the development of new channels.

The 'marshes' are infested by mosquitos, which cloud the air at night, and malaria ravages the local human population. Because of the nature and size of the swamp, effective mosquito control measures are virtually impossible. The fish fauna is typical of the lower Zambezi and distinct from that of Lake Malawi as explained previously. With the onset of the rains, fish move from the river channels into the freshly flooded areas to breed, but the diversity of fishes is always greater in river channels than it is in swamps. 61 species have been recorded in the lower Shire River so far. *Protopterus annectens*, which has been recorded throughout the lower Zambezi system is quite common on the margins of the marshes, aestivating during the dry season. The freshwater shark, *Carcharhinus leucas* also occurs here. Frogs, including a foam nesting species, abound in the swamps, and together with crickets and cicadas produce a cacophony of sound at night. *Crocodylus niloticus* is abundant, growing to 6 m in length and attaining weights of up to 2000 kg, but it is hunted commercially and stocks are slowly being depleted. High waters drown their breeding sites, and successive wet years are believed to reduce their numbers, but no counts have been made. From low flying aircraft they are frequently to be seen in circular ponds in the reed beds which they appear to have cleared for themselves. Birdlife in the marshes is prolific and includes many piscivorous species. *Haliaeetus vocifer* hunts the waterways by day while *Scotopelia peli* hunts them by night, both roosting in the peripheral trees. Many of the species mentioned in the national introduction are present including cormorants, herons, egrets, storks and ibises, feeding on fish, frogs, snails and mussels. Piscivorous and insectivorous kingfishers are present, also lily-trotters, while the reed beds are seasonally full of flycatchers and weavers. *Merops nubicus* nests in holes in the banks of the Shire River above Elephant Marsh in tens, if not hundreds, of thousands. With the advent of the dry season and the appearance of islands in the swamp, migrant birds appear, among them ruffs, green shanks and sand pipers, all feeding along the drying margins. Apart from hippopotamuses, large mammals are now uncommon in the marshes, although when Livingstone first explored the area in 1859 they were abundant. Elephants are now absent from the area despite the fact that Elephant Marsh was named for the presence in it of large herds; one seen (and partly slaughtered) by Livingstone's party numbering over 800 beasts.

Human Impact & Utilisation: The Shire Swamps support an important fishery, producing annual catches of 3000-15 000 tonnes, suggesting that effort is as intensive as it reasonably can be. There were 1693 canoes working on the two marshes in 1985, operated by 2809 fishermen (Tweddle pers. comm.). These are mostly of the dugout type, but planked canoes equipped with outboard engines are becoming more popular; they were first introduced in the early 1970s, with government assistance, because suitable trees for dugout canoes were becoming scarce. However, planked canoes are unable to slip through the reeds like dugout canoes and are less useful in many areas.

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The bulk of the annual catch is made with gill-nets, but long lines, scoop traps, seines, fence traps and spears are also used. Some areas yield much higher catches than others. The catch per canoe per year operating in the eastern part of Ndinde Marsh is for example, on average, twice as great as that taken per canoe per year in the northeastern part of Elephant Marsh. This is probably due to the behaviour patterns of the fish in relation to the vegetation and physiography of the marshes. Catches show two peaks each year, corresponding to the periods when fish are moving out over the floodplain to spawn at the beginning of the rainy season, and when they are forced to return to the river channels by falling water levels during the dry season. The second peak is the greater, reflecting the fact that the fish are concentrated in smaller and more accessible volumes of water in the dry season.

Of the 61 species of fish described from the lower Shire River, only five, *Clarias gariepinus, C. ngamensis, Eutropius depressirostris, Marusenius macrolepidotus* and *Oreochromis mossambicus* are important to the commercial fishery. Of these, the first three, two catfish and a cichlid, comprise over 90% of the catch. Species of secondary importance include *Astatotilapia calliptera, Hydrocynus vittatus, Labeo altivelis* and *L. congoro*. About 30% of the annual catch is consumed locally, while the remaining 70% is preserved for transport by smoking in kilns, or by sun drying. Access to Elephant Marsh is excellent, there being good peripheral roads and a railway. The north end of Ndinde Marsh can now also be reached by an all weather road, and traders come to the marshes to buy fish for markets in the towns. Some account of the fish fauna of the Shire Swamps is given by Hastings (1973), while information concerning the Shire fisheries is contained in Willoughby & Tweddle (1978), Willoughby & Walker (1978) and Tweddle *et al.* (1978).

Operation of the barrage at Liwonde affects the fishery in that if closure is too rapid the marsh drains quickly, with the result that anoxic and sulphurous water is flushed out so fast that there are large fish kills, and also many fish are stranded. By contrast, a carefully controlled closure, over a period of several weeks, leads to high catches as fish are encouraged to move off the floodplain slowly. A government commission now regulates closures to ensure that they have minimal environmental effect.

Cattle Grazing: The fringe lands are sometimes fired in the dry season and cattle, which are grazed on the surrounding lands, enter the marsh behind the falling waters. They graze and trample the vegetation, often paddling into shallow water in large numbers. Their dung replaces that which in the past was contributed to the marsh by wild animals. Parasitic diseases are common in the cattle, and many animals are in poor condition when they leave the marsh at the end of the season, despite the luxuriance of the grazing.

Agriculture: Sugar and cotton are grown under irrigation in the marginal lands, and plans have been mooted for extensive drainage and flood control schemes in Elephant Marsh. However, at present the two marshes provide a livelihood for very many people, and it seems that their destruction by large scale commercial projects would be unlikely to do anything but reduce the number of people the area could support. Pesticide residues from local agriculture had not, in 1985, reached significant levels in the lower Shire fish fauna (Tweddle, pers. comm.).

Conservation Status: Unprotected.

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10. Lake Chilwa

Location: 15°09'-15°31'S/35°33-35°50'E
Area: 185 000 ha (including peripheral swamp lands)
Altitude: 622 m asl
Nearest Towns: Liwonde (45 km NW); Blantyre (85 km SW)

General: Lake Chilwa is a large shallow endorheic lake situated in a depression in southeastern Malawi. It is bordered by wide areas of *Typha* swamp and sedge marsh, which in most places are backed by a grassy floodplain. The lake supports an important fishery, having provided, in some years, one third of the country's fish protein. The open water of the lake is very turbid and saline, supporting only a few specialised plant and animal species. In the swamps and marshes the water is less turbid, and environmental changes are less extreme, so that there the biota is more diverse. The soil of the lake bed changes from sand in the north to heavy clay in the south. A thick layer of fine silt overlies the whole area of the lake, which is easily stirred up by wave action, which occurs when strong winds blow across the lake.

The Chilwa basin is approximately rectangular, covering an area of about 7500 km^2, being 100 km across at its widest point and 160 km long in a north-south direction. It is bounded on the west by the Shire Highlands which rise to 1200 m asl, to the south by a flattish marshy area interrupted by the Mulanje Massif (2998 m asl), and to the east by a lower range of hills (900 m asl) in Mozambique. A sand-bar only 25 m higher than the floodplain separates Lake Chilwa from Lake Chiuta in the north. Although Lake Chilwa is much smaller now than it has been in the past, five distinct lake terraces indicate that there have been long periods of stability. There are several islands on the lake, two of which are inhabited. Nchisi Island, located near Kachulu on the western shore, is 4 km across and rises 430 m above the lake surface.

Today Lake Chilwa is roughly oval in shape, about 40 km from north to south and 30 km from west to east, with an open water surface close to 96 250 ha. In 1972, an 'average' year, the Chilwa system comprised 67 800 ha of open water, 57 800 ha of swamp and 59 400 ha of lacustrine floodplain. The maximum recorded water depth was 2.6 m in the SW corner. The level of the lake surface fluctuates by 0.8-1.0 m each year, but larger fluctuations of 2-3 m occur over periods of 6 to 12 years, and as mentioned, the lake may dry up completely.

There is a strong seasonal climatic pattern: May-September is cool with a little rain over high ground, September-November is hot and dry, and November-May hot and wet. Insolation is highest in September-October when sunshine averages 9-10 hours/day, and lowest in January-February when there is 5.5-7 hr sunshine/day. The mean annual temperature is 27°C, with mean monthly maxima of 32-34°C in the hottest months, October-December, and 24-25°C during the coolest months, May-August. Rainfall is unreliable and varies greatly from year to year.

Hydrology & Water Quality: The water level of the lake changes considerably over the course of a year, and the mean level varies from year to year. Occasionally the lake dries out completely (twice this century), the last major recession having been in 1968. Seventy percent of the total inflow comes from five perennial streams, the Domasi, Likangala, Thondwe, Namadzi and Phalombe Rivers, which rise either in the Shire

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Highlands or the Zomba Mountains further north. Mean annual precipitation over the lake is 800-900 mm depending upon station, but there are great annual variations. Precipitation reaches 1600 mm in the Shire Highlands and 2000 mm in the Mulanje Mountains. Mean annual evaporation from class A pans during the decade 1961-1970 was 1763 mm.

The lake and swamp show horizontal, vertical and seasonal variations in water quality. Conductivity varies from about 1200 µmhos/cm in the open waters and middle swamps, to 100 µmhos/cm at the landward edge of the swamp at times of moderate water level. Transparency is greatest at the edges where it may reach 90%, whereas by contrast the central lake is turbid and the transparency of open waters does not usually exceed 56%. In open water and the centres of the swamps, pH is frequently of the order of 8.7, but it is lower, c. 7.6, at the edges of the swamp. The lake has been extensively monitered for ionic composition, and the following figures, expressed in mg/l, are for the months of July and December respectively, averaged over a 10 year period: Na 350/780; K 10.5/23.1; Ca 13.4/13.2; Mg 6.3/8.6; Cl 277/515 and phosphate 1.2/2.0.

The conductivity of the lake water tends to remain fairly constant throughout the year, whereas in the swamp it shows an inverse relationship with the level of the water. However, during December-February, the fall in conductivity is somewhat greater than might be expected, and Howard Williams (in Kalk *et al.*, 1979) has suggested that fresh water from the rivers pushes all the water from the swamps into the lake, thereby causing a considerable water exchange. As the swamp and floodplain dry, cattle move in and graze the vegetation. When flooding occurs again many nutrients, including nitrogen, are released from the dry vegetation and animal dung.

Flora & Fauna: The very turbid waters of the lake keep it free from submerged vegetation. Occasional patches of the sedge *Scirpus littoralis* and the grass *Paspalidium geminatum* are found in the open water, and appear to be the only two species able to live in the deep water and to tolerate heavy wind and wave action. When the lake dried out in 1966-68 only three species survived on the hot mud, *Aeschynomene pfundii*, *Cyperus laevigatus* and *Diplachne fusca*. The mature *Aeschynomene* plant grows in water and can tolerate a wide range of salinities, but the seeds require a dry period for germination and the seedlings cannot grow under water. As a consequence this species had disappeared by 1973, by which time the lake had been full for several years. Following the dry spell, small isolated areas temporarily supported a richer flora which included *Aeschynomene nilotica*, *A. pfundii*, *Diplachne fusca*, *Echinochloa pyramidalis*, *Ipomoea aquatica*, *Ludwigia stolonifera*, *Paspalidium geminatum* and *Vossia cupidata*, together with *Nymphaea* spp. and the submerged macrophytes *Ottelia* and *Nitella* spp.

Most of the fringing swamps are dominated by pure stands of *Typha domingensis*. At the interface between lake and swamp a few free-floating species are found, e.g. *Pistia stratiotes* and various Lemnaceae, while *Ceratophyllum demersum* and *Utricularia* spp. are submerged species. In the wet season several species grow, flower and die on the expanding margins, within a few months, e.g. *Cyperus esculentus* and *Hibiscus cannabinus*. These are replaced by *Panicum repens*, *Nymphaea caerulea* and *Utricularia* spp. which then decline rapidly as water levels fall.

To the north of the lake a zone of alkaline soil is usually dry, but is periodically wetted by a rise in water level caused by southeasterly winds blowing over the lake. This area is characterised by *Cyperus laevigatus*, *Scirpus maritimus*, the grasses *Diplachne fusca*

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and *Panicum repens*, and scattered clumps of *Typha domingensis*. Alkaline marsh is also found to the south of the lake where the heavy clay soils have a pH greater than 7.5. Here mixed swards of *Vossia cuspidata* and *Cyperus longus* occur, interspersed with *Aeschynomene pfundii*. Neutral to acid marsh is found on the west side of the lake where the only stands of *Cyperus papyrus* are found at the mouths of the Likangala and Domasi Rivers. Here the soils have a pH of 5.0-7.0. The papyrus associations are surrounded by a zone of typical floodplain grasses. *Cyperus procerus* and the floating grass *Leersia hexandra* dominate the area between the two rivers.

Floodplains surround almost the entire lake and are inundated for 3-4 months each year, reaching a width of 35 km in the north. Grasses present here include *Acrocerus macrum*, *Cynodon dactylon*, *Echinochloa pyramidalis*, *Eragrostis gangetica*, *Hyparrhenia rufa* and *Sporobolus pyramidalis*.

The algal flora of the open waters changes with water quality. In 1977 there was a rich flora comprising species of *Cyclotella*, *Euglena*, *Nitzchia*, *Oscillatoria*, *Peridinium*, *Phacus*, *Scenedesmus* and *Tracheolomonas*.

Little benthic animal life is found under the open waters of the lake since the mud is soft and there are few aquatic macrophytes to provide suitable habitats in the turbid waters. Most invertebrates found in the swamps and marshes are associated with aquatic macrophytes. The floodplain grasslands provide one of the eight African 'outbreak areas' for swarming of the red locust *Nomadacris septemfasciata*, but the last plague originating here occurred from 1930-45. The grasslands of the floodplain are heavily grazed by domestic cattle where dung beetles (Scarabaeidae) are important for burying dung and helping to recycle organic nutrients. The most successful and agressive species include *Euonitis rellus intermedius*, *Liatongus militaris*, *Onthophagus depressus*, *O. gazella* and *Sisyphus* sp.

The open water of the lake is dominated by three omnivorous species of fish; *Barbus paludinosus*, *Clarias gariepinus* and *Oreochromis shiranus*. During recessions of the lake these fish migrate into the swamps where they take refuge in lagoons and streams. *Clarias gariepinus* is adapted to withstand desiccation and to tolerate saline water. It is able to traverse dry mud using its spiny fins since it has accessory breathing organs. The swamps harbour other fish, and those commonly caught for human consumption include *Alestes imbiri*, *Barbus trimaculatus*, *Haplochromis callipterus*, *Hemigramnopetersius barnardi*, *Labeo cylindricus*, *Marcusenius macrolepidotus*, *Petrocephalus catastoma*, *Pseudocrenilabrus philander* and *Tilapia rendalli*.

Among amphibians, *Xenopus muelleri* is found in larger pools on the floodplain, *Phrynobatrachus acridoides* lives in shallow, almost fresh water, but survives the dry season by moving to perennial streams. *Hyperolius parallelus* is found along the swamp edges, spending much of its time resting on stems of *Typha*. *Chiromantis xeramphelina* is also found on the swamp fringes, while the most highly specialised amphibian is Power's rainfrog, *Breviceps poweri*, which lives permanently on land.

Some nineteen species of reptiles are listed for the area, including some of special interest. *Crocodylus niloticus* is now rare in Lake Chilwa and in times of drought will bury itself in mud, migrate up rivers or traverse the sand-bar to Lake Chiuta. Many snakes are found in the wetlands including *Atheris superciliaris*, *Bitis arietans* and *Python sebae*. The soft shelled turtle *Cycloderma frenatum* is also present.

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Lake Chilwa has over 150 species of resident birds and up to 37 species of palearctic visitors. The open water of the lake attracts piscivores such as *Larus cirrocephalus*, *Pelecanus rufescens* and *Phalacrocorax africanus*. Ducks and geese frequent the lagoons and river mouths, and the swamps harbour a variety of other species including *Actophilornis africanus*, *Anas* spp., *Casmerodius albus*, *Ciconia* spp., *Egretta ardesiaca*, *Euplectes axillaris*, *Gallinula chloropus* and *Philomachus pugnax*. Birds of the open shores include *Phoeniconaias minor*, *Phoenicopterus ruber* and *Tringa nebularia*. *Circus ranivorus* and *Haliaeetus vocifer* are resident birds of prey.

Until the end of the last century the Lake Chilwa area supported a wide variety of game including kudu, bushbuck, rhinoceros, elephant, eland, impala, duiker, klipspringer, gnu, zebra, oribi, buffalo, hippopotamus, warthog, bushpig, leopard, lion and hyaena, but many of these are now absent from the area. Mammals still found there in relative abundance include *Aonyx capensis*, *Atilax paludinosus*, *Cercopithicus aethiops*, *Crocuta crocuta*, *Hippopotamus amphibius*, *Mastomys natalensis*, *Papio cynocephalus*, *Redunca arundinum*, *Tatera leucogaster* and *Viverra civetta*. In addition large numbers of domestic cattle graze the floodplains.

Human Impact & Utilisation: Lake Chilwa was at a crossroads of Central Africa until the turn of the century. Caravans of people, including slave traders, passed north-south and east-west through the area. The lake provided food, supplies and a place of rest for the travellers, some of whom remained and diversified the population. Others migrated to the area to hunt and fish. In the past the resident people have accommodated to the continually changing situation, migrating away from the lake during times of drought and returning to it to fish when the lake refilled. However, the places where they were once able to subsist on berries, roots and meat from wild animals are now extensively cultivated. The former flora and fauna has been destroyed and are no longer available in times of severe drought. It has been suggested that in the past the effects of drought have been far more devastating than overfishing and that commercial fish production could be increased markedly without causing a deleterious effect on the fish population. To this end a successful experimental trawling programme was carried out in 1970-71 in the deeper waters of the southwestern part of the lake, which previously had not been fished. In 1976 an estimated 19 746 tonnes were harvested. The catch for that year represents 159 kg/ha/yr for Lake Chilwa, and was close to one third of the total national fish landing for Malawi in 1976, indicating the importance of Lake Chilwa to the nation's food supply. However, the catch varies greatly from year to year, being high in wet years and low in dry years. In 1968 it fell to only 97 tonnes.

Today fishing forms a major part of the local economy supplemented by subsistence farming. The floodplain is also important for rice production and stock keeping. Major problems facing the area now include rapid accumulation of silt as a consequence of increased agriculture on the floodplains and in the catchment. Since the lake is endorheic the silt is not carried away, causing the lake to become more shallow and turbid, leading to greater oxygen deprivation. Another problem, also associated with agricultural practices in the catchment, is the build-up of insecticides and herbicides, again exacerbated by the fact that the lake has no outflow.

Conservation Status: Unprotected.

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11. Lake Chiuta

General: Lake Chiuta is situated (14°42'-14°53'S/35°47'-35°55'E) on the border between Malawi and Mozambique. It is a permanent lake having an area of 2500 - 13 000 ha according to season and rainfall, and is surrounded by extensive marshy areas, especially to the south. A sand-bar 15-25 m above present lake levels separates the marshes from those at the north end of Lake Chilwa. Lake Chiuta is intermittently connected to Lake Amaramba to the north in Mozambique, which is the perennial headwater of the Lugenda River, a major tributary of the Ruvuma River. The lake is shallow, having a maximum depth of 4 m, with mean conductivities of 120 µmhos/cm in the open water and 220 µmhos/cm in the swamp.

Flora & Fauna: The phytoplankton comprises species of Chlorophyceae, Conjugatophyceae, Cyanophyta and Chrysophyta. In the open lake the only emergent macrophytes are found around Chiuta Island, but the substratum is covered by a dense mat of *Utricularia* spp. On the western shore a zone of *Typha domingensis* reaches 10 - 30 m in width, although the stands are less dense than those on neighbouring Lake Chilwa. *Nymphaea* spp. are found floating on the open water in this area. To landward of the *Typha* zone, a belt of emergent vegetation, 20-40 m wide, comprises *Cyperus alopecuroides* and *Vossia cuspidata*, with the occasional occurrence of *Aeschynomene pfundii* and *Cyperus papyrus*. *Ceratophyllum demersum*, *Nymphaea* spp. and *Ottelia ulvifolia* are common in canoe channels. The southern area of the lake supports a diverse community of emergent vegetation.

Common zooplankters include species of Copepoda, Cladocera and Rotifera. So far 37 species of fish have been recorded in the lake and affluent streams, of which 33 have been recorded in the lake proper.

Human Impact & Utilisation: Fishing is near optimal level. According to a 1985 survey there are 240 canoes and 10 boats, operated by 203 fishermen with 102 assistants. The principal species caught in the open lake is *Oreochromis shiranus*, while *Clarias gariepinus* is important in the southern marshes. Smaller species commonly caught in traps and small meshed gill-nets include *Alestes imberi*, *Astatotilapia calliptera*, *Glassogobius giuris*, *Marcusenius livingstonei*, *Petrocephalus catostoma* and *Tilapia rendalli*. Lake Chiuta produces an average of 1400 tonnes of fish per year. Pollution is negligible. Bilharzia is present (Tweddle, pers. comm.).

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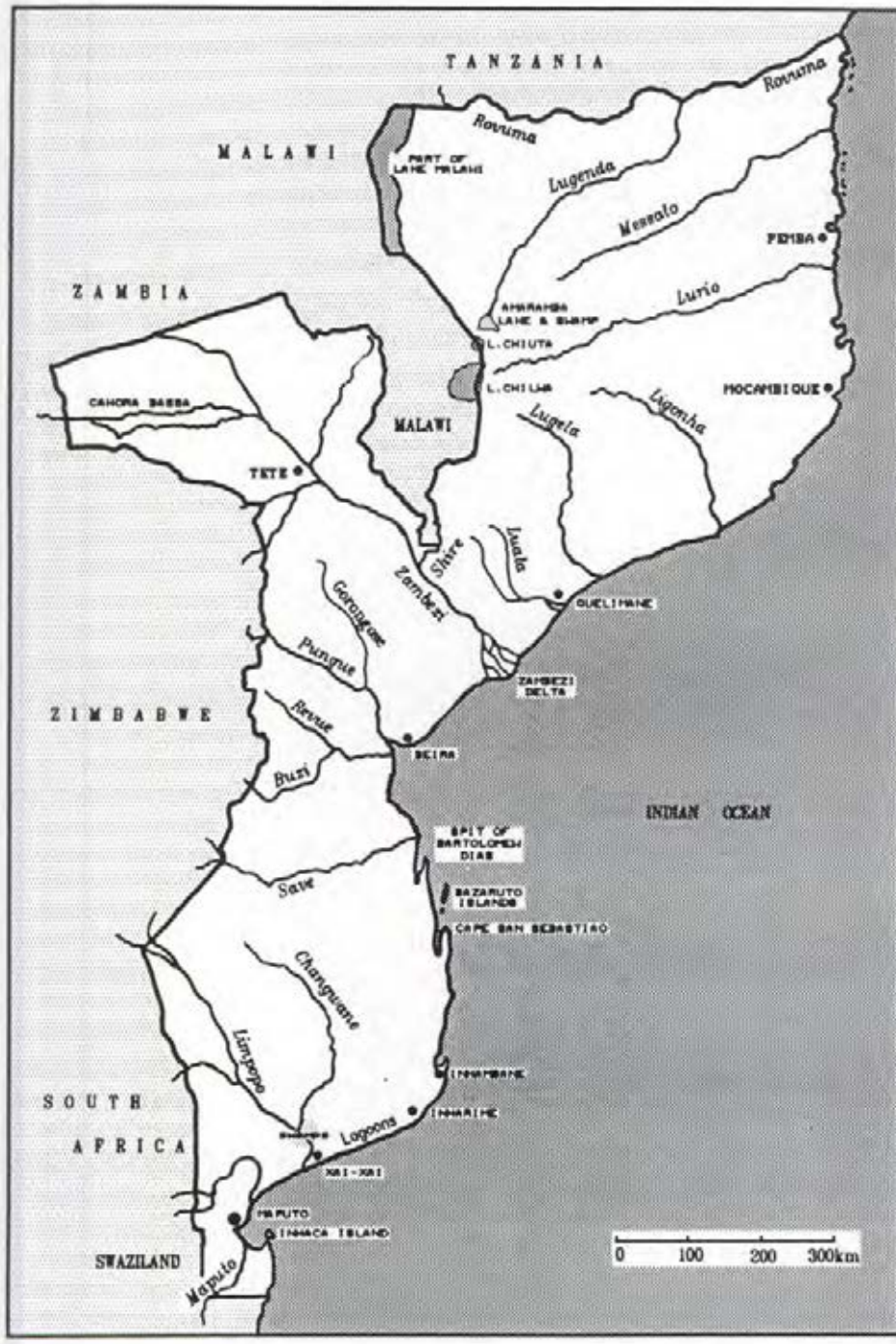

Map of Mozambique

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5.5 MOZAMBIQUE

Introduction

Mozambique occupies the southeastern seaboard of Africa from the Rovuma River mouth (10°30'S) to the South African border (26°49'S). It is bounded by Tanzania in the north, by Malawi, Zambia, Zimbabwe, South Africa and Swaziland in the west, and by the Indian Ocean in the east. It has an area of 784 755 km^2 and an estimated population of 13 140 000 (1983), giving a mean density of 16.7 persons/km^2. However, the population is heavily concentrated in two coastal regions, between Maputo (25°58'S/32°35'E) and Inhambane (23°51'S/35°29'E) in the south, and between the Zambezi Delta and Pemba (13°00'S/40°30'E) in the north. Much of the country, including the southern interior, the Zambezi Basin in Tete Province, and the northern highlands have fewer than 5 persons/km^2.

The northern part of the country is a great mountainous block with maximum elevations along the eastern edge of the East African Rift Valley system. Here the summits of Mt. Jeci (12°50'S/35°09'E) and Mt. Chiperone (16°30'S/35°44'E) reach 1836 and 2054 m asl respectively, and more centrally Mt. Namuli (15°25'S/37°00'E) reaches 2419 m. From these western heights the land slopes eastwards and southeastwards, comparatively gently, with many extensive plateaux, to the Indian Ocean. Drainage is by 18 perennial rivers, and many small streams.

The central region is dominated by the lower Zambezi Valley and its delta plains, but in the interior, in Tete Province, the rims of the valley are mountainous, reaching 2095 m asl at Mt. Domue (14°28'S/34°15'E) on the border with Malawi. In this part of the basin, drainage is into Lake Cahora Bassa, or into the Zambezi below it, by numerous fast flowing seasonal streams which descend the valley sides steeply. These rise in Zambia, Malawi and Zimbabwe. The Shire River, draining Lake Malawi, enters the Zambezi in the lowlands, shortly after which the main stream begins to break into distributaries.

The southern part of the country, south of Beira (19°49'S/34°52'E), comprises a broad coastal plain backed by mountains along the western national border. No land exceeds 500 m asl in the south, except for small tongues which extend a few kilometres over the border from Zimbabwe and South Africa, and more than 85% of the land surface is below the 200 m contour. However, it is here, at Mt. Binga (2436 m), on one of the tongues of high land reaching in from Zimbabwe (19°47'S/33°03'E), that the highest elevation in Mozambique is reached. A number of important watercourses drain the highlands along the western border, including, from N-S, those of the Pungue, Revue, Buzi, Gorongose, Save, Limpopo, Incomati, Umbeluzi and Maputo Rivers. Not all streams are perennial, indeed most are reduced to a series of isolated pools by the end of the dry season, especially since impoundments have been made in their upper courses. Most rise in other countries, and many are dammed before they reach Mozambique, e.g. the Save, Limpopo, Incomati, and Maputo Rivers.

Climate

For most of the year the weather is dominated by the high pressure system which prevails over the southern African Plateau, but NE and SE air streams from the Indian Ocean

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bring rain during the months of October-March. Despite its proximity to the sea, and the warm southward flowing Mozambique Current, much of the country is surprisingly dry. Rainfall is erratic and unreliable, with substantial annual variations, especially in southern and central districts.

The southern lowlands are hot and dry. Rainfall is highest on the coast, from where it decreases rapidly on passing inland, but rises again on the slopes of the mountains along the western borders. Mean annual rainfall is 750 mm at Maputo (25°58'S/32°35'E), but only 550 mm at Massingir (23°51'S/31°58'E), while over much of the southern interior between the Save and Limpopo Rivers it is below 400 mm.

The entire coastline receives 800-900 mm of rain a year, with four more humid pockets on SW-NE stretches of coast, where the SE Trades blow perpendicular to the coast in summer. Elsewhere the prevailing winds are oblique to the coast. The humid pockets are situated to the east of Xai-Xai (25°03'S/33°48'E)), between the Tropic of Capricorn and Vilanculos (22°01'S/35°19'E), from Beira (19°49'S/34°52'E) to the southern part of the Zambezi Delta, and from the vicinity of Quelimane (17°53'S/36°51'E) to Pebane (17°14'S/38°10'E). In the first two areas mean annual rainfall is 1000-1200 mm, while in the second two it is 1200-1400 mm.

The north of the country is generally more humid than the south except for part of the lower Zambezi Valley in Tete Province, which receives less than 600 mm/yr. There are a series of very humid pockets along the western border on the upper slopes of the mountains between Mt. Binga and Mt. Inyangani (18°18'S/32°54'E in Zimbabwe). Between 1500-2000 mm of rain falls in these places in the short wet season, and the Pungue, Revue, Lucite and Buzi Rivers rise there, or close by in Zimbabwe. The upper courses of these streams are rocky, and full of cascades and cataracts. Rainfall also exceeds 1500 mm/yr on the isolated Gorongoza Massif (18°30'S/34°03'E), standing midway between the western highlands and Beira on the coast. All the higher mountainous areas north of the Zambezi are wet. Mean annual precipitation exceeds 2200 mm over a substantial area around the summit of Mt. Namuli, and a surrounding area of 36 000 km^2 receives between 1200-1800 mm/yr. In this region the Lurio, Meluli, Ligonha, Molócué, M'lela, Licungo (Lugela) and Luala Rivers have their sources.

Insolation is generally high, with mean annual receipts close to 160 000 cal/cm^2, and temperatures over 40°C are not uncommon in the southern lowlands and the Zambezi Valley. At Chókwé (24°32'S/33°00'E) some 100 km from the coast, temperatures range from a mean daily maximum of 32.5°C in January, and an absolute maximum of 44°C, to a mean monthly minimum of 11.2°C in July, with an absolute minimum of 3°C. Frosts are unknown in the lowlands, but may occur in the mountains. Mean annual class A pan evaporation is in excess of 2000 mm over most of the southern half of the country including the Zambezi Valley up to Lake Cahora Bassa. Humidity is high and fairly constant throughout the year with mean relative humidities near 70% in the south, rising to approach 100% locally for short periods after summer storms. Winds are light to moderate. Most stations in the southern lowlands record mean annual speeds of 6-8 km/hr, but high winds may accompany summer storms. Most of the country experiences at least 3000 hours of sunshine a year (8 hr/day).

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Wetlands

The most important wetland systems occur on the coastal plain. They comprise riverine floodplains with swamps and seasonal pans, and tidal (mangrove) forests at the coast. In addition there are some 400 coastal lagoons, over 1000 lakes, and numerous artificial impoundments, of which Lake Cahora Bassa, on the Zambezi, is by far the largest.

Wetland Flora

Tidal Forests: The richness of the flora of most mangrove forests tends to increase with the supply of freshwater (Mepham & Mepham, 1985); thus the tidal swamps in northern and central Mozambique have more diverse floras than those of the south. Along the northern sector of the coast the mangrove association is continuous with that in Tanzania. There is considerable variation in structure and floristic composition from swamp to swamp, depending upon local conditions, but generally *Sonneratia alba* is the seaward pioneer, providing a dense outer fringe up to 20 m in height. *Pemphis acidula* is a beach tree that thrives on old coral within reach of the waves, and often intrudes into the *Sonneratia* fringe if it is interrupted by a coral outcrop. The fringe is never extensive, giving way behind, to a broad *Rhizophora mucronata* zone which usually comprises the bulk of the forest. Here the trees may reach 30 m in height locally. *R. mucronata* is also the pioneer in the upper reaches of estuaries, at small river mouths, and wherever the influence of freshwater is felt, but this species prefers muddy to sandy soils. By contrast *Sonneratia alba* is more a tree of the open coasts and coral platforms. Both these species tend to occupy sites that are flooded deeply every day. Towards the back of the swamp, where tidal flooding is less deep and less frequent, *Rhizophora* is replaced by *Bruguiera gymnorrhiza*, with trees forming a canopy up to 25 m high. Frequently however, both *Rhizophora* and *Bruguiera* are of lesser stature because the forests are in a constant state of regeneration due to repeated felling. *Xylocarpus granatum* is a common associate of both *Rhizophora* and *Bruguiera*, occurring close to creek banks, and in muddy depressions in the *Bruguiera* zones. Patches of *Acrostichum aureum* occur wherever there is a gap in the canopy. Where the saline tidal forest has a transition with brackish water tidal forest, on estuaries and deltas, the *Bruguiera* forest may merge into a *Barringtonia racemosa-Heritiera littoralis* association. Many other arborescent species occur on the fringes of this association, in a transition to freshwater swamp forest, including *Ficus* sp., *Garcinia livingstonei* and *Voacanga thouarsii*.

In drier sites, thickets of *Ceriops tagal* occur to landward of the *Bruguiera* zone, especially on more saline soils, forming broad belts 100-200 metres wide. These may then give way to an *Avicennia marina* zone, often with an admixture of *Lumnitzera racemosa*, where trees are scattered in savanna fashion over a ground cover of herbs. These latter include *Chenolea diffusa, Salicornia pachystachya, Sarcocornia indica, Sesuvium portulacastrum* and *Suaeda monoica*. Grasses are often present including *Paspalum distichum* in wet saline sites, *Dactyloctenium geminatum* in wet but only brackish sites and *Sporobolus virginicus* on the dry fringes.

Often the typical sequence of seaward zones, *Rhizophora, Bruguiera* and *Ceriops*, is telescoped along creeks, where on the steeper slopes, narrower bands of the different species follow each other in quick succession in ascending from low water mark. These

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mixed riparian strips extend back as tall galleries along creeks, deep into the landward, less tall *Avicennia* zone. In northern Mozambique, in dry and steeply sloping sites, the junction with the non-tidal lowland vegetation may be abrupt, in a vegetationally complex landward fringe, but in some wet estuarine and bayhead sites, it may be gradual, with a transition from tidal to non-tidal swamp forest. Alternatively, in the most arid sites, which occur along the open coast, away from the influence of rivers, there are bare mud-flats, or saline herb fields between the mangrove trees which are then stunted. Common saltmarsh herbs here include species of *Salicornia, Sarcocornia, Sporobolus* and *Suaeda*.

Marine angiosperms grow to seaward of the mangroves all along the coast. There are 8 common species in Mozambique; *Cymodocea rotundata, C. serrulata, Halodule uninervis, Halophila ovalis, Thalassia hemprichii, Thalassodendron ciliatum, Syringodium isoetifolium* and *Zostera capensis*. Of these only *Halodule uninervis* penetrates into the muddy brackish water channels between mangroves, where it tolerates salinities as low as 10‰. *Halophila ovalis* and *Zostera capensis* grow up the shore to the low water mark of neap tides, to seaward of the mangroves, and are thus exposed by low spring tides. *Cymodocea* spp. generally occupy a deeper zone and are rarely fully exposed at low tide, although they may float at the surface in just a few centimetres of water. They too occur on sandy/muddy substrates. *Thalassia hemprichii* grows in the shallow water of sheltered bays, on a variety of substrates and often precedes mangroves serally. It is frequently exposed at low tide. *Thalassodendron ciliatum* occurs in rock pools and on coral below low water mark of spring tides. *Syringodium* occupies a range of habitats; it may grow in clumps on mud-flats well above the level of low spring tides, but also on coral reefs at depths of several metres.

In the Zambezi Delta, and along the coasts on either side of it, the more accessible parts of the mangrove swamps have been heavily exploited for firewood. Some of the more remote parts still boast a *Rhizophora* canopy 25 m high, but the forest is mostly lower, c. 15 m. In several places tongues of moist riverine forest, subject to seasonal flooding, interdigitate with the tidal forests. Among other species these forested strips contain *Cordyla africana, Diospyros mespiliformis, D. usambarensis, Erythrophleum suaveolens, Hunteria zeylanica, Meinecylon sansiboricum, Pandanus livingstonianus* and *Schrebera trichoclada* with *Barringtonia racemosa, Bruguiera gymnorrhiza, Heritiera littoralis* and *Voacanga thouarsii* on their fringes, transitional to the mangroves.

On the muddy coasts between Beira and the Save River, along watercourses and in depressions on the landward fringes, the tidal forest grades into non-tidal swamp and riverine forests. Species which occur in the transitional swamps here include *Annona senegalensis, Aporrhiza nitida, Barringtonia racemosa, Casearia gladiiformis, Cassine aethiopica, Cordyla africana, Deinbollia xanthocarpa, Diospyros mespiliformis, Ehretia amoena, Ficus trichopoda, Heritiera littoralis, Phoenix reclinata, Strychnos spinosa, Vitex doniana* and *Voacanga thouarsii*. *Artabotrys monteiroae* and *Entada pursaetha* are woody climbers. Along the beach, where littoral vegetation abuts the mangrove, other trees may be common in the fringes of the tidal forests, and in this central region such species include *Brexia madagascariensis, Caesalpinia bonduc, Colubrina asiatica, Dodonaea viscosa, Eugenia capensis, Erythrina variegata, Hibiscus tiliaceus, Guettar-*

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da speciosa, Lumnitzera racemosa, Mimusops caffra, Sophora inhambanensis and *Thespesia populnea.*

Avicennia marina becomes progressively more important in the mangroves towards the south where it becomes the seaward pioneer. *Xylocarpus granatum* is uncommon south of the Save River, and *Sonneratia alba* drops out of the association in the vicinity of Inhambane. Beyond this, *Lumnitzera* and *Ceriops* are less abundant and reach their southern limits just across the South African border. This pattern of distribution probably has as much to do with the predominance of sandy rather than muddy shores in southern Mozambique, as with the increase in mean wind velocity and wave energy, and the progressive decline of winter temperatures in passing south. Tidal amplitude also decreases in passing south, falling to 2.8 m at Morrumbene and 2.4 m at Inhaca Island. The southern mangrove swamps tend to give way to grass, sedge and reed swamps at the heads of estuaries, and along drainage lines, in which places *Phragmites australis* is dominant. Often *Avicennia marina, Barringtonia racemosa, Bruguiera gymnorrhiza, Lumnitzera racemosa* and *Syzygium cordatum* grow in clumps among the reeds, with *Erythrina lysistemon* and *Phoenix reclinata* on the fringes. Accounts of the ecology of the tidal forests at Morrumbene and at Inhaca Island have been given by Day (1974) and Macnae & Kalk (1969) respectively.

Mixed Freshwater Swamp Forest: A characteristic swamp forest association occurs throughout the lowlands of Mozambique, bordering mangroves and fringing rivers, lakes and lagoons. This generally comprises all or some of *Barringtonia racemosa, Ficus verruculosa, F. trichopoda, Hibiscus diversifolius, Hibiscus tiliaceus, Phoenix reclinata, Rauvolffia caffra, Sapium ellipticum, Syzygium cordatum, S. guineense* and *Voacanga thouarsii*, with less commonly *Annona senegalensis, Aporrhiza nitida, Brexia madagascariensis, Cassine aethiopica, Cordyla africana, Croton steenkampianus, Deinbollia xanthocarpa, Diospyros mespiliformis* and the multi-stemmed liliaceous tree, *Dracaena reflexa*, which forms dense clumps up to 10 m high. In places on the coastal plain, *Syzygium cordatum* forms almost monospecific swamp groves. *Dalbergia armata* may climb in the fringe forest in the south, or it may grow as a small tree on the drier margins. *Artabotrys monteiroae* and *Entada pursaetha* are other woody climbers. True swamp forests along the upper courses of the Gorongose, Busi and Pungue Rivers contain some lowland species such as *Aporrhiza nitida, Annona senegalensis, Cordyla africana, Rauvolffia caffra, Sapium ellipticum*, and *Syzygium guineense*, but the figs, phoenix palms and voacangas are scarce, and other species such as *Raponea melanophloeos, Tarenna pavettoides* and a stilt rooted species of *Uapaca* appear.

Riverine Forest: Riverine fringe forests or fringe thickets contain species tolerant of regular seasonal inundation. In the south they typically include some or all of the following species; *Acacia forbesii, A. karroo, Azima tetracantha, Breonadia microcephala, Cassia abbreviata, Chaetacme aristata, Clerodendrum glabrum, Coffea racemosa, Ehretia amoena, Euclea natalensis, Excoecaria bussei, Ficus verruculosa, F. vogellii, Garcinia livingstonei, Grewia inaequilatera, Hymenocardia ulmoides, Kigelia africana, Kraussia floribunda, Lannea stuhlmannii, Maytenus senegalensis, Mimusops fruticosa, M. obovata, Pteleopsis myrtifolia, Rhus guentzi, Sideroxylon inerme, Spirostachys africana, Strychnos madagascariensis, S. spinosa, Tabernaemontana elegans, Terminalis prunioides, T. sambesiaca* and *Ziziphus mucronata*. Climbers

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or scandent shrubs which add to the diversity of this vegetation include *Acridocarpus natalitius, Artabotrys brachypetalus, Bauhinia tomentosa, Combretum holstii, C. paniculatum, Entada wahlbergii, Grewia caffra, Melodorum gracile* and *Salvadora persica.*

A rather different spectrum of species is found in the lowland riverine forests of the central region, especially towards the coast where it is humid and the alluvium is deep. The principal species are *Alchornea laxiflora, Annona senegalensis, Aporrhiza nitida, Blighia unijugata, Carpolobia conradsiana, Cassine aethiopica, Cleistanthus apetalus, C. schlecteri, Clerodendrum myricoides, Coffea racemosa, Craterispermum schweinfurthii, Deinbollia xanthocarpa, Diospyros mespiliformis, D. natalensis, D. usambarensis, Dodonaea viscosa, Ehretia amoena, Erythrophleum suaveolens, Ficus verruculata, Grewia microcarpa, Heinsia crinata, Holarrhena pubescens, Khaya nyasica, Kigelia africana, Lonchocarpus capassa, Macphersonia hildebrandtii, Maprounea africana, Markhamia acuminata, Mascarenhasia arborescens, Maytenus mossambicus, Memecylon sansibaricum, Millettia stuhlmannii, Neorosea jasminiflora, Pachystela breviceps, Pandanus livingstonianus, Phoenix reclinata, Phyllanthus reticulatus, Polysphaera lanceolata, Psychotria mahonii, Rauvolffia caffra, Rothmannia globosa, Scolopia stolzii, Strychnos henningsii, S. madagascariensis, S. spinosa, Tamarindus indica, Tarenna laurentii, Trichilia capitata, T. emetica, Vitex doniana* and *Voacanga schweinfurthii.* Climbers include *Artabotrys brachypetalus, A. monteiroae, Entada pursaetha, Grewia caffra* and *Melodorum gracile.* Rocky areas on the banks and in the rivers are dominated by *Oncoba spinosa.*

The vegetation of the Zambezi, as it flows through Tete Province, differs from that described above in containing certain floodplain trees and a different spectrum of riverine trees. Tete Province is dry, and the river and many of its tributaries support species which tolerate drier soils and less prolonged inundation than that along other watercourses. Many trees reach 30 m in height and common species are *Acacia albida, A. galpinii, A. kirkii, A. nigrescens, A. polyacantha, A. sieberana, Allophyllus africanus, Balanites maughamii, Bridelia cathartica, Canthium frangula, Combretum imberbe, Cordia goetzei, C. sinensis, Diospyros senensis, D. squarrosa, Dombeya kirkii, Garcinia livingstonei, Gardenia jovistonantis, G. resiniflua, Grewia flavescens, Mimusops zeyheri, Premna senensis, Schrebera trichoclada, Sterculia appendiculata, Tapura fischeri* and *Terminalia sambesiaca.* Climbers include *Acacia schweinfurthii, Bauhinia tomentosa, Combretum paniculatum,* while species associated with pan margins on the floodplain include *Combretum fragrans, Diospyros senensis, Holmskoldia tettensis, Maytenus senegalensis* and *Vernonia colorata. Adansonia digitata* may occur on the edges of the floodplain. The flora of the Zambezi Delta reveals a merging of that of the arid river valley in the Tete Basin with that of the more humid coastal rivers near Beira.

The floras of the northern rivers include most species found along the central rivers, but *Barringtonia racemosa, Phoenix reclinata* and *Voacanga thouarsii* are relatively more important than in the south, and the former is often found very far inland.

Some atypical streamsides occur in the interior and southern coastal regions. Any of the southern trees may be found along them, but they are very open and small trees or shrubs of *Bridelia cathartica, Croton steenkampianus, Oncoba spinosa* and *Salvadora angustifolia* are characteristic. Sandy river banks, levées, and perennial sand banks in the large

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river beds are occupied by *Annona senegalensis, Borassus aethiopum, Clausaena anisata, Grewia sulcata, Hugonia orientalis, Sesbania sesban, Lonchocarpus capassa* and *Terminalia sericea*. The Save and upper Limpopo Rivers are especially sandy and one species, *Newtonia hildebrandtii*, growing to 25 m in height, is virtually confined to sandy soils along the Save. Another species, *Guibortia conjugata*, is a rare tree south of the Save, and is also confined to sandy river terraces.

In central districts, from the Save to the Zambezi, streamside thickets subject to periodic inundation occur in the mountainous headwater zones along the Zimbabwean border. Here *Bequaertiodendron magalismontanum, Combretum erythrophyllum, C. padoides, Ekebergia capensis, Ensete ventricosum, Grewia gracillima, Maesa lanceolata, Rapanea melanophloeos, Syzygium guineense, Tricalysia capensis* and *Vernonia leucocalyx* are common, with an array of herbaceous associates entirely different from those found in their lowland counterparts.

Reed Swamps: In small systems the central zones are dominated by *Phragmites australis* and/or *Typha capensis*, or occasionally by clumps of *Cyperus papyrus*, any of which may reach 3.5 m in height. Often these tall reed swamps have an understorey of *Melanthera scandens* and *Polygonum salicifolium*, with *Melanthera* reaching 1.5 m above the water. Frequently *Mariscus congestus* occurs at the deep water fringes of a reed swamp. There are generally very few floating-leaved aquatics in the small lakes, particularly in the south, but *Nymphaea capensis* is widespread both in openings in the reed swamps and along channels, and *Utricularia stellaris* is probably the most common submerged species. Among free-floating aquatics, *Lemna minor* and *Spirodela polyrhiza* occur in most systems. In some shallow swamps, where water level fluctuates quite widely, *Echinochloa pyramidalis* may be dominant over large areas. In deep water, rooted-floating and free-floating species occur among the papyrus reed bases, chiefly *Nymphaea caerulea, N. capensis, N. lotus, Pistia stratiotes, Trapa natans* and *Vossia cuspidata*. *Lemna* and *Spirodela* spp. are widespread and *Eichhornia crassipes* occurs in some systems. Beneath open water *Ceratophyllum demersum, Najas* sp., *Potamogeton* spp., *Utricularia* spp. and *Vallisneria* sp. form beds.

Mixed Herb Swamps: In mixed herbaceous communities, such as often occur on the landward sides of reed swamps in the Mozambique lowlands, common species include the sedges *Cladium mariscus, Cyperus aequalis, C. isocladus, C. obtusiflorus* (syn. *C. compactus*), *Fuirena umbellata* and *F. stricta* together with *Blumea caffra, Erigeron canadensis, Ethulia conyzoides, Glinus oppositifolius, Ipomoea aquatica, Ludwigia stolanifera, Melanthera scandens, Phyla nodiflora, Polygonum salicifolium, Triumfetta pilosa, Veronica anagallis-aquatica* and the fern *Dryopteris gongylodes*. This latter species is often dominant over large areas. There may be two distinct communities in the herb swamp, with another set of species occupying the less permanently inundated fringes. Here other sedges are common, including *Fimbristylis ferruginea* and *Pycreus macranthus*, together with the low or trailing herbs *Commelina diffusa, Conyza ulmifolia, Helichrysum decorum, Hydrocotyle bonariensis, Lobelia senegalensis, Nidorella auriculata, Pentodon pentandet, Periglossum niossambicense, Torenia thouarsii* and *Xyris anceps*.

Grass Swamps: These frequently occur on the landward sides of herb/reed swamps, where the soil is waterlogged for much of the year but inundated only for short periods.

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In such sites *Dactyloctenium aegyptium, D. geminatum, Digitaria milanjiana* and *Eragrostis ciliaris* occur, with *Ischaemum arcuatum* in the wettest sites. Common associates include *Asystasia gangetica, Agathisanthemum (Oldenlandia) bojeri, Cassia mimosoides, Centella coriacea, Cryptolepis obtusa, Cyperus denudatus, Dicerocaryum zanguebarium, Helichrysum foetidum, Limeum viscosum, Lobelia senegalensis, Sonchus oleraceus*, and the climbers *Coccinia rehmannii* and *Smilax kraussiana*. *Andropogon eucomis, Imperata cylindrica, Rhynchelytrum repens, Panicum laevifolium, P. meyerianum* and *Urochloa stolonifera* occur on higher sites. *Imperata* is widely used as a thatching grass and local people often burn the swamp margins to encourage its growth, since it is rhizomatous and highly fire resistant.

Wetland Fauna

Fish: The estuaries are rich in marine species. *Anguilla bengalensis, A. bicolor, A. marmorata, A. mossambica* (Anguillidae); *Alestes imberi, A. lateralis, Hydrocynus vittatus, Micralestes acutidens* (Characidae); *Oreochromis mortimeri, Pseudocrenilabrus philander, Serranochromis carlottae, S. codringtonii, Tilapia rendalli* (Cichlidae); *Clarias gariepinus, Heterobranchus longifilis* (Clariidae); *Limnothrissa miodon* (Clupeidae); *Barbus fasciolatus, B. lineomaculatus, B. marequensis, B. unitaeniatus, Labeo altivelis, L. congero, L. cylindricus, L. molybdinus* (Cyprinidae); *Aplocheilichthys johnstoni, A. kattangae* (Cyprinodontidae); *Distichodus mossambicus, D. schenga* (Distichodontidae); *Malapterurus electricus* (Malapteruridae); *Eutropius depressirostris* (Mochokidae); and *Synodontis nebulosus, S. zambezensis* (Schilbeidae) are present in the Zambezi and in Cahora Bassa Reservoir. Species of *Glossogobius, Marcusenius* and *Mormyrops* are also important in all the rivers. *Carcharhinus leucas, Megalops cyprinoides* and *Pristis microdon* are present in most large rivers, penetrating the Limpopo as far as Zimbabwe and the Zambezi to Cahora Bassa. *Protopterus annectens* is widespread in seasonally flooded areas as well as some permanent swamps.

Amphibians: These include *Afrixalus fornasinii, Hemisus marmoratum, Hyperolius* spp., *Phrynomerus bifasciata, Pyxicephalus* spp., and *Xenopus* spp.

Reptiles: Snakes are quite common in the swamps and floodplains and include *Crotaphopeltis hotamboeia* (mainly S), *Lycodonomorphus mlanjensis* (Shire Valley), *L. rufulus, L. whytei, Naja melanoleuca, N. mossambica, Natriciteres olivacea, Philothamnus hoplogaster, P. natalensis, Psammophis sibilans* and *Python sebae*. *Atheris superciliaris* occurs in the north and in the Shire Valley and *Pelamis platurus* has been found stranded in tidal pools along the coast, suggesting that it may visit mangroves at high tide. *Dendroaspis angusticeps, Dasypeltis scabra, Thelotornis capensis* (S only, also mangroves) and *T. kirtlandii* (N only) are found in swamp and riverine forest. *Varanus niloticus* is present in most systems, while *Crocodylus niloticus* is widespread. *Pelusios castaneus, P. rhodesianus, P. sinuatus* and *P. subrufa* are present in many lakes and muddy pans. *Kinixys belliana* and *K. natalensis* occur in the coastal lowlands, often associated with stream banks and wet woodland containing *Syzygium cordatum*, on the fruits of which they feed. *Caretta caretta, Chelonia mydas, Dermochelys coriacea, Eretmochelys imbricata* and *Lepidochelys olivacea* are present along the coast.

Birds: *Struthio camelus* is found on the floodplains of the central interior during the dry seasons. The numerous reed filled lakelets of the central and southern districts attract

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large numbers of weavers including *Amblyospiza albifrons, Anaplectes rubriceps, Hyphanturgus ocularis, H. olivaceiceps, Ploceus cucullatus, P. intermedius, P. subaureus, P. velatus, P. xanthops and P. xanthopterus*. Several bishops and widows also frequent the reed beds, e.g. *Euplectes ardens, E. axillaris, E. hordaceous* and *E. orix*. Other common species are *Acrocephalus arundinaceus, A. schoenobaenus, Bias musicus, Bradypterus baboecalus, Calidris ferruginea, Centropus cupreicaudus, C. superciliosus, Chlorophoneus sulphureopectus, Circaetus fasciolatus, Circus ranivorus, Cisticola erythrops, Estrilda astrild, Hagedashia hagedash, Lanorius ferrugineus, Lonchura fringilloides, Melittophagus bullockoides, Platysteira peltata, Quealea erythrops, Riparia cincta, Tringa nebularia* and *Uraeginthus angolensis*. *Grus carunculatus* is also found in reeds in central districts.

Birds frequenting the larger lakes and riversides include *Acrocephalus baeticatus, Actophilarnis africanus, Alcedo semitorquata, Anhinga rufa, Ardea cinerea, A. goliath, Ardeirallus sturmii, Ardeola rufiventris, Calamocichla gracilirostris, Charadrius hiaticula, Chlidonias leucoptera, Ciconia episcopus, C. nigra, Cisticola galactotes, Corythornis cristata, Ceryle rudis, Egretta ardesiaca, E. intermedia, Gallinula chloropus, Glareola pratincola, Grus carunculatus, Haliaeetus vocifer, Larus cirrocephalus, Limnocorax flavirostris, Megaceryle maxima, Merops rubicus, Microparra capensis, Motacilla aguimp, Mycteria ibis, Nycticorax nycticorax, Pandion haliaetus, Pelecanus onocrotalus, Phalacrocorax africanus, Plotalea alba, Pluvialis squatarola, Porphyrio alleni, Prinia subflava, Pterocles bicinctus, Rhynchops flavirostris, Riparia paludicola, Scotopelia peli, Tachybaptus ruficollis, Tringa hypaleucas, Xiphidiopterus albiceps* and *X. senegallus*. *Ardea purpurea, Ardeola rallaides* and *Casmerodius albus* are virtually confined to reed beds. The riparian forests and thickets support a different avifauna with such species as *Apalis melanocephala, Buccanodon leucotis, Camaroptera brachyura, Ceryle rudis, Erythrocercus livingstonei, Megaceryle maxima, Merops boehmi, M. superciliosus, Phylloscopus trochilus, Pirenestes minor, Platysteira peltata, Psalidoprogne holomelaena, Telophorus quadricolor, Terpsiphone viridis* and several parrots. *Sheppardia gunningi* is a species uncommon south of the Zambezi.

Birds common along highland streams on the Zimbabwean border include *Chloropeta natalensis, Cossypha heuglini* and *Prynoprogne fuligula* in thick riverine bush, with *Euplectes capensis* over swampy streams.

Mammals: Several rodents are common in the wetlands including *Aethomys chrysophilus, Lemniscomys griselda, Otomys angoniensis, Pelomys fallax, Praomys natalensis, Saccostomus campestris* and *Thrynomys swinderianus*. *Pedetes capensis* is also common in these areas, feeding on the underground portions of the grasses of the wetland fringe. *Dasymys incomtus* and *Otomys irroratus*, common in reed beds elsewhere in southern Africa, appear to be rather scarce in Mozambique. *Tatera inclusa* is confined to the lower Pungue/Urema/Zangue system, while *Thamnomys dolichurus* occurs in riverine forests from the Limpopo to the Shire. *Heliochrysum rufobrachium* and *Paraxerus cepapi* are found in the canopy of swamp and seasonally inundated forests. *Anomalurus derbianus* occurs in thicket and forest along the northern rivers. *Cercopithecus albogularis* frequents riverine trees throughout the country and populations have increased in wetlands in recent years, particularly in the protected part of the Zambezi Delta, in parallel with its principal predator, *Panthera pardus*.

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Aonyx capensis, Atilax paludinosus and *Lutra maculicollis* are common at watersides throughout most of the country, while *Felis caracal* and *Genetta massambica* are other small species found in reed swamps. Among large mammals, *Dugong dugon* occurs in the lower reaches of most, if not all rivers. Erskine observed them at the confluence of the Limpopo and Elefantes Rivers in 1869, but it is doubtful if they penetrate this far inland nowadays. Many savanna species visit the floodplains and riversides in the dry seasons. Among large species found in these sites *Aepyceros melampus, Alcelaphus lichtensteini, Canis adustus, C. mesomelas, Cephalophus monticola, C. natalensis, Connochaetes taurinus, Diceros bicornis, Equus burchelli, Hippotragus niger, Hyaena brunnea, Kobus ellipsiprymnus, Phacochoerus aethiopicus, Potamochoerus porcus, Redunca arundinum, Sylvicapra grimmia, Taurotragus oryx, Tragelaphus angasi* and *T. strepticeros* are the most important, but are seldom encountered in anything but small numbers. However, the central southern area contains the largest populations of *Acinonyx jubatus* and *Loxodonta africana* in Mozambique, and the only populations of *Damaliscus lunatus, Giraffa camelopardalis* and *Hippotragus equinus*. The density of all these species is generally higher in the valleys of large rivers, especially the Save.

List of Wetlands Described

1. Tidal (Mangrove) Swamps
2. Coastal Lakes & Lagoonal Systems
3. Riverine Swamps & Floodplains
   (a) Rivers of Maputaland
   (b) The Limpopo System
   (c) The Inharrime River & Drainage of Interior Inhambane
   (d) The Save, Gorongose, Buzi & Pungue Rivers
   (e) The Lower Zambezi River
   (f) Rivers of Zambezia Province
   (g) Rivers of the NE Coast
4. Lake Cahora Bassa
5. Interior Lakes
   (a) Lake Malawi
   (b) Lake Amaramba
   (c) Lake Chiuta
   (d) Lake Chilwa

1. Tidal (Mangrove) Swamps

General: Mangrove stands occur at all river mouths in Mozambique, and in many sheltered bays and lagoons. In parts of the northern and central districts mangroves are continuous along the open coastline, but they become less common in the south. Estimates of the total area occupied by tidal forests vary between 85 000 -100 000 ha but are probably conservative. Current information is difficult to obtain due to the

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unsettled situation in the country, which precludes internal travel in many areas. Descriptions of individual sites are inappropriate since they are so numerous.

Over the northern coastal sector, which runs almost due N-S between the Tanzanian border and the town of Mossuril, the highlands approach locally, to within 5 km of the coast. This is highly indented, of high relief in places, and protected by numerous offshore islands and coral reefs. There are several large sheltered bays, including, from north to south, the Bays of Tunghi, Montepuezi, Pemba, Memba, Fernao Veloso and Porto Mocambo. In addition other small bays and most river mouths are sheltered by sandy spits on their southern sides. No fewer than 10 major streams and innumerable minor ones reach the coast in this sector, but because the coastal plain is narrow the rivers are not tidal for any great distance, and tidal forests are in consequence confined to the vicinities of their mouths and to the shores of bays. While mangrove forests are floristically well developed in the region, they are seldom very extensive between their landward and seaward faces, but for long distances mangrove swamps are semi-continuous along the coast.

Although reef-building corals extend the full length of the Mozambican coast, they are less well developed south of Mossuril (14°55'S/40°41'E) in Zambezia Province and afford little protection to the shores. However, between Mossuril and the Zambezi, the coastline comprises many small deltas interspersed by sandy strips. Wave attack is perpendicular to the shore and longshore currents are insignificant. A dozen major streams reach the coast here, including the Meluli, Ligonha, Molucue, Licungo and Luala. This section of the coast becomes muddier towards the SW and sandier towards the NE. Tidal forests are present despite the lack of offshore reefs. No doubt the mangroves thrive because of the bountiful alluvium while the corals are absent because of it. Mangroves are especially well developed near Angoche (16°10'S/39°58'E) on the Meluli Delta, and again near Moma (16°46'S/39°10'E) at the mouth of the Ligonha. Then again near Nova Naburi (16°47'S/38°52'E) at the mouth of the Molucue River, near Moebase (17°04'S/38°41'E) at the mouth of the M'lela (17°08'S/38°34'E), at the mouth of the Raraga River (17°24'S/37°45'E), and at Quelimane (17°53'S/36°57'E) on the Luala Estuary. All these rivers cross the northern end of the eastern coastal plain to reach the sea. Thus their final gradients are low and they are tidal for many kilometres upstream. Mangroves are continuous along the open coast in places; elsewhere they occur immediately behind low coastal dunes. The tidal river channels are flanked by riparian forests which, at least during the wet seasons, grade from salt water tidal to freshwater tidal. Mangroves spread laterally along tributaries which enter the main streams parallel to the coast, a situation best seen at the Raraga Mouth, where 11 major streams enter the river between parallel lines of stranded dunes. A continuous belt of permanent swamp forest, over 100 km long and 10-20 km wide, extends from a point on the Macuse River (17°40'S/37°03'E) to a point on a tributary of the Raraga River (17°16'S/37°53'E).

The Zambezi discharges via distributaries, obstructed by numerous sand bars, through a wide swampy delta. Mangrove swamps are extensive in the lower delta, but they do not extend up the main channels for more than 15 km, although the tide penetrates much farther than this. The steepness and depth of the banks in the delta reduces flooding, an

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effect specially marked now that flood releases are controlled from the impoundments of Kariba and Cahora Bassa.

South of the Zambezi, the alluvium from no less than 18 rivers has produced a continuously deltaic coast as far as Beira (19°49'S/34°52'E), and mangroves here occur on the open sea coast. They are also present in depressions behind frontal sand dunes, and along the numerous channels which in a series of shallow loops give the coast a scalloped appearance. Mangroves are also prolific south of Beira, for a distance of some 160 km, on a stretch of muddy, highly indented, and island dotted coast. This is fed with alluvium and freshwater by six major rivers including the Pungue, Buzi, Gorongose and Save, which drain the central western highlands. At the mouth of the Pungue River, at Beira, a vast swamp some 50 km deep and 27 km long, reaches inland from the south bank of the river, grading from saline to brackish, while the swamp on the north bank is smaller and has suffered considerable depradation being close to the Port of Beira. Coastal swamps are more or less continuous from the Pungue to the Save. They are extensive at the mouth of the Buzi River, and there is a particularly fine stand at Novo Sofala Bay (20°10'S/34°40'E). They continue down the coast, in a belt traversed by a dozen small streams, to the delta of the Save River. In this sector swamps reach inland for 5-15 km. There are several large and many small offshore islands, all of which support some mangroves. The delta of the Save is covered by mangroves, and tides penetrate far upstream. Swamps and lagoons fringe the lowest 40-50 km of the river. The largest lagoon, Lagoa Zinhave (33°55'E), is 2.5 km long, 1 km wide, and 27 km from the coast in a straight line. Its peripheral vegetation includes common tidal trees such as *Avicennia marina* and *Hibiscus tiliaceus*. Several dozen little tributaries, 3-30 km long, drain the surrounding swampy lands and enter the Save over its lower 40 km. This extremely swampy section of the coast ends at Macavane (21°28'S/35°04'E) where the Govuro River enters the head of a bay behind the spectacular spit of Bartolomeu Dias. This river is entirely coastal and flows parallel to the coast from S-N. It is dry in winter, but has a catchment of 11 200 km^2, over which mean annual rainfall is between 80-1000 mm. The landward side of Bartolomeu Dias Bay is deeply dissected, deltaic, and covered with tidal forests, for 9 little streams enter the bayside here, but the great spit itself is sandy with only a few mangroves. From a floristic point of view the tidal forests between Beira and Macovane are the richest in Mozambique, and are probably among the richest on the entire East African seaboard. Wave action in this region is gentle but tidal amplitude is large, being 5.6 m at Beira, ensuring that flood waters extend a long way inland.

By contrast, no major rivers occur along the succeeding strip of coast between Bartolomeu Dias and Inhambane, and the lack of silt and freshwater is reflected by the scarcity of tidal forests here. Moreover in this section the coast is strongly influenced by the Agulhas (Mozambique) Current flowing southwards at the edge of the continental shelf. This warm stream lies progressively closer to the coast as it flows south, being scarcely 5 km offshore at the border with South Africa. The current flows most strongly in the immediate vicinity of, and parallel to, its boundary convergence with the continental shelf and the cooler inshore water. When NE winds are behind it, it reaches velocities of 5 knots (2.5 m/sec). Eddies, generated at the boundary with the water over the continental shelf, cause tongues of warm surface water to circle landwards where they are deflected up the coast to the north. In consequence inshore waters are maintained at

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temperatures exceeding 21°C as far south as Port Elizabeth (33°58'S/25°36'E) in South Africa, thus extending conditions suitable for mangrove development to far higher latitudes than on the west coast of Africa. Since the prevailing wave attack on the beaches of this section is from the SE, and thus oblique to the shore, northward longshore currents develop, and these in concert with the eddies developed by the Agulhas Current, ensure that vast quantities of sand are driven northward along the beaches between Inhambane and the Zambezi. The many northward pointing sandspits, each of which shelters a quiet mangrove clad bay, bear testimony to this.

The best examples of sandspits are at Bartolomeu Dias (21°10'S/35°09'E), Cabo São Sebastião (22°08'S/35°33'E), Inhambane (23°51'S/35°29'E) and Inhaca (26°01'S/32°58'E). The spit of São Sebastião, south of Vilanculos, is 15 km wide and 45 km long. It protects a bay 8 km wide and 30 km long which is almost fully occluded by tidal forest. At a conservative estimate the mangrove stand exceeds 20 000 ha. Further south in the little Bay of Pomene, protected by the Punta da Barra Falsa (22°53'S/35°34'E), there is a mangrove swamp in the estuary of a coastal stream, the Rio Murri, and a thin and discontinuous fringe of mangroves extending north for some 30 km towards Vilanculos along open sandy coast.

In passing south from the Bay of Pomene, some coastal dunes rise to heights of 191 m asl, but are breached in places by seasonal coastal streams, e.g. the Rio das Pedras. Tidal forests are absent from the long stretches of sand beach between bays on this coast. The next important mangrove swamp is in the upper reaches of the estuary at Morrumbene (23°41'S/35°25'E), a northern inlet of the Bay of Inhambane. Channels up to 2.5 km wide are fully occluded by arborescent vegetation here, with reed swamps up-channel behind the mangroves, and sea grass beds down-channel in front of them where the estuary is flanked by sand banks. In the much larger southern part of Inhambane Bay mangroves are less well developed and shores are much sandier.

From Inhambane the coast veers southwestwards to the Limpopo River mouth, again perpendicular to the wave attack, along the comparatively wet northern shore of the Bay of Maputo. This is another sandy sector where the coastal dunes average 75 m in height, with a few rising to 120 m. Lines of stranded dunes, parallel to the shore, extend inland for many kilometres, and their swales provide a very swampy and lagoon ridden hinterland, but the coast is almost devoid of mangroves. These occur only in a few lagoons which open to the sea, e.g. Lagoa Mabembue (24°52'S/34°26'E), and inside the mouths of the Limpopo and Incomati Rivers. By contrast they are well developed along the southern shore of Maputo Bay which is sheltered and locally muddy, especially at the mouth of the Maputo River. Mangroves occur on the open shore to the east of this river, where diffuse drainage from the North Mosi Swamp reaches the bay, and also on the sheltered shores of Inhaca Island nearby.

Flora & Fauna: The flora is discussed in the introduction. The tropical tidal soils on which mangroves develop in Mozambique are very rich in invertebrate life. Day (1974) records 404 invertebrate species in the Morrumbene Estuary, including 72 species of polychaete worms, 51 bivalves, 63 gastropods and 67 crabs, in or on the mud. The invertebrate fauna of forested tidal swamps is characteristic and does not vary greatly from site to site along the coast, although few species are absolutely restricted to sites with arborescent vegetation. Many also occur in adjacent saltmarshes and some are

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common to sandy and even rocky shores. However, the community *per se* is restricted to mangrove swamps. Common species are *Alpheus crassimanus, Upogebia africana,* and *Saccostrea cucullata* which attaches itself to the trunks, stilt roots and pneumatophores of the seaward mangroves. *Balanus amphitrite, Cerithidia decollata* and *Littorina scabra* also occur on the mangrove trunks. Among the crabs present, species of *Uca* dominate the sandy fringes, while species of *Sesarma* occur under the tree canopy and in any saltmarsh vegetation, with *Scylla serrata* in the mud at lower levels. Mangrove estuaries are highly productive and provide nurseries for large numbers of paeneid prawns including *Metapaeneus monoceros, Penaeopsis hilarulus, Paeneus canaliculatus, P. indicus, P. monodon* and *P. semisulcatus.* The nests of red weaver ants, *Oecophylla smaragdina,* are common in the trees.

Day (1974) recorded 114 species of fish in the Morrumbene Estuary. Apart from the marine species which visit mangroves at high tide, there are resident fish which spend their lives in the mangrove channels and tolerate fresh to brackish water. Some of these are typical river fish at the lower limits of their distribution, and others are marine species which penetrate freshwater. Among the resident species in southern and central Mozambican mangroves the following are common; *Ambassis safgha, Anguilla bicolor, A. mossambica, Belonichthys fluviatilis, Clarias gariepinus, Ctenopoma ctenotis, Eleotris melanosoma, Gilchristella aestuarius, Gobius nebulosus, Kuhlia rupestris, Oreochromis placidus, Periophthalmus kalolo, Platygobius* sp., *Syngnathoides biaculeatus, Therapon jarbua* and *Tilapia sparrmanii.*

Crocodilus niloticus frequents the freshwater reaches of mangrove estuaries, as does *Varanus niloticus.* Several snakes have been recorded in tidal forests, including arboreal species, as indicated in the introduction. *Caretta caretta* and *Dermochelys coriacea* visit the sandier parts of mangrove estuaries.

A variety of birds utilise the mud and sand flats, others the tree canopy, others the channels and pools. *Halcyon senegaloides* is virtually confined to the habitat. Other common kingfishers include *Alcedo semitorquata, Ceryle rudis, Corythornis cristata, Halcyon albiventris, H. senegalensis* and *Megaceryle maxima.* Birds common in the canopy are *Merops superciliosus* and *Zosterops senegalensis. Apalis ruddi* occurs between Inhaca and Inhambane, while the range of *A. flavida* extends north of the Zambezi. Around pools and channels, *Ardea cinerea, A. goliath, A. purpurea, Bubulcus ibis, Butorides striatus, Egretta garzetta, Haliaeetus vocifer, Nycticorax nycticorax, Pandion haliaetus, Scopus umbretta* and *Scotopelia peli* are found, while *Actitis hypoleucos, Calidris minuta, Calidris testacea, Charadrius hiaticula, C. marginatus, C. pecuarius, Corvus albus, Dromas ardeola, Pelecanus rufescens, Phalacrocorax carbo, P. africanus, Pluvialis squatarola, Tringa nebularia* and *Xenus cinereus* frequent the open flats. Weavers, as listed in the introduction, inhabit the associated reed swamps and *Phoenix* palms, together with *Estrilda astrild, Lonchura cucullata, Quelea erythrops* and *Vidua macroura.*

Mammals found in tidal swamps include *Atilax paludinosus, Cephalophus monticola, C. natalensis, Cercopithecus albogularis, C. pygerythrus, Dugong dugon, Felis serval, Hippopotamus amphibius, Potamochoerus porcus, Paracynictus selousi, Redunca arundinum* and *Sylvicapra grimmia.* Dolphins also come far up some of the estuaries into mangrove lined channels.

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Human Impact & Utilisation: The northern forests have in general been more intensively exploited than those of the south. This is a direct reflection of local population density. *Rhizophora mucronata* is widely utilised for firewood and charcoal, the younger parts of the forests having been cut for this purpose from time immemorial by indigenous people. Mangrove timber has also been utilised locally for building purposes. In the northern sector, Arabs have obtained mangrove timber, chiefly *Heritiera* and *Rhizophora* poles. Although the bulk of the Arab trade on this coast was with Kenya and Tanzania, some was with Beira. Larger bivalves and worms are dug from the mud-flats for food and bait, and gastropods are collected from the mud surface. The mangrove channels are invariably fished and permanent fish traps are a feature of many mangrove swamps. All mangrove stands reveal some degree of disturbance, but this is most pronounced near ports.

Conservation Status: Small areas of tidal forest and associated reed swamps are included in the Reserva Especial do Maputo, on the southern shore of the Bay of Maputo, and others are protected in the Reserva do Pomene at Punta da Barra Falsa. Yet others are situated in the Zambezi Wildlife Utilisation Area on the southern side of the Zambezi Delta. Of these sites, the last is by far the most important as it protects large stands of high closed canopy tidal forest and adjacent freshwater swamp forest, both on the open sea coast and on distributaries of the Zambezi. It has been proposed that Inhaca Island be designated a Nature Reserve, which would protect further, and different, tidal communities.

2. Coastal Lakes & Lagoonal Systems

General: In consequence of the sandy lowland nature of the coast of southern Mozambique, and peculiarities of the wind and wave attack, vast quantities of sand are swept alongshore from Maputaland to the Save River, and dunes back the beaches. The mouths of seasonal streams draining the hinterland are deflected alongshore so that they open to the sea via lagoons, many of which close during the dry season. Thus the coast is fringed by lagoons for long distances. Moreover, since changes in sea level have stranded old coastlines inland, dune systems and old beaches and lagoons occur in parallel with those at the coast, at only slightly greater elevations. Some of the stranded lagoons are now completely isolated, but others are linked by watercourses to the present coastal system. Swamps occur in the stranded dune swales, along watercourses and around the stranded lakes, and a brief description of these follows, working from south to north.

Several lakes occur in Maputaland, south of Inhaca Peninsula. The largest of these are Lake Saline (26°45'S/32°50'E) and Lake Piti (26°36'S/32°53'E), which have open water areas of 750 and 3250 ha respectively and are surrounded by swampy lands. There are many smaller lakes on the peninsula and a 20 000 ha block of swampy land penetrates 25 km inland from the coast, between Inhaca Peninsula and the Maputo River to the west. This swamp has a central drainage channel, the Rio Futi, which is not always clear, and which does not have a permanent connection either with Maputo Bay, or with the Maputo River, into both of which it may discharge in summer. Elevations in the swamp are as low as 2 m above mean sea level more than 15 km from the coast, and the central part becomes brackish during the winter. Tidal fluxes are apparent in the Rio Futi. The

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swamp includes many small open water lakes, and abuts the Saline and Piti lagoons. On the west bank of the Maputo River, close to the South African border, Lake Manjame (26°46'S/32°24'E) has 750 ha of open water and is also the centre of a swampy depresssion. There are a dozen small swampy lakes on Inhaca Island, the largest of which, Lake Hlangwini, covers some 195 ha, while the smallest are almost fully occluded by reeds.

Between the Incomati River and Inhambane the coast is almost continuously fringed by lagoons, the most extensive system on the coast being centred upon Poelela Lagoon (24°33'S/35°07'E) which itself has a mean open water surface of 9250 ha. This lake is situated on the 'corner' of the coast, south of Inhambane. It is closed from the sea, but drains southwestwards along the coast for a distance of 75 km through a further series of closed lagoons, to a mouth at Mabembue (24°52'S/34°26'E). In order, from Poelela, the successive lagoons are Maiene, Massava, Quissico (3250 ha), Inhagotau, Canda and Mabembue. There are extensive swamp and lake systems inland, to the north and west of Lake Poelela, and these eventually drain to it via the Inharrime River. The largest swamp, extending over some 72 000 ha is to the north, on the Plain of Inhassune, and during the summer water from this area collects in the Inhassune River and flows west and then south to join the Inharrime River which discharges to Poelela Lagoon. The Inharrime River also drains a swampland system to the west, and receives overspill from several lakes, among which Lake Marrangua (24°42'S/34°15'E; 5500 ha) is the largest. These lakes and swamps are situated in stranded beach syatems.

Lake Marrangua (24°43'S/34°15'E) is an endorheic lake with an open water surface of about 7500 ha, situated some 25 km inland, behind Canda Lagoon on the westward drainage of the Poelela system. It has a local catchment of 2283 km^2 and is a stranded lake that once had connection with the sea.

On the coast to the north of Poelela, the closed lagoon at Nhacoongo is 30 km long, and this is followed, in moving north, by the great sandspit of Inhambane. Dunes reach 75 m asl along the seaward side of this, while on the western side, close to the Bay of Inhambane, there are numerous lakes and swamps. A further cluster of coastal lakes occurs to the south of Vilanculos, and also on the sandy spit of São Sebastião. This is 15 km wide, 45 km long, and covered with swampy lakes which become more numerous towards the end of the spit. The largest lake measures 5.5 km long and 2.8 km wide, while the smallest is a mere pool. There are also coastal lakes on the islands of Santo Antonio, Santa Isabel, Bangué, Bazaruto and Benguma off the tip of Cabo São Sebastião.

Hydrology & Water Quality: Most lakes and poola are fed by small affluent streams but some small ones are only seasonal and dry up completely each year. Water quality varies widely in the permanent water bodies. Temperatures fluctuate more in small lakes than large lagoons, sometimes reaching 34°C in summer, while pH values of 4-7.5 have been obtained in different small lakes between Maputaland and Inhambane. Generally the lakes are not saline and lie on sandy beds with substantial organic deposits.

Flora & Fauna: Small lakes are often almost occluded by vegetation and many exhibit four distinct vegetational zones; a central reed swamp, dominated by *Phragmites* or papyrus, followed by a shallow open water zone, followed by a mixed herb-sedge swamp, with an outer grassy zone which is flooded only periodically. The vegetation of all zones varies depending upon the depth of the water and the degree of interference to

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which they are subject. Brief accounts of the principal species are given in the introduction.

Where lakes abut forested dunes, mixed swamp forest trees, as listed in the introduction, occur along steep lake margins. However, where more gently sloping grassy swamp margins rise to meet forest, the fringing trees or shrubs usually include *Albizzia gummifera, A. versicolor, Cassia mimosoides, Chrysanthemoides monilifera, Oncoba spinosa, Strychnos spinosa, Syzygium cordatum, Tabernaemontana elegans* and *Phoenix reclinata*, with festoons of *Cissampelos mucronata* and *Dioscorea sylvatica* growing over them.

Large lakes, subject to wind and wave action, have clear central open water areas, and are fringed by reed or papyrus swamp. Rooted, floating-leaved, and free-floating species occur in sheltered bays, and *Najas marina* occurs in many coastal lakes. Papyrus is more common in the swamps around large lakes than it is in small ones. Many of the herbs mentioned in the introduction grow in watercourses and in damp patches and shallows around the large lakes. *Syzygium cordatum* forms patches of almost pure swamp forest adjacent to some lakes in Maputaland, while elsewhere in the same district extensive patches of mixed swamp forest (described in the introduction) grow at lakeheads and along contiguous watercourses. Between Xai-Xai and Inhambane, *Acacia xanthophloea, Hibiscus diversifolius* and *Kraussia floribunda* are locally common in lacustrine swamp forest while *Terminalia sericea* is common on the landward sides of reed swamps. The more northerly lakes are often fringed by dense woody thickets, or patches of mixed hygrophilous forest, containing *Annona senegalensis, Cordyla africana, Ficus vogelii, Maytenus senegalensis, Peltophorum africanum, Sesbania sesban* and *Vernonia colorata*. Many of the riverine species mentioned in the introduction are also found on the margins of lakes.

Little is known of the invertebrate fauna of any of these very numerous lakes. However, Boltt (1975a) reports on the benthos of Poelela Lagoon, while Hill *et al.* (1975) report on its limnology. The fish fauna of the small lakes is also poorly known, but the larger ones, which are fairly intensively fished are better reported (Hill *et al.*, 1975). The small reed fringed or reed filled lakes abound with frogs and toads, and among reptiles there are snakes, terrapins, tortoises, crocodiles and monitors. Forest birds occur in the adjacent trees, but the reeds attract large numbers of weavers, bishops, widows, warblers and flycatchers. Most lake/swamp systems have resident populations of semi-aquatic mammals and bats roost in the fringing thickets. Reedbuck and duiker are common. *Hippopotamus amphibius* occurs in all large systems. Most savanna animals utilise these coastal lakes and swamps from time to time, tending to migrate towards them in the dry season when the inland pans and watercourses are dry. The species involved depend upon the situation of the lake concerned; elephants are frequently encountered in the wetlands of Maputaland. Details of the fauna are given in the introduction.

Human Impact & Utilisation: The coastal lakes have been heavily utilised for water for irrigation, and canals have been dug back from many small lakes so that marginal lands can be drained, irrigated and cultivated. Thus many lake margins have been cleared for shifting agriculture. Peripheral lands are often burnt to encourage the growth of *Imperata cylindrica* for thatching. All sizeable lakes are fished by the local population.

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Several large towns have grown up on the banks of the larger lagoons, e.g. Quissico and Nhacoongo on lagoons of the same name, and Inharrime on Poelela Lagoon. Local travel, from village to village, is accomplished by boat on many of the coastal lagoons of Inhambane Province.

Conservation Status: Some coastal lakes are protected in the Reserva Especial do Maputo, and some very small ones in the Bazaruto National Park and the Pomene Reserve. However, these represent less than 1% of the total area occupied by this kind of habitat in Mozambique. Further, the coastal lakes are quite diverse, and the spectrum of diversity is not fully reflected by those protected.

3. Riverine Swamps & Floodplains

General: Lack of space precludes the detailed description of individual riverine wetlands since they are so numerous. There are no huge seasonal grass covered floodplains in Mozambique, as there are in other countries, but the total area of riverine wetland is nevertheless very large. Mozambique is essentially a swampy country. Narrow floodplains and riparian swamps occur on almost every river in the lowlands. In places large areas of permanent swampland cover the lower coastal plain between rivers, and in addition to reed and papyrus swamps, there are extensive patches of riverine swamp forest. The comparatively arid southern interior regions are traversed by many seasonal drainage lines which are, over long distances, filled with marshy vegetation and little permanent lakes.

(A) RIVERS OF MAPUTALAND

General: The major rivers of Maputaland are the Maputo, with a catchment area of 29 800 km^2, flowing in from Natal in South Africa; the Umbeluzi with a catchment of 5622 km^2, flowing in from Swaziland; and the Incomati which drains some 45 875 km^2 and enters from South Africa. All these streams discharge into the Bay of Maputo close to the city of that name. Two minor streams, the Tembe and Matola rise entirely within Maputaland. The major streams are all impounded before they reach Mozambique and consequently the flows in their lower courses are controlled to greater or lesser extents. Nevertheless, the Maputo River has a floodplain with peripheral pans and lakes, and it flows through much swampy land, particularly along its east bank, for the full 100 km of its transit between the border and the sea.

The Umbeluzi floods in its lower reaches, but much of its floodplain has been drained and converted for irrigation agriculture. Swamps, grading into mangrove swamps, occur at the head of, and along, the small estuary which it shares with the Tembe River at the western extremity of the Bay of Maputo.

The Incomati is formed by the confluence of the Komati and Sabie Rivers at the town of Sabie (25°19'S/32°16'E), above which, in Mozambique, both tributary streams have narrow floodplains. Below Sabie the river flows north and east, again across a narrow floodplain, until it swings south and enters a great marshy area, which develops below the confluence of many streams, some 13 km north of Manhica (25°23'S/32°51'E). This region comprises lakes, notably Lake Chuali, and permanent swamps as well as seasonal floodplain areas. When all affluents are in spate, at least 25 000 ha are inundated. To the

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north of this swamp, between the courses of the River Maxim Chopes (a tributary) and the Limpopo, there is a further block of swampland which covers almost 50 000 ha, with maximum dimensions of 30x20 km.

(B) THE LIMPOPO SYSTEM

General: The Limpopo is the second largest river in Mozambique with a catchment of more than 390 000 km^2. It drains parts of Botswana, South Africa and Zimbabwe before reaching Mozambique. Even so, flows in it are extremely variable and it is often dry over long sections during the winter. It loses 185 m in altitude along the 561 km of its course through Mozambique, thus descending to the sea with a mean gradient of only 1:3030. Having entered Mozambique its upper course lies in a narrow and steep-sided valley, scarcely 7 km wide in places, until at Mepuze (23°08'S/32°15'E) the valley widens and the river flows over plateau country to its confluence with the Elefantes (Oliphants) River at Queguele (24°07'S/32°38'E). For some 150 km above the confluence a narrow tongue of higher land, carrying a plateau at an altitude close to 200 m, intrudes between the two rivers. The end of this is covered by hundreds of seasonal pans, extending over an area 75 km long and up to 15 km wide.

Also, prior to the confluence there are swamps along the Limpopo, in a belt 1-2 km wide, and in two strip-like depressions which are fossil courses of the river, lying parallel to it at distances of 5 and 15 km. These still collect water during the rains. Both depressions and the riverine floodplain extend for unbroken distances of 20-40 km, and in this region there are approximately 17 000 ha of semi-permanent swamps.

Below Queguele the Limpopo Floodplain, which is still comparatively narrow, continues until the river flow is checked by a barrage, the Barragem de Macarretane, just above Chókwé (24°31'S/33°00'E). Below this point flood waters are controlled to some extent, but the floodplain widens as the river approaches its confluence with the Changane near Chibuto (24°40'S/33°33'E). Thereafter it meanders over a broad swampy floodplain to the coast where it flows into a lagoon, 8 km long and 1.6 km wide, before breaching the scrub covered dunes in a channel some 200 m wide.

Old levées and river channels cover the entire lower floodplain, the abandoned channels frequently giving rise to stagnant lakes and ponds. These are especially common to the west of the river, reflecting the fact that the main stream has been shifting eastwards for the last several thousand years. To the east, surrounded by swampland and isolated from the river, is Lake Inhamisse, with an open water surface of 750 ha. Fossilised oyster beds, at comparatively shallow depths in parts of the lower floodplain, indicate that marine conditions prevailed in the region in Recent times. Drainage throughout this area is diffuse in the rainy season, but in the winter it is concentrated on the main river channel. The river is tidal for many kilometres and saline water penetrates well into the lower swamps when winter tides are high. In 1957 the swamps spread for at least 8 km on either side of the main channel, and the river was navigable for 57 km. Today there may be 40 000-60 000 ha of swamp and floodplain below Chókwé.

The Limpopo Floodplain is of Recent age, situated on a wider Pleistocene terrace, all incised into an ancient peneplain. The soils of the modern floodplain are well sorted and are mainly non-calcareous grey-brown eutric fluvisols, according to the FAO Soil Classification of 1974. Coarse material accumulates on the levées, and finer sediments

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are size graded away from the river channels, ranging from sandy loams through sandy clays to fine clays at the edges of the floodplains. In the upper reaches of the river there are some permanently swampy areas with heavy black clay soils hard against the peneplain and far away from the river. Throughout the floodplains the topsoils have pH values of 6.3-7.1, while the subsoils range from 6.9-7.6.

The largest and least disturbed wetland area in the Limpopo system however, occurs on the Changane and its tributaries. This river arises from several streams which have their origins on the borders of the Gonarhezou Game Reserve in SE Zimbabwe and in the swamps on the southern boundary of the Zinhave National Park. They form a great dendritic system anastomosing at a point (22°37'S/33°18'E) at the NE tip of the Banhine National Park. From here the Changane flows nearly due south, between two low plateau blocks, receiving more tributaries on its west bank. Discontinuous riverine swamps occur along all these streams, and the gently undulating areas they drain are covered by chains of lakes and swamps along seasonal or periodic watercourses leading to the streams. The lakes are usually a few hundred metres in diameter, but collectively they have a substantial area. However, between these seasonal watercourses, in isolated depressions, there are literally thousands of small endorheic lakes and swamps. Along the Changane itself, between 23°00'-23°27'S, swamps extend for some 21 km in a patch 2.5-5.5 km in width, covering a minimum of 7000 ha. To the south, the width of the swamps increases. They are particularly well developed up the Sangulane, a major west bank tributary. Above Chibuto the floodplains of the Changane and Limpopo become one. 75 000 ha must be a conservative estimate of the total area of flooplain, lake and swampland in the Changane catchment.

(C) THE INHARRIME RIVER & DRAINAGE OF INTERIOR INHAMBANE

General: The interior of Inhambane Province, south of latitude 22°S, has a diffuse drainage system. The area north of Funhalouro (23°05'S/34°23'E) is characterised by innumerable endorheic swamplets and seasonal pans, but in the south, in addition to many little endorheic systems, there are swampy seasonal drainage lines leading eventually to the Inharrime River System. From here drainage is to Poelela Lagoon and thereafter, at least theoretically, to the Indian Ocean. A conspicuous seasonal watercourse/swamp/lake system, about 1 km wide, runs approximately due south along longitude 34°24'E, from latitude 23°45'-23°59'S where it is lost in the great expanse of swampland surrounding Lake Nhangulaze (24°00'S/34°27'E). This lake has an open water surface of 1250 ha and is set in an area of unbroken swamps, which in total encompasses 60 000 ha and measures 43x18 km in maximum dimensions. These swamps drain into the lake which in turn discharges via a small stream to the Inhassune River after it leaves the swampy Plain of Inhassune. 65 km downstream it joins the Inharrime River which in total drains an estimated 11 850 km^2 of Inhambane Province.

(D) THE SAVE, GORONGOSE, BUZI AND PUNGUE RIVERS

General: All these rivers are very seasonal in their flow regimes. The Save River has a catchment of 92 100 km^2 and both it and its principal tributary, the Lundi, are impounded in Zimbabwe. Significantly less water flows down to the sea than did formerly. The river crosses the country from west to east, roughly separating the dry southern part of the

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country from the more humid north. For much of its 330 km course through Mozambique the river flows in a well incised bed some 1-2 km wide, but while in summer this may be brim full from bank to bank, its flow in winter is frequently confined to a central channel barely 45 cm deep and scarcely 50 m across. In winter the river bed is a shining expanse of sand banks, with only occasional rocky or sandy pools and pebble banks. However, water is never very far below the sandy bed, and a little digging with bare hands generally reaches the water table. In some parts a series of little muddy pools lies close under its banks, which may be quite steep. Among these, Lake Zinhave (33°55'E), some 2.5 km long and 1 km wide, is probably the largest. Few wetlands occur along the upper reaches of the Save, but narrow swamps occur on most of its tributaries, particularly those of its lower reaches, and between these watercourses the country is gently undulating with hundreds of small lakes and reed swamps. Sometimes these lakelets mark the meandering and indistinct line of what becomes a temporary watercourse after local rain. The land separating the Save River from the Repembe River (a tributary of the Gorongose) is dotted with such lakes and swamps. Some swamps on drainage lines occupy 5000 ha and one on the Repembe itself covers 50 000 ha and encompasses a 5000 ha lake. Elsewhere between these rivers numerous apparently endorheic swamp patches exceed 2500 ha and several lakes reach 1000 ha.

The Gorongose River drains 13 150 km^2 of lowland country. Its two headwater streams rise at elevations of 150 m, while its principal tributary, the Repembe, rises at about 220 m asl. The rivers meander a lot to the east of longitude 34°E, thereafter flowing through swampy lands for 100 km to the muddy coast south of Beira. Swamps occur on all tributaries, and on the Repembe, as mentioned in the preceding paragraph.

The Buzi River rises on Mt. Selinda (20°24'S/32°43'E) just inside Zimbabwe. It flows NE, picking up its major tributaries, the Lucite, which rises on Mt. Binga, and the Revue which rises on Mt. Nusa (18°45'S/32°00'E), before being impounded in Mozambique below the town of Manica (18°56'S/32°59'E). These upper catchments are all in very high (1500-2000 mm) rainfall zones, and while the upper courses of the Lucite and Revue are rocky with cascades, the rivers are fringed by upland hygrophilous forest, and there are numerous small lakes and reed fringed pools. In its middle course the tributaries of the Buzi, coming from the hills in the SW, are fringed by swamps 1-2 km wide at altitudes 130-190 m asl. In its lower reaches the Buzi drains much more swampy land, especially along its minor tributaries. It supports patches of riverine forest or riverine thicket forest where banks are high, but spreads over swampy floodplains from low banks elsewhere. In places, chains of shallow lagoons fringe the edges of the floodplain. They are filled each rainy season but isolated each winter, at which time the river may be reduced to a trickle and its tributaries to successions of swamps. Tall grasses then cover the floodplains, with clumps of trees, including *Borassus* palms, on the levées.

The Pungue River rises in a sponge on the western side of Mt. Inyangani, 2000 m asl in Zimbabwe, and then flows over waterfalls and cataracts and through gorges in a rapid descent to an altitude of 500 m. Thereafter it flows east, supporting riverine and hygrophilous forest on its banks, and then SE towards the coast at Beira, collecting numerous tributaries en route. The most important of these is the Urema. This develops from two headwater streams. One, the Nhandugue, rises in the highlands and comes down north of the Gorongosa Massif to join the Urema proper. This is a short stream,

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rising about 45 m asl on a shallow watershed which drains north to the Zambezi and south to the Pungue. The great arc of land 25 km wide and 325 km long, which extends from Beira up the Pungue/Urema Valley to the watershed, and then down the Zangue Valley to the Zambezi, never exceeds 50 m asl. It marks the former course of the Zambezi, which once reached the sea at Beira, and is still well watered and swampy. Here there are some 450 000 ha of wetland. The swamps along the lower reaches of the Pungue reach 15 km in width up to Vila Machado (19°18'S/34°11'E) from where the Pungue ascends into low hills, but below this there is a very large swamp at the confluence of the Pungue and Urema. Both above and below Vila Machado, the Pungue floods during the rainy season and has chains of lagoons along the edges of the flooded area. The river has distinct levées and in winter its bed may be sandy and dry containing mere streamlets of water. At such times the floodplains are covered with a mixture of grasses, 1-3 m tall where inundation is deep, but less than 1 m high on the margins.

(E) THE LOWER ZAMBEZI RIVER

General: The Zambezi enters Mozambique at Zumbo (15°36'S/30°30'E) where it immediately swells into the impoundment of Lake Cahora Bassa, dealt with in section 5.5.4a. It leaves the lake in a narrow gorge some 35 km long, then descends the Quebrabasa Rapids and flows southeastwards in a narrow valley along the floor of the Tete Basin. It receives tributaries flowing down from the rocky highlands of Zimbabwe in the south and from Zambia and Malawi in the north. The channel lies between escarpments as far as the town of Tete (16°09'S/33°35'E), where the valley floor begins to broaden and the river develops a narrow floodplain. There is a floodplain up to 5 km wide and about 40 km long on the south bank between Tambara (16°45'S/34°16'E) and Chiramba (16°55'S/34°39'E), and swamps around Lake Lifamba on the north bank opposite Tambara. For much of its course between Tete and its delta, the bed of the Zambezi is 1-5 km wide and is studded with islands in places. During the dry season the river flows in several deeply incised channels, but in summer the entire bed may be one swiftly moving current.

Perhaps the most important tributary of the Zambezi in its lower course is the Shire River, which drains Lake Malawi. The River Ruo, a tributary of the Shire, forms the border between Mozambique and Malawi up until the confluence of the two streams at Chirome (16°32'S/35°10'E) at the lower end of Elephant Marsh. Below this the course of the Shire marks the border and the whole Shire Valley is swampy. Ndinde Marsh, in Malawi, stretches down the Shire from Nsanje (17°55'S/35°16'E) to the southern tip of Malawi, and thereafter swamps extend downstream in Mozambique towards an extensive lake/swamp system just above the confluence of the Shire and Zambezi Rivers (17°42'S/35°20'E) near Mutarara. Two lakes, of which Lake Mimbingue (5x3 km) is the larger, are set in the swamps which cover more than 25 000 ha on the north bank of the Zambezi. Drainage from the lakes and western swamps is into the Zambezi via a short channel known as the Zhu-Zhu River, but the eastern swamps drain via the Shire River.

About 50 km downstream, the town of Caia (17°50'S/35°21'E) marks the point where once the Zambezi turned abruptly SE on its way to Beira. There is evidence to suggest that, since the beginning of the Quarternary, the principal sites of discharge of the Zambezi have migrated along the coast. During an exceptionally high flood in the early

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1950s, water from the Zambezi is reputed by local people to have reached the sea at Beira having followed the course of the old Pungue from Caia, but this seems unlikely, given that a watershed 50 m asl would have had to have been crossed. Here too, at Caia, on the north bank, the Cua-Cua rises, effectively the first distributary of the greater Zambezi Delta. It flows due east for 150 km to Quelimane, capturing several streams leaving the mountains en route, including the Luala. At times of high flood it carries water away from the Zambezi, suggesting that in future the main flow may eventually move to a mouth at Quelimane. During more recent very high floods in 1973, it was noticeable that excess water travelled via the Cua-Cua and not the Zangue. The Cua-Cua and all its tributaries inundate floodplains when in spate and flow through a great deal of swampy land. There are innumerable little lakes on small anastomosing streams in a generally swampy area north of the Cua-Cua, between it and a major tributary, the Lua-Lua. Lake Tanie (17°42'S/36°37'E), covering some 7500 ha, is set in another permanently swampy area.

Development has been quite intensive down the Zambezi Valley below Tete, and sections of the floodplain, e.g. between Caia and Quelimane, have been recovered for coconut plantations. Moreover, since the severe restrictions on the summer flows imposed by the huge dual impoundments of Kariba and Cahora Bassa, the Zambezi floods very little of the area that it once used to. At its mouth the Zambezi discharges by distributaries obstructed by numerous sand bars. In the past, after the rains, it used to inundate much of a wide swampy lower delta. This measures 40 km in length, 65 km in width along the seaward face, and covers a total of 130 000 ha. It includes much swampy floodplain and areas of mangrove forest. A deal of land, to both north and south, is also very swampy, and much is still forested.

(F) RIVERS OF ZAMBEZIA PROVINCE

General: The major perennial rivers of Zambezia Province, the Licungo (Lugela), Ranaga, M'lela, Molócuè, Ligonha and Meluli, in passing from SW-NE, are comparatively short streams. The largest, the Licungo has a catchment of 22 726 km^2 and is 336 km long, but the others are significantly smaller, the catchment sizes being 16 200 km^2 for the Ligonha and less than 10 000 km^2 for the others. They all flow from the humid highlands of Nampula, SE to the sea. The upper courses of these rivers are set in shallow boulder strewn valleys, with numerous small cataracts, and they descend steeply to the coastal plain, below the 100 m contour. This they traverse for distances of between 35-100 km. The Molócuè, for example, descends from its source at an average gradient of 1:125, but flattens to 1:1000 in its final 100 km transit of the coastal plain. Upstream these rivers support riverine forest and thicket forests, or patchy reed swamps, but on the plain they are flanked by extensive belts of swamp forest and herbaceous swamp, grading into tidal swamps towards the coast. Large areas of reed and swamp forest lie parallel the coast, behind a shallow dune system. Between them these rivers carry a lot of water during the rainy season. The Licungo has sources high on the slopes of Mt. Mulanje (3000 m) in Malawi (16°00'S/35°37'E), and on Mt. Namuli in the wettest part of Mozambique. Mean annual rainfall exceeds 2200 mm in both source regions. In proceeding northeastwards up the coast the succeeding rivers carry less water. Although

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the Ligonha is the second largest stream it drains a drier catchment and usually floods less than the other streams.

(b) RIVERS OF THE NE COAST

General: The most northerly and largest river on this coast, the Rovuma, has a catchment of 155 400 km^2 and is the third largest river in Mozambique. It forms the border between Mozambique and Tanzania for some 700 km, almost the entire length of the border. The river has sources in both countries on the mountains at the eastern edge of the Rift Valley and receives numerous important tributaries on both banks. Two thirds of the catchment (101 160 km^2) lie in Mozambique and one third (54 240 km^2) in Tanzania. It flows comparatively gently to the sea, descending the widely spaced contours through undulating country. In its middle course it loses 300 m in altitude between Mazoce (11°34'S/35°55'E) and Gomba (11°23'S/38°30'E) over a riverine course of about 350 km, therefore descending with a mean gradient of 1:1162. Below this it flattens to a mean gradient of 1:1515, finally traversing an ever widening, funnel shaped, coastal valley for 130 km in a remarkably straight line. Here the river floods seasonally, but almost exclusively on the Mozambican side. Swamps occur along the river in its lowest 40 km, becoming more frequent towards the mouth. The Nhica Swamp (10°37'S/40°16'E), occupying some 7500 ha, and over 15 km long, on the south bank, is among the largest. Others are the Quitemba Swamp (10°57'S/40°13'E) and, farther from the river, the Miula Swamp (11°10'S/40°16'E). The former covers 2500 ha and the latter about 7000 ha. A number of lakes occur on the floodplain along the south bank of the river, including seven sizeable ones. Of these, Lake Nangade (11°03'S/39°42'E) is the most important. It is 12 km long and covers 5700 ha.

All the rivers on the NE coast, the Rovuma, Messalo, Montepuez, Megaruma, Lurio, Mecubúri and Monapo, have very seasonal flows, and carry less alluvium and water to the coast than those which reach the sea in Zambezia Province. They all descend more regularly than the rivers of Zambezia, and most have narrow sections of riverine swamp along their middle courses and along their tributaries. The lower courses of some, e.g. the Montepuez, spread into long narrow lakes, immediately prior to the coast. Lake Biribizi, on the Montepuez River, is the best example. It is 30 km long, but its main section is 15x4 km.

Flora & Fauna: Freshwater swamp forest occurs along muddy river banks and in depressions on floodplains away from the rivers. Its principal species occur throughout Mozambique but the southern forests do contain different proportions of these, and often a different spectrum of secondary species from those of the north. Along great lengths of their courses in the lowlands the rivers support gallery forest or thicket subject to seasonal inundation.

A variety of other vegetational types occur on the floodplains of the southern rivers. On the landward side they are mostly fringed by woodlands which include fringe trees of *Acacia xanthophloea, Balanites pedicellaris, Ficus sycomorus* and *Trichelia emetica. Adansonia digitata* occurs on the edges of some floodplains of the upper Limpopo. Grasses prevail in sites which are regularly inundated and intensively grazed. Lawns of *Cynodon dactylon* predominate, but with *Imperata cylindrica* in higher drier sites, especially if they are regularly burnt. Around pans *Acacia xanthophloea, Peltophorum*

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africanum, *Maytenus senegalensis* and *Vernonia colorata* are common species. Permanently wet areas may be dominated by *Echinochloa pyramidalis*, often with some *Cyperus fastigiatus*, while the more deeply flooded sites are dominated by papyrus or reed swamp. Seasonal ponds tend to be dominated by *Potamogeton crispus* and *Najas pectinata*, while permanent ponds, if not reed filled, are covered by *Nymphaea* spp., and *Trapa bispinosa*. Very extensive reed or papyrus swamps occur on many systems near the confluences of streams, often occupying thousands, or even tens of thousands of hectares. However, in these, old river levées and sandy patches support woody thickets or forests.

The fauna of the rivers and their associated wetlands is described in the introduction. Since the prohibition of hunting in the Zambezi Wildlife Utilization Area, *Hippopotamus amphibius* has become almost prolific and inhabits all the swamps, including the mangroves. While crocodiles are still common, they are nowhere nearly as abundant as they were at the turn of the century, when on the Limpopo they reached plague proportions. Elephants are increasing in numbers, but where hunting pressure has been great they are often found sheltering in the deepest swamps.

Human Impact & Utilisation: Space precludes a detailed examination of human impact on all individual river systems, but the rivers chiefly affected are the Zambezi and those south of it. The northern streams have suffered less disturbance.

Before the Zambezi was dammed at Kariba a regular flood cycle was observed with peak flows of 6 000-28 000 m^3/sec in its lower course during February-March, falling to 400-1000 m^3/sec in October-November. The impoundment at Kariba reduced peak season flows immediately below the dam by as much as 24% in some years, but increased the dry season flows. However, the Kafue River, which enters below Kariba, is now doubly impounded, and the second Zambezi impoundment has been constructed at Cahora Bassa. The net effect of these interferences is that the flood regime on the lower Zambezi is now greatly reduced and extremely erratic. Moreover it is mostly out of season. There are now two and occasionally three flood discharges each year. This is largely due to the fact that although 90% of the input to Cahora Bassa is regulated (by the Kariba, Itezhitezhi and Kafue Gorge Dams), major problems in flood prediction still remain and there is constant fear that the dam may be overtopped.

The lower Zambezi does not have an extensive floodplain, but many people depended upon small floodplain areas and their associated pans for subsistence, and many of these no longer flood. Agricultural development, based on irrigation, has taken place locally along the lower reaches, and this is especially so along the Cua-Cua towards Quelimane. Among other crops, rice and coconuts are grown in areas once subject to flooding. The impoundments have also brought changes in the quality of the river water, and a comprehensive account of its altered chemistry at Cahora Bassa is given by Bernacsek & Lopes (1984b).

Impoundments also affect the total flows and annual flow patterns in the Revue/Buzi, Save, Limpopo, Incomati, Umbeluzi and Maputo Rivers. Irrigation projects necessarily deplete rivers of their water, and have a drying affect upon floodplains and riverine wetlands. Such projects have been established on the edges of the Elefantes Floodplain below the impoundment at Massingir, and on the fringes of the Limpopo Floodplain below the impoundment at Marracetane. Work on the irrigation of a further 20 000 ha

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along the Elefantes River just above its confluence with the Limpopo is currently in progress. Surveys of the magnitude of salt water intrusion up the Limpopo are also being undertaken with a view to the agricultural development of the lower floodplain of this river. The flow of the Limpopo is also affected by 12 impoundments on its tributaries in South Africa. Water is extracted from the Umbeluzi River in Swaziland, and small scale irrigation projects near Maputo were established many years ago. There are plans to expand the area under irrigation from the Umbeluzi. Conditions in the Incomati River are affected by the extraction of water from the Komati River in Swaziland, and the impoundment of the Olifants River in South Africa at Witklip. Flow in the Maputo River has been reduced by the extraction of water from the Usutu River for irrigation in Swaziland, and by the impoundment of the Pongolo River in South Africa. It is a fact that the status of most riverine wetlands in southern Mozambique has deteriorated as a result of upstream developments in the past 50 years.

Overgrazing and burning has been a problem in many areas, but among protected areas it has been especially bad in the Zambezi Wildlife Utilisation Area, where the new controlled flood regimes favour the spread of wildfire and the deeper encroachment of grazing and browsing animals into the swamps. Less than 4000 people live in the lower delta and less than 100 in the coastal belt of the Wildlife Utilisation Area. Nevertheless, intense hunting, much on a commercial basis for ivory and meat, caused prodigious slaughter of wildlife both in the delta and in the associated Gorongosa area. Elephants were totally eliminated from all open woodlands and small surviving herds were found to have taken refuge in the most inaccessible wetlands. Only 250 beasts remained in the delta area in 1968. Over 4000 crocodiles were killed each year between 1950 and 1965. Professional meat hunting was prohibited in 1960 and all hunting was outlawed in 1974, but subsequently, poaching has been a serious problem because it has not been possible to enforce the law. Recently, with the advent of Emofauna, the body charged with administering Mozambican National Parks and Game Reserves, and with educating local people in conservation matters, the problem is decreasing. A government cropping program was instituted in the Zambezi Wildlife Utilisation Area in 1981, but will not be employed in the National Parks.

Subsistence agriculture and fishing takes place along many rivers, where local residents cultivate little gardens on the floodplain during the dry season, and catch or trap fish from the river. They also rely on a number of local fruits (such as that of the *Borassus* palm) and eat waterlily roots collected from stagnant lagoons along the riversides, but they clear riverine thickets for their gardens, and burn the grass swamps regularly. Malaria and human bilharzia are rife in the riverine wetlands and onchocerciasis is common. Much of the central southern area is infested with tsetse fly.

Conservation Status: Comparatively little of the vast amount of riverine wetland is protected. The Maputo River constitutes the western boundary of the Reserva Especial do Maputo in the south, and here many thousand hectares of reed and papyrus swamp, floodplain and pan, have been protected since 1932. Some 125 km of the Changane River and its tributaries, with their associated strip wetlands, are protected in the Banhine National Park (established 1973), together with numerous endorheic reed swamps and some lakes and pans along seasonal watercourses. Almost 100 km of the south bank and bed of the Save River is protected where it forms the northern boundary of the Zinhave

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National Park (established 1973). Substantial areas of wetland; reed swamp, papyrus swamp, swamp forest, riverine thicket and forest, river bed and riverine lagoon system, are protected in the Gorongosa National Park (established 1960), the southern boundary of which is formed by a stretch of the Pungue River. The south bank of the Zambezi River in the delta, together with many small associated streams, amounting to almost 100 000 ha of floodplain and riverine wetland, are protected in the Zambezi Wildlife Utilisation Area. Part of the Molcu River and some small tributaries with riparian swamps, at an altitude of 150-220 m, are protected in the Gile Reserve (established 1960). On the northern border, many dambos, isolated swampy patches and strip drainages are protected in the Niassa Game Reserve (established 1960). It has been proposed that this entire area be included in the larger proposed Rovuma National Park, which will extend frontage along the south bank of the Rovuma River to a total distance of 210 km. Several of the parks and reserves mentioned above are very poorly explored. This is especially so for the Gile and Rovuma areas.

4. Lake Cahora Bassa

Location: 15°29'-16°00'S/30°28'-32°43'E
Area: c. 266 500 ha at present retention level
Altitude: 330.5 m asl at capacity
Nearest Towns: Zumbo (at W end lake); Tete (125 km SE)

General: Construction of the dam took place between 1966-1975. The lake has an extreme length of 246 km, an extreme width of 39.8 km, and a mean depth of 20.92 m at present maximum retention levels. At the planned maximum operating level of 330.5 m, mean depth will increase to 22.56 m and the lake surface will expand to over 280 000 ha. There are three satellite reservoirs on the south shore; at Zumbo (14.3 km^2), Mague (24.2 km^2) and Chicoa (12.1 km^2). Temperatures in the region are highest in October with a mean monthly figure of 31.1°C and maxima and minima of 38.8 and 21.5°C, while the coldest month is July with a mean figure of 22.4°C and maxima and minima of 30.0 and 13.0°C. Mean annual rainfall over the lake is 650 mm, virtually all of this falling between November-March.

Hydrology & Water Quality: The bulk of the water entering the dam comes from the Zambezi, but there are 20 north shore and 36 south shore affluent streams. The total north shore catchment amounts to 16 006 km^2 and none of the streams is perennial. The south shore catchment amounts to 40 966 km^2 and two rivers, the Hunyani (23 897 km^2) and Messenguezi (5556 km^2) are perennial. Hydroelectric power is presently generated by a station on the south shore, with a capacity of 2075 MW, but the planned second phase power station on the north shore, with a capacity of 1925 MW, has not yet been built. The maximum theoretical discharge capacity of the dam is presently 16 250 m^3/sec, but this will increase to 21 450 m^3/sec with the construction of the second hydroelectric plant. However, current discharge capacity is often impaired because the south shore power station is out of action due to sabotage. Thus it has been a matter of concern that the lake might overtop the dam with disastrous consequences, since flood prediction is still unsatisfactory. Indeed the dam was nearly overtopped at the end of March 1978 when a massive flood was released from Lake Kariba without adequate warning being given to

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the staff at Cahora Bassa. No prior draw down was made and the water level rose rapidly to reach an all time high level of 327.74 m. During this emergency 1.27 billion m^3 of water was discharged from the lake over a period of less than 5 days, when a maximum discharge rate of 14 753 m^3/sec was achieved by fully opening all 8 flood gates. It is feared that opening all the gates simultaneously, when the water head is high, might fracture the concrete structure of the dam. Discharges through the turbines are preferred and should play a crucial part in water level control when the system is functioning properly. The estimated residence time of water in the lake is 0.61 years. The mean total annual influx of 90.79 billion m^3 substantially exceeds the capacity of the reservoir which is 55.7 billion m^3. As much as 44% of the total annual influx may occur during March-April.

Affluent water tends to be warm, c. 26°C, during the main influx phase in March-April, and high winds at this time ensure that the western basins are not stratified. However, the reservoir cools from May-July when the freshwater mass passes up reservoir to the eastern basins. Air temperatures reach their maxima in October, and surface temperatures in the eastern basins may then rise to 28-29°C. Bottom temperatures are in the region of 20°C. The lake is an olive green colour due to high concentrations of clay particles which lead to shallow Secchi depths. Readings of 60-85 cm are obtained during June-September, but transparency increases seasonally in sheltered coves where readings of over 3.0 m may be obtained. The water is well oxygenated. Dissolved oxygen in Chicamba Basin was found to fall from 7.3-7.5 mg/l at the surface to 6.95-7.15 mg/l at 100 m depth, but readings as low as 5.5 mg/l have occasionally been made in the lower parts of the water column. Mean concentrations of the main ions in mg/l, for the period 1977-1982, are as follows: Na 6.08, Ca 16.08, Mg 4.16, chloride 8.66, bicarbonate 70.54, sulphate 6.69 and silicate 5.07. The mean pH is 7.60, with a range of 7.00-8.20.

Flora & Fauna: *Azolla pinnata*, *Eichhornia crassipes*, *Pistia stratiotes* and *Salvinia molesta* all occur on the lake and are potential nuisance weeds, but have not yet proved to be a serious problem. Beds of submerged macrophytes are beginning to establish in some bays, but the great fluctuations in water level which have occurred since the dam was filled mitigate against their establishment. Further, much of the lake shoreline is rocky and precipitous. Overall phytoplankton densities are low. The community is dominated by motile green flagellates including species of *Eudorina* and *Trachelomonas*. These tend to be confined to the upper 5 cm of the water column, while diatoms prevail beneath them.

The zooplankton is not dense. Rotifers (*Brachionus* spp., *Gastropus* spp., *Keratella tropica*), cladocerans (*Bosmina coregoni* and *Diaphanosoma brachyurum*) and copepods (*Diaptomus* sp.) are present. The large numbers of standing dead trees in the lake provide an extensive surface for 'aufwuchs' community growth. The periphyton has a large biomass and initially had a rapid growth rate. The animal component of the 'aufwuchs' community includes flagellate and ciliate protozoa, nematodes and turbellarians.

The fish fauna is rather different from that at Kariba. Fish known from the impoundment are listed in the introduction, but at least 27 species from the middle Zambezi fish fauna failed to survive in the reservoir. Crocodiles and monitor lizards are known from the tributaries but are not common in the lake. The lake supports a growing avifauna, and

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semi-aquatic mammals from the affluent streams and catchments are visitors to the lake shore, including otters and water rats.

Human Impact & Utilisation: As mentioned in the previous section, the dam has had a deleterious effect on the downstream hydro-ecology of the Zambezi. While the dam was being filled, water was discharged at a rate of only 60 m^3/sec, by contrast with the normal mean flow of 2000-3000 m^3/sec.

Commercial and subsistence fisheries occur on the lake. The total estimated catch for 1982 was 4343 tonnes, but it is estimated that a maximum sustainable yield of 6700 tonnes could be achieved. There is at present no sardine fishery, but this is envisaged and could produce a mean annual yield of 8000 tonnes. Some 450 fishing boats, exclusively dugout canoes, operate on the lake using gill nets with stretched mesh sizes of 102-127 mm. The principal species taken are *Alestes imberi, Clarias gariepinus, Distichodus schenga, Hydrocynus vittatus, Labeo* spp. and *Oreochromis mortimeri*. Shore based fishing with long lines leads principally to catches of *Anguilla* spp., *Clarias gariepinus, Distichodus schenga, Eutropius depressirostris, Heterobranchius longifilis, Hydrocynus vittatus, Malapterus electricus, Mormyrops deliciosus* and *Synodontis zambezensis*. At present gill nets are continually being snagged on submerged trees left in the lake, but it is possible that large tracts of peripheral trees could be cleared during the large draw down of water level that will be necessary for building the phase II North Shore Power Station.

Conservation Status: Unprotected.

5. Interior Lakes

(A) LAKE MALAWI

Location: 9°30'-14°27'S/33°58'-35°19'E
Area: c. 2 450 400 ha (c. 700 000 ha in Mozambique)
Altitude: 474 m asl
Nearest Towns: Mozambique (580 km E); Pemba (615 km E)

General: Lake Malawi (Nyasa) lies in the southern part of the East African Rift Valley and drains southwards via the Shire River to the Zambezi. It has an extreme length of 557 km, a maximum width of 89.4 km at a latitude of 12°03'S, and a maximum depth of 706 m. Estimates of its surface area vary very greatly between authorities (e.g. 11 900 square miles, Welcomme 1972; 8680 square miles, Times Atlas 1985) and the figure given is our estimation (9461 square miles). Mozambique has a shoreline of 255 km on the eastern shore of the lake, and some 700 000 ha of the lake surface is Mozambican territory, including the islands of Likoma and Chizumulu. The Mozambican shores are steep and harbour no important wetlands, but fisheries on Likoma and Chizumulu Islands yielded a catch of 3600 tonnes in 1976. Most of the catch is exported, either to mainland Mozambique or to Malawi. The Mozambican part of the lake is unprotected. A detailed account of the lake is given in section 5.4.6, Lake Malawi.

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(B) LAKE AMARAMBA

Location: 14°22'-14°40'S/35°52-35°58'E
Area: c. 8350 ha (4350 ha open water + 4000 ha swamp)
Altitude: 635 m asl
Nearest Town: Mozambique (525 km E)

General: Lake Amaramba lies in a shallow depression with much swamp land to the south and east. It is 36.25 km long with a mean width of 1.2 km. It drains part of Malawi, with a small river entering its southern extremity, but in wet periods it becomes continuous with Lake Chiuta some 9 km to the south, through a region of swamp land. The Lugenda River, the largest tributary of the Rovuma, drains the entire system, leaving Lake Amaramba at its northern extremity. We have little information on the flora and fauna of the lake and it is unprotected.

(C) LAKE CHIUTA

Location: 14°42'-14°47'S/35°50'-35°54'E
Area: 32 000 ha (3500 ha open water + 28 500 ha swamp)
Altitude: c. 639 m asl
Nearest Town: Cuamba (75 km E)

General: The Mozambique-Malawi border crosses this small lake in such a way that about 17 km of shoreline and 2000 ha of water surface falls within Mozambique. The lake is 10 km long and up to 3.5 km wide. Large swamps extend southwards from the lake into both Malawi and Mozambique. In total these cover about 28 500 ha, and about 6250 ha of these are in Mozambique. A sand bar along the southern border of the swamps separates the Lake Chiuta system from the Lake Chilwa system farther south. Details of the lake, which drains into the Lugenda River via Lake Amaramba, are given in section 5.4.10, Lake Chiuta. The system is unprotected.

(D) LAKE CHILWA

Location: 15°09'-15°31'S/35°33'-35°50'E
Area: 185 000 ha (inc. lacustrine swamps)
Altitude: 622 m asl
Nearest Towns: Quelimane (293 km SSE; Mozambique 525 km E)

General: The shore of the lake forms the border between Mozambique and Malawi for approximately 26 km, but very little of the water surface is Mozambican territory. The swamps, however, extend into Mozambique. The system is dealt with in some detail in section 5.4.9, Lake Chilwa.

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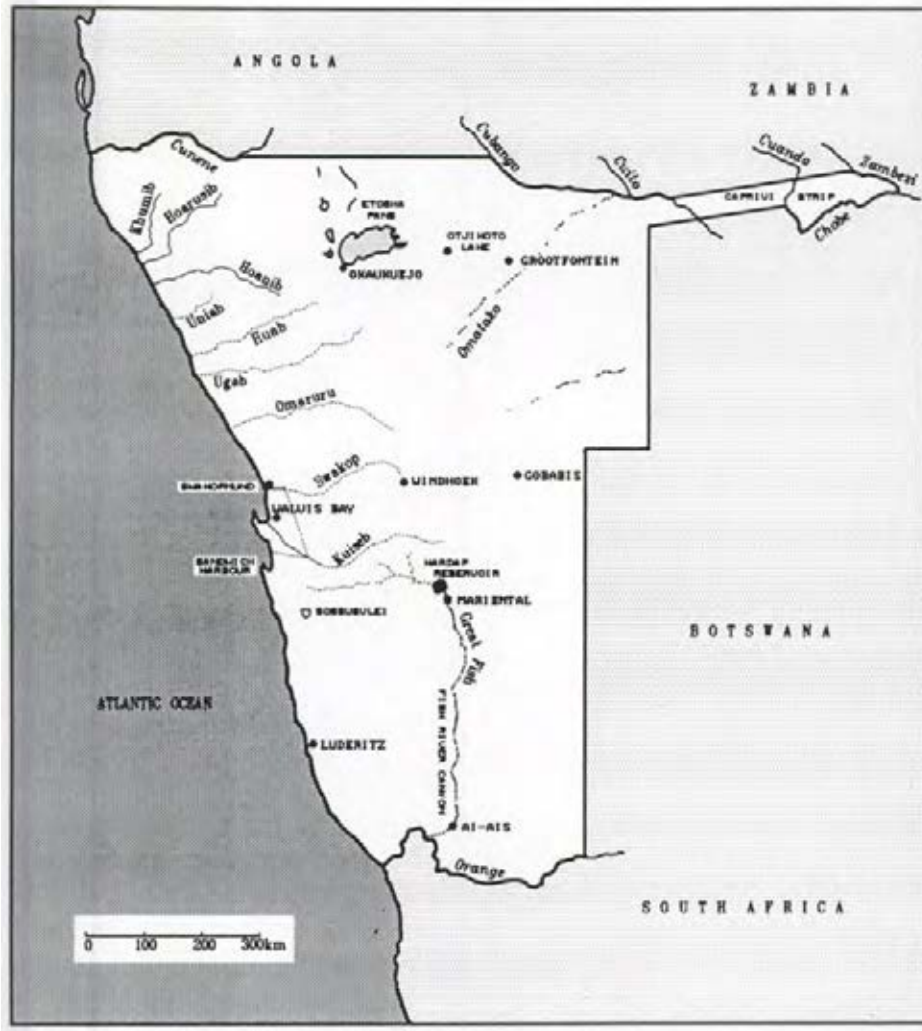

Map of Namibia

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5.6 NAMIBIA

Introduction

Namibia extends between latitudes 17°00' and 29°00'S on the SW coast of Africa. It is bounded by South Africa in the south, Botswana in the east, Zambia and Angola in the north, and by the Atlantic Ocean in the west. It has a coastline of more than 1400 km, an area of 824 295 km^2, and a population of 1 032 000 (1981), giving an extremely low population density of 1.25 persons/km^2. There is a narrow coastal plain, backed continuously by a highly dissected mountain range, rising to isolated peaks of over 2000 m. The 100 m contour is seldom more than 30 km from the coast and in places, e.g. at Cape Cross (21°47'S/13°57'E) and Cape Dernberg (27°46'S/15°35'E), it approaches to within 1 km of the sea. In the northern sector, between the Cunene and Kuiseb Rivers, the high peaks of the mountains are situated 75 100 km inland. The highest point in Namibia, Brandberg Mountain, 2606 m, lies 80 km inland here. In passing southwards, from the Cunene River, the nature of the coastal plain changes from sand desert to gravel desert, but there is an abrupt change back to sand desert at the south bank of the Kuiseb River. Sand desert then persists along the southern coastal sector to the mouth of the Orange River. In the southern sector the mountains are more distant from the coast, c. 150-175 km inland.

To the east of the mountains the land falls to an interior plain which continues for distances of 300-400 km to the border with Botswana. This plain has an elvation of 1000-1300 m asl and is covered by Kalahari sands. Only along the coast and in the valleys of the Great Fish and Orange Rivers does the land surface dip below the 1000 m contour. Most of the country is extremely sparsely vegetated and the coastal strip is occupied by the Namib Desert. The southern interior is predominantly dwarf shrub savanna, with very scant grass cover. This grades through open thornbush grasslands in the central districts to open woodland with a continuous grass ground cover in the northeast.

With the exception of the Orange River on the southern border, and the Cunene, Cubango, Linyanti/Chobe and Zambezi Rivers on the northern borders, there are no perennial streams in Namibia. Drainage lines on the seaward side of the mountains are southwesterly through the desert towards the coast. Drainage from the eastern side of the northern mountains is to the NE, terminating in irregularly flooded endorheic pans, but from the central and southern parts of the range it is SE to the Nossop/Molopo River system on the border with Botswana, or south to the Great Fish River. Many river valleys, such as those of the Kuiseb and Great Fish Rivers, are extremely deeply and dramatically incised. In places the floor of the Fish River Canyon is less than 25 m wide and 500 m below the surrounding land surface.

In the far northeast of Namibia the Caprivi Strip is a corridor, 30 km wide, between Angola and Botswana, which provides access to the Zambezi River along a short frontier with Zambia. Off the coast there are a number of rocky islands, some Namibian and some South African, all of which support large seabird communities. The coastal waters carry a wealth of fish as a consequence of the nutrient rich Benguela Current,

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and an exclusive fishing zone of 200 miles was declared in 1979 following overfishing by both domestic and foreign fleets between 1960-1970.

Climate

Precipitation is unreliable, being much greater in some years than others, although there is a broad pattern of long drought periods alternating with short pluvial phases, in which above average rainfall occurs for 3-5 years in succession. Mean annual rainfall for the past 60 years has been as low as 50 mm in parts of the Namib Dessert, which occupies the entire coastal strip. However, precipitation rises to 500 mm in the northeast of the country, and to 750 mm at the eastern extremity of the Caprivi Strip. Except in the southwestern corner of the country, most rain falls in the southern summer. Over most of the country rain falls on fewer than 65 days per year. However, regular morning fogs bring moisture to the coastal strip and are crucially important to its ecology. Fog develops when moist Atlantic air meets the cold Benguela Current just offshore. Fogs then drift inland for many kilometres and frequently persist until midday.

Wetlands

Florally and faunally the most important wetlands are those associated with the perennial rivers of the north, but there are numerous pans, including that at Etosha, which is undoubtedly the best known, although not the largest seasonal pan in southern Africa. In addition there are interesting and unusual coastal wetlands in sheltered bays on the Namib coast, such as those at Sandwich Harbour and Walvis Bay (the latter in the small South African enclave surrounded by Namibia, and dealt with in the account of South Africa), and others at river mouths. That at the Orange River mouth is under South African administration and is also dealt with in the national account of that country. Temporary pools and small floodplains occur along many of the ephemeral rivers, there are some large sinkholes containing deep permanent water on the interior plain, and two remarkable lakes in the dunes of the Namib Desert. There are also a number of artificial impoundments, the largest being the Hardap Dam near Mariental.

Flora & Fauna

The wetlands are so different from each other that it is convenient to describe their floras and faunas individually in each account.

List of Wetlands Described

1. Coastal Wetlands
    (a) Walvis Bay
    (b) Sandwich Harbour
    (c) Cape Cross Lagoons
    (d) The Cunene River Mouth
    (e) The Orange River Mouth
2. The Oshakati Pan System

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3. The Caprivi Wetlands
   (a) The Cubango Wetlands
   (b) The Cuando-Linyanti-Chobe-Zambezi System
4. Etosha Pan
5. Lakes Guinas and Otjikoto
6. Other Floodplains and Pans
7. Sossusvlei and Tsondabvlei
8. Periodic Streams
9. Artificial Impoundments
   (a) Hardap Dam
   (b) Augeigas Dam
   (c) Sartorius von Bach Dam
   (d) Naute Dam

1. Coastal Wetlands

(A) WALVIS BAY

Location: 22°52'-23°01'S/14°26'-14°30'E
Area: c. 4000 ha (the bay & associated mudflats)
Altitude: sea level
Nearest Town: Walvis Bay (on bayshore)

General: The town, port and some surrounding territory form an enclave administered by South Africa, and the wetlands in this area are dealt with in the national account for that country. However, briefly, a 10 km long, northward-pointing, sandy spit shelters a lagoon adjoining the modern town and port of Walvis Bay. The whole area is situated on the delta of the Kuiseb River which seems to be, or to have been, migrating northwards up the coast. Today, surface flows in the Kuiseb do not reach the sea, but there is subterranean water. Drainage lines from the Kuiseb River lead northwestwards through the desert to the southern shore of Walvis Bay, and in places support floodplains which are vegetated after rain. One pan of complex structure is situated in the Walvis Bay enclave (23°03'-23°11'S/14°31'-14°41'E), while another, farther south is in Namibia. This latter pan/floodplain (23°20'-23°32'S/14°47'-15°01'E) is barely 1 km wide but almost 50 km long, and is surrounded by sand desert and dunes.

Along the northern boundary of the enclave, the intermittent Swakop River reaches the sea and there is presently a small lagoon at its mouth. This may not be a permanent feature, however, having been formed only recently during a flood of the mid-1980s. Nevertheless it is becoming vegetated and attracts substantial numbers of birds. Another small semi-permanent pool exists a few km inland in the lower reaches of the Swakop River.

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(B) SANDWICH HARBOUR

Location: 23°19'-23°24'S/14°28'-14°30'E
Area: c. 8000 ha
Altitude: sea level
Nearest Town: Walvis Bay (40 km N)

General: Sandwich Harbour (Sandvis) is a coastal lagoon 15 km long and up to 3 km wide. It is orientated N-S, isolated from the interior of Namibia by the sand dunes of the Namib Desert, and bounded by the Atlantic Ocean on the west. It opens to the sea centrally, between sandspits, through a mouth some 200 m across. The dunes along the landward shore rise abruptly to heights of over 100 m. There are extensive, sparsely vegetated, tidal mudflats at the southern and southwestern sides of the lagoon, covering about 2000 ha, and scant saltmarshes along the eastern landward shore, interspersed with some small freshwater springs. However, at the northern end of the lagoon, there is a freshwater marsh currently covering 150 ha, in a belt 5km long and 300 m wide. This is protected from the sea by a narrow barrier beach, although natural processes have been progressively reducing the width of the wetland since the early 1960s when it was over 1km wide. The reed beds here contain *Phragmites australis* and *Typha latifolia*, but the surrounding dunes are barren and the next nearest vegetation of any consequence is in the delta of the Kuiseb River 25 km to the NE.

Hydrology & Water Quality: Sandwich Harbour is tidal, with a maximum depth of 5 m at low tide, but a mean depth of much less than this. However, the northern wetland is supported by the upwelling of potable water from a large subterranean aquifer under the Namib Sand Sea (Hellwig, 1988), to which water from the Kuiseb River may contribute. This also supports several minor springs along the eastern shore of the lagoon. It is generally believed that the lagoon was once the mouth of the Kuiseb River which subsequently moved northwards along the shore to Walvis Bay.

Flora & Fauna: The mudflats support algae, and some 'seagrass' beds, while the saltmarshes which fringe the lagoon are dominated by the creeping succulent herb *Sarcocornia natalensis*. Water from the freshwater springs collects in pools at the foot of the dunes, but these are generally brackish due to their proximity to the lagoon. They are partially fringed by *Phragmites australis* and *Typha capensis*. Farther from the water the grasses *Eragrostis cyperoides*, *Odyssea paucinervis* and *Sporobolus virginicus* intermingle in a coarse sward. Elsewhere the sedge *Scirpus dioicus* covers large areas. The narras plant, *Acanthosicyos horrida* (Cucurbitaceae), grows on small dune humps on the periphery of the grassy areas. This species has a long tap root, up to 12 m long, which penetrates to a moist horizon. Above ground there is a densely tangled and fiercely spiny greyish shrub, which develops hard, spherical, knobbly, melon-like fruits on the ground. These contain substantial quantities of potable water.

The tidal flats are rich in invertebrate life and the lagoon is an important nursery area for juvenile fish. Both these factors predispose the site to the possession of a dense avifauna, with counts of palearctic waders in excess of 7000 birds/km^2. Some 80 species of birds have been recorded here, in four main groups: sea birds, palearctic waders, inland water birds and land birds. Among these are at least 8 endangered species including *Hydroprogne caspia*. Sandwich Harbour and Walvis Bay together support up to 170 000 coastal birds. Several species migrate between the two lagoons and the interior pans, leaving the

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interior in the dry season, while others come all year from breeding colonies on the offshore islands. Species seen here include *Acrocephalus baeticatus, Alopochen aegyptiacus, Anas capensis, A. erythrorhyncha, A. hottentotta, A. smithii, Ardea cinerea, A. melanocephala, Arenaria interpres, Calidris alba, C. canutus, C. ferruginea, C. minuta, Charadrius hiaticula, C. leschenaultii, C. marginatus, C. pallidus, C. pecuarius, C. tricollaris, Circus ranivorus, Chlidonias hybrida, C. leucoptera, C. nigra, Cisticola juncidis, Corvus albus, Dendrocygna bicolor, Egretta alba, E. garzetta, Estrilda astrild, Fulica cristata, Gallinula chloropus, Haematopus moquini, Hirundo dimidiata, H. rustica, H. spilodera, Hydroprogne caspia, Lanius collaris, Larus cirrocephalus, L. dominicanus, L. novaehollandiae, Limnocorax flavirostra, Limosa lapponica, Melierax canorus, Motacilla capensis, Netta erythrophthalma, Numenius arquata, N. phaeopus, Oxyura punctata, Passer melanurus, Pelecanus onocrotalus, Phalacrocorax capensis, P. lucidus, Philomachus pugnax, Phoeniconaias minor, Phoenicopterus ruber, Ploceus velatus, Pluvialis squatarola, Podiceps cristatus, P. nigricollis, P. ruficollis, Prinia flavicans, Recurvirostra avosetta, Stercorarius parasiticus, S. pomarinus, Sterna balaenarum, S. bergii, S. hirundo, S. paradisea, S. sandvicensis, Sula bassana, Tadorna cana, Thalassornis leuconotus, Tringa hypoleucos, T. nebularia, T. stagnatilis* and *Tyto alba*. In addition to these a large number of vagrants have been recorded here, and an annotated checklist is given by Berry & Berry (1975). Numbers of some species are large. The population of *Phalacrocorax capensis* may be 20 000, while that of *Charadrius marginatus* can exceed 6000, which may represent two thirds of the world population of this species.

Human Impact & Utilisation: There used to be whaling and fishing stations at Sandwich Harbour, but there have been no permanent human inhabitants since 1969, and the site is seldom visited. The area is fenced off and the entry of casual visitors is prohibited.

Conservation Status: The site is situated in the Namib-Naukluft National Park and is fully protected. It was first protected, with status as a game reserve, in 1904.

(C) CAPE CROSS LAGOONS

Location: 21°47'S/13°57'E
Area: c. 500 ha
Altitude: Sea level
Nearest Town: Swakopmund (116 km SSE)

General: A sand barrier has formed along the shore, south of the rocky cape, being continually eroded and rebuilt by the strong northward flowing longshore drift. Behind this barrier is a series of small lagoons fed by sea water seepage and high tide washovers. They are saline and are fringed by sparsely vegetated salt flats, and the area supports a large *Arctocephalus pusillus* colony, estimated to comprise 150 000 animals. Wooden guano platforms were erected in the 1950s, to encourage cormorants to breed, and by 1991 some 30 000 pairs were breeding. Guano is still collected here. Among bird 28 species recorded here are *Anas capensis, Calidris ferruginea, Phoenicopterus ruber* and *Podiceps nigricollis gurneyi* (Williams, 1991).

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(D) CUNENE RIVER MOUTH

Location: 17°15'S/11°46'E
Area: c.500 ha
Altitude: Sea level
Nearest Town: Swakopmund (675 km SSE)

General: There is a small freshwater lagoon at the mouth of the Cunene River which supports lush emergent vegetation and is often visited by the desert dwelling elephant, *Africana loxodonta*. There are islands in the lagoon on which *Crocodylus niloticus* breeds and *Chelonia mydas* is also quite common. So far as is known, this lagoon provides the southernmost known population of the Nile soft-shelled turtle, *Trionyx trianguis*, and a freshwater prawn, *Macrobothrium bollenhoveni*. According to van Zyl (1991) there are 7 endemic fish species present. Bird recordings have not been made here regularly, but in recent years *Calidris pusilla* has been the only species seen in significant numbers. However, other species of interest include *Pandion haliaetus*, which is resident, flocks of migrating *Sterna balaenarum*, and a gull, *Larus cirrocephalus*. Proposed dam building activities at Epupa Falls may well destroy this wetland, as it is anticipated that the mouth might become dry for 4 consecutive years while the reservoir is filling. At present the lowest 40 km of the south bank of the river is protected by the Skeleton Coast National Park of Namibia, while the northern bank is protected by the Iona National Park of Angola.

(E) THE ORANGE RIVER MOUTH

Location: 28°34'-28°38'S/16°28'-16°29'E
Area: c.700 ha
Altitude: Sea level
Nearest Town: Luderitz (250 km NW)

General: There is a lagoon with islands and some vegetated wetlands, but these are currently under South African jurisdiction and are dealt with in the account of that country.

2. Oshakati Pan System

Location: 17°23'-18°00'S/14°50'-15°56'E.
Area: c. 60 000 ha pans
Altitude: 1109-1136 m asl,
Nearest Town: Grootfontein (125 km SE)

General: In the northwest of Namibia, fossil drainage lines, inter-connecting many long linear pans, extend southwards from the Cunene Flats of Angola into Namibia. Here there is a system of over 100 partially inter-connected pans, almost all of which are oriented NW-SE. The system occupies an area approaching 5000 km^2, but less than 20% of this is pan or drainage channel. The pans are part of an ancient system which is believed to have carried water from the Cunene River, across the Cunene Flats to a vast lake in the Etosha region, before the Cunene suffered river capture in Angola and began to flow to the sea. The pans lie in a broad shallow trough which slopes gently south-southeastwards. Water enters the northern sector, in Angola, from the Mui and Cuvelai Rivers,

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and at high flood from the Cunene. It then spreads over the flats in Angola and in wet years penetrates far down the drainage lines into Namibia. Several drainage lines extend from the southern edge of the Oshakati Pan System towards the Etosha region, the largest of which, the Ekuma Channel, still carries water into Etosha Pan where it has formed a delta on the northwestern shore.

3. The Caprivi Wetlands

(A) THE CUBANGO WETLANDS

Location: 18°02'S/21°25'E-18°15'S/21°47'E
Area: c. 2000 ha total
Altitude: c. 3400 m asl
Nearest Town: Bagani (on Okavango River in Caprivi)

General: Some small discontinuous swampy areas occur along the Cubango River where it crosses the Caprivi Strip from Angola to Botswana to become the Okavango River. In places the river flows in several channels and papyrus and *Phragmites* fringe the banks. To landward of the reed beds there are, in places, small semi-permanent ponds, the water levels of which may fluctuate by as much as 3.5 m during the course of a year. There are gallery woodlands here containing *Hyphaene benguellensis*, strangler figs, and many trees common to the upper Okavango Delta.

(B) THE CUANDO-LINYANTI-CHOBE-ZAMBEZI SYSTEM

Location: in area 17°39'-18°40'S and 23°18'-25°10'E
Area: c. 393 000 ha total wetland in Namibia
Altitude: 973-935 m asl
Nearest Towns: Congola (at W end); Kasane (at E end);

General: The Cuando River, which rises in Angola, has a swampy floodplain some 5 km wide for over 65 km where it traverses the Caprivi Strip and thereafter forms the border between Namibia and Botswana. Here it provides about 33 500 ha of wetland (17°39'-18°12'S/23°18'-23°26'E). The river then forms a delta 35 km deep and 65 km wide at its base, with an area of about 90 000 ha, known as the Linyanti Swamp (18°11'-18°40'S/23°23'-23°55'E). This is mostly wetland, and is mostly situated in Namibia, but small southwesterly and southeasterly extensions cross into Botswana, and the Selinda Spillway from the Okavango Delta of Botswana enters the southwestern extension. Through this spillway the Okavango River has at times made contributions to the hydrology of the Linyanti system, although this is by no means common nowadays. Structurally the Linyanti Swamp is similar to the Okavango Delta. It is situated in a depression at the southernmost extremity of the Caprivi Strip, and on entering the depression the Cuando River divides into distributaries with levées which spread from an apex into a typical delta comprising shallow inter-distributary floodplains or *mekapo*, and deep permanent lakes. The largest lakes are Saraugxa Lediba (18°35'S/23°34'E), which covers 400 ha, and Zibadianga Lediba (18°40'S/23°32'E) of equivalent size. Water reaching the base of the delta is collected into the Chobe River which then flows sluggishly northeastwards.

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After leaving the Linyanti Swamp the Chobe River forms the border with Botswana for a distance of 200 km, as far as the town of Kasane (17°50'S/25°05'E), but for some of this distance it may also be known as the Linyanti River. Wetlands are virtually continuous along the Chobe River from the Linyanti Swamp to Kasane, reaching their greatest width in the vicinity of Liambezi, where the river broadens northwards to form Lake Liambezi (17°59'S/24°15'E). This is a shallow water body, 15 km long and 10 km wide, with a maximum open water surface of some 7850 ha. Here the river may rise 15 m in flood, inundating a floodplain up to 60 km broad which extends on both sides of the river, over flat sandy lands. In some places, during the dry season, the river flows in multiple channels between sandy islands, but for most of its length it flows in a single channel between quite steeply sloping banks. Towards the confluence of the Chobe and Zambezi Rivers, near Kasane, the flood waters of the two streams jointly inundate the intervening plain of 170 000 ha (17°30'-17°50'S/24°20'-24°36'E) if their floods are in phase, but if not, if the Zambezi alone is in flood, flow in the Chobe may be temporarily reversed. Rainfall increases northeastwards along the Chobe River, the mean annual receipt being 580 mm at Linyanti Swamp but over 700 mm at Kasane.

Flora & Fauna: The river channels of Linyanti Swamp are fringed by *Cyperus papyrus*, up to 4 m high, in belts 15-20 m wide. In patches papyrus may be replaced by *Phragmites mauritianus* or *Typha capensis*, or these species may occur on the landward side of the papyrus. *Miscanthidium junceum* occurs on less deeply inundated sandy substrata and in places there are dense groves of *Phoenix reclinata*. These species also fringe Lake Liambezi, and long stretches of the Chobe River and its backwaters.

Where the Chobe river banks are subject to periodically strong currents, they slope steeply, or may be undercut, and are covered at the top by dense forest or riverine thicket. The dominant species of riverine forest, often with a canopy over 15 m high, are *Acacia albida*, *A. erubescens*, *A. nigrescens*, *Allophyllus africanus*, *Berchemia discolor*, *Combretum imberbe*, *C. zeyheri*, *Croton megalobotrys*, *Diospyros mespiliformis*, *Erythrophleum africanum*, *Garcinia livingstonei*, *Homalium abdessammadii*, *Kigelia africana*, *Lonchocarpus capassa*, *Pteleopsis myrtifolia*, *Strychnos potatorum*, *Syzygium cordatum* and *S. guineense*. Other species found at the waterside or in riverine thicket, 5-9 m high, are *Cassine transvaalensis*, *Clerodendrum glabrum*, *C. myricoides*, *Combretum albopunctatum*, *Cordia sinensis*, *Ehretia amoena*, *Euclea divinorum*, *Ficus verruculosa*, *Friesodielsia obovata* (syn. *Popowia obovata*), *Gardenia jovistonantis*, *G. resiniflua*, *Grewia bicolor*, *G. flavescens*, *G. schinzii*, *Hibiscus diversifolius*, *Markhamia acuminata*, *Maytenus senegalensis*, *Myrica serrata*, *Oncoba spinosa*, *Pappea capensis*, *Premna senensis*, *Rhus quartiniana*, *Salix subserrata*, *Sesbania sesban*, *Tarenna luteola*, *Vangueria randii*, *Vernonia amygdalina*, *Ziziphus abyssinica* and *Z. mucronata*. Woody climbers or scandent shrubs are locally abundant, and they include *Acacia schweinfurthii*, *Artabotrys brachypetalus*, *Byrsocarpus orientalis*, *Combretum mossambicense*, *Dalbergia martinii*, *Fernia aeruginescens* and *Phyllanthus reticulatus*. On the landward sides of the riverine vegetation, on higher grassy floodplains, and on the margins of marshes and pans, there are tall trees such as *Acacia polyacantha*, *A. sieberana*, *Combretum hereroense*, *Peltophorum africanum* and *Terminalia sericea*, all of which can exceed 15 m in height and occasionally reach 20 m. *Ficus natalensis* and *Parinari curatellifolia* are common on elevated sandy ridges in the river and on abandoned levées.

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Lake Liambezi supports a diverse aquatic flora. *Cyclosorus interruptus* and *Vossia cuspidata* are abundant in the water at the bases of the papyrus culms, and floating-leaved aquatics occur around the outer margins of the tall communities, between rafts of floating vegetation, and over shallow patches in the lake. *Brasenia schreberi* and *Nymphaea caerulea* are the commonest species, covering large areas, but they have numerous associates, e.g. *Caldesia reniformis, Nymphaea lotus, Nymphoides brevipedicellata, N. indica, Potamogeton schweinfurthii* and *Trapa natans*. Where the water is too deep for rooted species, and where it is kept clear of floating species by virtue of wind and wave action, submerged aquatics form dense beds. Here *Ceratophyllum demersum, Lagarosiphon ilicifolius, Limnophila ceratophylloides, L. indica, Najas pectinata, Nesaea crassicaulis, Ottelia* spp., *Rotala myriophylloides* and *Vallisneria aethiopica* are common. Under the open water, in mid-lake, small free-floating, but totally submerged species occur, the most important of these being *Aldrovanda vesiculosa* (Droseraceae) and *Utricularia* spp. (Lentibulariaceae). Areas of shallow water, away from the lakeshore, support rooted emergents, among which *Eleocharis* spp., *Eriochrysis pallida, Phragmites mauritianus, Sacciolepis africana* and *Typha latifolia* are prominent. Free-floating aquatics are numerous and include *Azolla pinnata, Lemna perpusilla, Salvinia molesta* and *Spirodela polyrhiza*.

In the peripheral swamps, and in the Linyanti Delta, lower lying areas which are inundated for long periods each year, yet which become dry seasonally, are covered by a dense *Scirpus inclinatus-Cyperus articulatus* association, reaching 2 m in height.

The permanent swamps and channels have a resident fauna, but a range of other animals moves between the wetland and the adjacent savannas. The fish fauna of the Chobe River and associated lake/pan/swamp system is typical of the upper Zambezi Basin, and includes *Clarias gariepinus, C. ngamensis, Hepsetus odoe, Hydrocynus vittatus, Labeo lunatus, Oreochromis macrochir, Schilbe mystus, Serranochromis angusticeps, S. macrocephalus, Synodontis woosnami, Tilapia andersoni* and *T. sparrmanii*. A wealth of animal life is associated with the riverine forests, the reed beds and river banks. This includes an abundance of frogs and toads and many reptiles. Among the latter are *Crocodylus niloticus, Pelusios* spp., *Varanus exanthematicus, V. niloticus* and some 25 species of snakes. These include arboreal forms such as *Dasypeltis scabra, Dendroaspis angusticeps, Philothamnus semivariegatus* and *Thelotornis kirtlandii*, terrestrial species such as *Naja mossambica* and *N. nigricollis*, and the semi-aquatic types *Dromophis lineatus, Limnophis bicolor* and *Natriciteres olivacea*. *Python sebae* is found in the trees, on the ground and in the water.

At least 200 species of birds are associated with the river and its peripheral vegetation, among which *Merops nubicoides*, which nests in holes in the river banks, and *Quelea quelea*, are the most numerous. Both appear in vast numbers each year. The latter species frequents pan and reed swamp margins, often bending the reeds to the ground by virtue of the weight of birds perched on them. Other important birds seen here are *Ardeola ralloides, Asio capensis, Chalcomitra senegalensis, Cisticola rufilata, Ephippiorhynchus senegalensis, Glaucidium capense, Grus carunculata, Haliaeetus vocifer, Hieraaetus spilogaster, Kaupifalco monogrammicus, Leptoptilos crumeniferous, Lophaetus occipitalis, Necrosyrtes monachus, Pelecanus onocrotalus, Phalacrocorax africanus* and *Polyboroides typus*. *Egretta vinaceigula*, which is endemic to a small area,

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including SW Zambia, Ngamiland and the Caprivi Strip, is still moderately abundant here, but its range has contracted markedly in recent years and it must be regarded as vulnerable.

Mammals resident in, or visiting the wetlands regularly, are *Aepyceros melampus, Aethomys chrysophilus, Aonyx capensis, Damaliscus lunatus, Dasymys incomtus, Dendromus mesomelas, Hippopotamus amphibius, Hippotragus niger, Kobus ellipsiprymnus, K. leche, K. vardoni, Loxodonta africana, Lycaon pictus, Manis temmencki, Mus minutoides, Otomys angoniensis, Panthera pardus, Paraxerus cepapi, Pelomys fallax, Praomys shortridgei, Saccostomus campestris, Syncerus caffer, Tragelaphus spekei* and several bats, including fruit bats.

Human Impact & Utilisation: The river and Lake Liambezi are fished by local people, but there are no commercial fisheries. Hunting occurs throughout the Caprivi Strip. Because of the regular high floods the wetland area *per se* has not yet been developed and is little exploited by the indigenous population, although the adjacent lands are to be opened up to agriculture. Supplies and passengers are transported up and down river between Kasane and Liambezi, and even farther west, but at times in the dry season the density of *Salvinia molesta* in the main channel has been known to make the river temporarily unnavigable.

Conservation Status: Some small areas of wetland in the western Caprivi are protected in the Caprivi Game Reserve, established in 1963, and four specific wetland reserves have been proposed for the eastern Caprivi, where the land is being opened for agriculture. However, as these have not yet been formally proclaimed the important wetlands of the Caprivi are still unprotected.

4. Etosha Pan

Location: 18°30'-19°28'S/14°20'-17°10'E
Area: 460 000 ha main pan + 55 000 ha subsidiary pans
Altitude: 1073-1086 m asl
Nearest Towns: Windhoek (400 km S); Namutoni; Okaukuejo (at pan margin)

General: Etosha Pan, together with numerous subsidiary pans, is situated on the interior plain of Ovamboland in the north of Namibia. It is a shallow saline depression which has not been fully flooded during the past 50 years. In most years it contains water for 4-6 months, but it is dry and salt-encrusted at other times. The smaller pans contain standing water for much shorter periods. During the Pliocene the Cunene River formed a lake in the region, but it was subject to river capture upstream which left its lower course dry, and Etosha Pan as the remnant of a once great lake.

The Etosha Pans lie on the Kalahari Beds, which comprise limestones, calcareous sands and gravels. The floors of the pans are made of clay, silt and fine to coarse sand. Water drains into the pans and remains there until it finally evaporates, leaving salty deposits. Where it is regularly flooded the floor of the main pan is a hard, salt-encrusted, cracking clay, but towards the western end, where it is seldom flooded, it is a sandy plain. Small depressions in the pans, known locally as 'fountains', provide more or less permanent water-holes which are heavily utilised by animals during the dry seasons.

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Published estimates of the area of the main pan exceed 600 000 ha, but measurements from satellite images show that it is in fact about 460 000 ha, with maximum extents of 128 km from west to east and 52 km from north to south. The total area of subsidiary pans is approximately 55 000 ha. The main pan lies in flat to gently undulating savanna country. The minimum altitude of the pan floor is 1073 m near the Ekuma River mouth in the NW corner, while the maximum is 1086 m in the SW.

Climate: There are usually three distinct seasons; wet and hot (January-April), dry and cool (May-August) and dry and hot (September-December). January is the hottest month with mean maxima and minima of 38.3 and 11.8°C respectively, while July is the coldest month with corresponding figures of 28.9 and 1.5°C. Precipitation during the wet season is unreliable and varies considerably from year to year, e.g. only 90 mm in 1946, but 975 mm in 1950. In most years more rain falls on the eastern edge of the pan than on the western edge, and mean annual figures are 440 mm at Namutoni and 418 mm at Okaukuejo. In the wet season sudden thunderstorms lash the pan, often followed by prolonged periods of intensely hot sunshine when temperatures may exceed 40°C. In winter, nights are cold with occasional mild frosts, and days are warm, although desiccating winds may gust across the pan at speeds up to 56 km/hr.

Normally evaporation exceeds precipitation by a factor greater than 6:1. During the 5 years (60 months) from 1974 to 1978, rainfall exceeded evaporation in only 2 months, February and March 1976. Mean class A pan evaporation is 2662 mm. Prevailing winds are from the NE, except during the hot dry months of September-December when they may swing round to SW.

Hydrology & Water Quality: Direct precipitation accounts for only a small proportion of the pan's water, most being supplied by three periodic rivers, the Ekuma, the Oshigambo and the Omurambo Ovambo. The first two of these drain the plains to the north of the Pan, and the Ekuma may carry water from southern Angola. The mouths of these streams have formed deltas in the northwest of the pan. The Omurambo Ovambo drains an area to the east of the pan, which it enters at its eastern extremity. Several small pans and narrow floodplains are associated with these three drainage lines before they reach the main pan. In addition there are other pans immediately west of the main pan, the largest of which is Natukanaoka Pan. In the wettest years Etosha Pan is partially flooded from January to April or even June, but droughts are frequent, and during dry cycles (e.g. in 1980) there may be no standing water away from water holes. During these periods the rivers do not flow at all and their courses consist of a series of pools and ponds. In 1971, a moderately wet year, some 250 000 ha of the pan was flooded with water ranging in depth from 1 m at the Ekuma Delta to 1 cm at the SE edge. The SW sector of the pan was not flooded at this time, and indeed it is doubtful if it has been fully flooded this century. The small pans along the major drainage lines leading to the main pan hold water for short periods in wet years when the rivers flow, but the western pans are much drier.

River water flowing into the main pan early in the wet season has a pH close to 7.6, whereas pan water is always more alkaline, the pH rising as the pan dries. It has been measured as 9.2 in July, 9.4 in September, and over 10.0 before finally drying. In 1971 incoming river water had the following respective concentrations, expressed in ppm, successively for July and September: sodium 482 (July) and 12 800 (September);

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potassium 10 and 106; sulphate 104 and 2790; nitrate 7 and 0; silicate 25 and 40; and chloride 600 and 15 800 (Berry 1972). Corresponding pan water concentrations, in ppm, were: sodium 7820 and 22 650; potassium 111 and 300; sulphate 890 and 3700; nitrate 0 and 0; silicate 40 and 40; and chloride 10 400 and 29 850.

Flora & Fauna: The floors of the pans are largely unvegetated, but areas which remain moist support algal and bacterial growth, comprising species of *Anabaena*, *Nodularia*, *Nostoc* and *Oscillatoria*. Low islands, subject to partial inundation during floods, support perennial grasses, including *Odyssea paucinervis*, some reeds and sedges, and occasionally some of the scrubby trees which occur on the periphery and along incoming drainage lines. These include *Acacia ataxacantha*, *A. eriolaba*, *A. erubescens*, *A. hereroensis*, *A. kirkii*, *A. luederitzii*, *A. mellifera*, *A. nebrownii*, *A. reficiens*, *A. tortilis*, *Combretum apiculatum*, *C. engleri*, *C. hereroense*, *C. imberbe*, *Dichrostachys cinerea*, *Elephantorrhiza suffruticosa*, *Erythrina decora*, *Olea africana*, *Sclerocarya caffra*, *Spirostachys africana*, *Terminalia brachystemma* and *Terminalia prunoides*. The surrounding vegetation is chiefly *Colophospermum mopane* scrub savanna with a ground cover of grasses in which species of *Anthephora*, *Aristida* and *Enneapogon* predominate. *Colophospermum mopane* is deciduous and is mostly bare by the end of the dry season.

Over 300 bird species have been recorded on the pan which is the largest known breeding area of the two flamingoes, *Phoeniconaias minor* and *Phoenicopterus ruber*, in southern Africa, and in some years the combined flamingo population of the pans is said to reach 1 million birds. Other species recorded include *Aquila rapax*, *Ardea cinerea*, *Corvus alba*, *Larus cirrocephalus*, *Leptoptilus crumeniferus*, *Laphotis ruficristo*, *Pelecanus onocrotalus*, *Platalea alba*, *Plegadis falcinellus*, *Struthio camelus*, *Terathopius ecaudatus*, *Threskiornis aethiopicus* and *Torgos tracheliotus*. Accounts of flamingo and pelican breeding on the main pan are given by Berry (1972) and Berry *et al.* (1973).

Most of the larger mammals of the southern savanna plains of Africa occur in Etosha National Park, which is one of the largest and most renowned game parks in the world. Few of these species do not utilise the pans, and among the more noteworthy are *Acinonyx jubatus*, *Aepyceros melampus petersi*, *Alcelaphus buselaphus*, *Connochaetes taurinus*, *Damaliscus lunatus*, *Diceros bicornis*, distinctive races of zebra, *Equus burchelli antiquorum* and *Equus zebra hartmannae*, *Giraffa camelopardalis*, *Hippotragus equinus*, *Loxodonta africana*, *Madoqua kirki*, *Oryx gazella*, *Panthera leo*, *P. pardus*, *Taurotragus oryx* and *Tragelaphus strepticeros*. Smaller mammals comprise *Canis mesomelas*, *Felis silvestris*, *Ictonyx striata*, *Lycaon pictus*, *Mellivora capensis*, *Otocyon megalotis*, *Papio ursinus*, *Pedetes capensis*, *Suricata suricata*, *Vulpes chama* and *Xerus inauris*.

Human Impact & Utilisation: Most pans in the area provide waterholes and salt licks for wildlife, and in consequence attract large numbers of tourists. There are three camp sites in the Etosha National Park offering bungalows, cabins and tents for rental. During 1983 a total of 51 834 people visited the park; 13 959 from overseas, 18 583 from Namibia and 19 292 from South Africa. No other people live in the park apart from park staff, and the grazing of domestic animals is prohibited. However, the use of anti-malarial agents in the catchment areas in recent years has

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led to the appearance of chlorinated hydrocarbons in the food chains of the pan. Most river water originates in Ovamboland and since 1965 indoor sprays have been applied to the roofs and upper walls of tribal huts. Today some 120 000 kg of 5% DDT solution is used annually for this purpose in the pan catchments, and eggs of the lesser flamingo were found to contain traces of the following compounds in ppm: DDT 0.013; TDE 0.097; DDE 0.19; dieldrin 0.03; and BHC 0.03 (Berry, 1972).

Conservation Status: The pans are situated in the Etosha National Park and are fully protected, being covered by a Nature Conservation Ordinance of 1975. However, the area has been protected as a game reserve since 1907.

5. Lakes Guinas and Otjikoto

Location: 19°18'S/17°22'E (Guinas); 19°14'S/17°33'E (Otjikoto)
Area: c. 3 ha (total)
Altitude: c. 1250 m asl
Nearest Town: Windhoek (390 km WSW)

General: Lake Otjikoto, or Otjikoto Fountain as it used to be called, is a dolomite sink hole on the Waterberg Plateau, ESE of Etosha Pan. It is filled with clear hard water at least 36 m deep and is set about with cliffs and steep walls some 20 m high. It is situated in level ground in bush country and as the explorer Charles Andersson wrote 'a person might pass within fifty paces of it without being aware of its existence'. It measures about 120 m across, and there are caves in its walls just above water level, in which bats and owls live. The water has been used as a town supply for Tsumeb, and for irrigation by local farmers, and the lake is fenced off to prevent animals falling in. Lake Guinas is another, larger, but less spectacular sink hole, 19 km WSW. Lake Otjikoto is of scientific interest because of its fish fauna. Originally it contained a unique dwarf cichlid species, which possibly still survives, but another species, *Tilapia guinasana*, was introduced from Lake Guinas and this species quickly became predominant and is now referred to as 'Otjikoto cichlid'. Subsequently, *Oreochromis mossambicus* was introduced illegally, in 1980, and this species has increased quite dramatically at the expense of the others.

Conservation Status: Unprotected. Lake Otjikoto is a popular venue for tourists because of its semi-desert and therefore spectacular setting, and its accessibility from the road between Tsumeb and Ondangwa. It has therefore been despoiled to some extent. A great deal of rubbish has been tipped into it over the past 100 years. Lake Guinas is also easily accessible from the Otavi-Ondangwa road.

6. Other Floodplains and Pans

General: Small swampy areas, dominated by *Phragmites mauritianus*, occur along the Cubango/Okavango River where it forms the border between Angola and Namibia. A section of this river is protected in the Mahango Reserve, in Kavango District.

Extensive grass covered floodplains occur on the interior plains to the east of the town of Grootfontein (19°33'S/18°05'E) centred on a complex of drainage lines related to the Omatako River system. The area may remain unflooded for many years at a time, but during wet cycles it provides an important habitat for wetland birds. No precise

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information is available concerning the area inundated, or its fauna and flora. The area is unprotected.

There is a major pan system north of Grootfontein in the Bushmanland District. The pans are linear and arranged in parallel lines oriented WNW-ESE. Some individual pans exceed 25 km in length and 1 km in width. The system covers an area from 18° to 19°S, and from 18° to 19°E. Precise information is unavailable concerning the area subject to flooding, and the fauna and flora of the pans. Flooding may not occur for several successive years, yet when it does the area becomes an important wetland habitat. The northernmost pans of this system may come within the boundaries of the proposed Bushmanland Reserve.

Other pans exist north of Grootfontein, near Tsintsabis, 18°50'S/17°58'E. Again precise information regarding the frequency with which these pans are flooded is not available, but it is believed that, in wet years, some wetland birds breed there. These include *Pelecanus onocrotalus*, *Phoeniconaias minor*, *Phoenicopterus ruber* and *Podiceps nigricollis*, together with several herons, ibises and storks. The area is presently unprotected.

A further group of pans is situated in eastern Bushmanland near Tsumkwe (19°40'S/20°30'E). These hold water infrequently after storms.

An extensive but infrequently inundated pan/floodplain system occurs on a group of anastomosing streams which drain the eastern slopes of the Tsarisberge Mountains. Here, several converging streams carry broad pan-like floodplains, up until their joint confluence at a point 24°50'S/16°54'E near Maltahohe. The entire system probably extends for 170 km with an average width of 5 km, giving it a total area in the region of 85 000 ha. Parts of the system hold water after storms in the adjacent mountains.

Immediately to the north of this a large but infrequently flooded pan marks the outflow of a stream draining the eastern slopes of the Naukluft Mountains to the basal plain. The rectangular pan (24°01'-24°11'S/16°22-16°24'E) covers some 15 000 ha and is 30 km long.

7. Sossusvlei and Tsondabvlei

Location: 24°40'S/15°24'E (Sossusvlei); 23°55'S/15°23'E (Tsondabvlei)
Area: c. 3000 ha (maximum inundated area - both pans)
Altitude: c. 600 m asl (Sossusvlei); c. 700 m asl (Tsondabvlei)
Nearest Town: Mariental (130 km NE)

General: The Naukluft Group of Mountains (24°14'S/16°11'E) is part of the main range, but is isolated from it by deep valleys. They are situated about 175 km inland and some 200 km SW of Windhoek, and comprise gorges, caves and springs, which have deeply eroded the dolomite formation. Two ephemeral rivers rise here, the Tsondab on the northern side of the group, and the Tsauchab on the south. When they carry water both streams flow coastwards into the sand desert of the Namib, where each terminates in a vast clay pan surrounded by dune summits 300 m asl.

Once it has left the mountains, the Tsauchab disappears abruptly down a narrow gorge in the plain which then becomes progressively wider and shallower until it has lost

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altitude and opens into the sand desert. Here it discharges into Sossusvlei, a clay pan, with a maximum area of c. 2000 ha, which may, in parts, retain water for several months after a flood. However, it does not receive water regularly, and when it does, only small areas of the total pan may be covered. Ridges and fingers of dune sand intrude onto the pan, and these, and the shallowly flooded periphery, carry a scant fringe of trees (many dead) and grassy vegetation. In some places, at high water, tree bases are inundated for weeks on end, and the trees emerge from the temporary lake as green islands set in from its banks. Some small watercourses within the dry pan have semi-permanent pools, fringed by reeds and sedges, and a variety of animals, including gemsbok, springbok and ostriches, feed and drink at these pools. A wealth of wetland birds utilise the pan when it holds water. Sossusvlei is open to the public and is a popular tourist attraction, but access is only by 4 wheel drive vehicles and permits are valid only for one day.

The Tsondab River terminates in Tsondabvlei, a similar but smaller system covering some 1050 ha. This pan is more heavily wooded than Sossusvlei, and supports a large indigenous population of *Torgos tracheliotus*. This area is reserved for scientific research and is not available to the public.

Human Impact & Utilisation: Virtually none, the systems are so remote.

Conservation Status: Both systems, pans and rivers, are located within the Naukluft Mountain Park, established in 1979, and are fully protected.

8. Periodic Streams

General: Throughout northwestern Namibia the most densely vegetated sites are areas of river bed in the valleys of watercourses which rise in the eastern highlands and traverse the desert west-southwestwards towards the Atlantic Ocean. Between the Angolan border and Walvis Bay several such watercourses reach the sea, while others become lost in the dunes of the Namib Desert. All of these have some deeply entrenched sections, and all have sections with braided channels and narrow floodplains. From north to south the most important are the valleys of the Khumib, Hoarusib, Hoanib, Uniab, Huab, Ugab, Omaruru, Swakop and Kuiseb Rivers. Storm rains in the eastern catchments cause these streams to flow vigorously for a few days at a time and they may sometimes come down in flood, inundating their discontinuous floodplain sections. The valley floors quickly become green, and the grasses covering them grow to be 2-3m tall at maturity 3 months later. In some years the river channels carry water more than once, but at other times they may remain unflooded for several consecutive years. After a flood a river quickly dries to a series of pools and moist depressions. Pools tend to be most persistent in deeply shaded gorges or canyons, especially where a depression is occupied by a superficial fill of gravel or rock debris. The river bed sands remain moist below the surface, even in dry years, at depths of 50 cm to 1 m. The floors of the canyon sections may be very hot and exceptionally humid. For example, daytime temperatures of 45°C and night-time temperatures of 35°C are not uncommon in the canyon of the Great Fish River, which is a tributary of the Orange River and the only important river in southern Namibia.

Oases of vegetation occur in the vicinity of springs which trickle from steep canyon sides, or which well up in the stream beds to form permanent waterholes. Many small wetland sites exist along the northern rivers, where pools are usually fringed by

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Phragmites mauritianus, *Cyperus* sp., *Juncus* sp., *Scirpus* sp., and various grasses. Most pools have limited fish faunas, which include barbel, yellowfish, and sometimes bream. Most support small resident bird communities, and act as waterholes for a variety of mammals. Some support a few gnarled *Acacia albida* trees or bushes, but arborescent vegetation is scarce, normally being destroyed when the rivers come down in flood. Some *Phoenix dactylifera* palms flourish at Ai-Ais (27°56'S/17°30'E) in the lower Fish River Canyon, but were doubtless planted. Sandy patches overlying moisture may support straggling vines of the wild prickly cucumber, *Cucumis africanus*, which provides another source of moisture for animals. Adjacent to some of the rivers, patches of xerophytic vegetation emerge from the surrounding sands, over rocky structures which retain moisture.

After a flood, the temporarily lush northern river valleys are visited by several large mammal species, including *Antidorcas marsupialis hofmeyri*, *Diceros bicornis*, *Giraffa camelopardalis*, *Loxodonta africana*, *Panthera leo* and *Tragelaphus strepsiceros*. Lions range along these valleys as far west as the coast where they are known to have killed seals, while jackals *(Canis mesomelas)* which will eat dead seals, crabs, and young and dying seabirds, are common all along the Skeleton Coast. Black rhinoceroses are now very uncommon in the river valleys, but have been recorded in the Hoanib Valley in recent years.

Hot springs, rich in fluoride, chloride and sulphate, occur at two points along the Great Fish River, as it traverses its 160 km long canyon. The best known is at Ai-Ais (27°56'S/17°30'E) near the mouth of the canyon, which has been turned into a spa, but another, some 65 km upstream (27°40'S/17°36'E) forms a large warm pool, with water temperatures close to 60°C and this is relatively undisturbed. After a normal flood on the Great Fish River, a series of long narrow pools remains on the rock strewn floor of the canyon. These are remarkably persistent, despite high ambient temperatures. Humidity is always high in the canyon which in places is only 27 m wide and up to 550 m deep. *Alopochen aegyptiacus* is quite common, and is said to breed in the canyon.

Human Impact & Utilisation: The more isolated northern rivers are virtually undisturbed, except by farmers and herders who occasionally visit them about their duties, but the Great Fish River Canyon is the scene of foot safaris, organised from the resort at Ai-Ais. However, since the full traverse of the canyon takes about 20 days, this is not frequently undertaken. The lower pools of the canyon are, nevertheless, often the scene of bathing parties and picnics.

Conservation Status: Most of the Kuiseb River valley and canyon is contained in the Namib-Naukluft Park and is fully protected. The lower 40 km or so of a number of other streams cross the northern desert region of the Skeleton Coast Park, and are also protected. However, most of the course of the Great Fish River is unprotected.

9. Artificial Impoundments

(A) HARDAP DAM

General: The principal impoundment is the Hardap Dam 24 km north of Mariental (24°36'S/17°59'E) at the head of the Great Fish River. The dam is set in the Hardap

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Recreation Resort and the lake covers 2500 ha at capacity and stores 323 million m^3 of water behind a dam wall 39.2 m high. Hotels, restaurants and other tourist facilities are available and the lake caters for all manner of aquatic sports from water-skiing and wind-surfing to swimming and angling. The dam is well stocked with fish and there is a fish research unit in the park. There is also a substantial and well stocked game reserve, animals from which utilise the lake.

(B) AUGEIGAS DAM

General: The Augeigas Dam, a smaller dam, is set in the Daan Viljoen Game Park, 2000 m asl in the Khomas Highlands, 24 km west of Windhoek (22°34'S/17°06'E). The lake has been made into a tourist venue, with hotels and restaurants, and the shores have been planted about with exotic trees. The waters are well stocked with fish and a variety of game animals roam freely in the park. Some 200 species of birds have been observed on the lake, and there are resident populations of coot, wild ducks and geese.

(C) SARTORIUS VON BACH DAM

General: This is situated close to Okahandja (21°59'S/16°58'E), 1500 m asl, in a Recreational Resort some 75 km north of Windhoek. No permanent accommodation exists in the park but camping is permitted, and angling in the lake is by license.

(D) NAUTE DAM

General: The Löwen River is impounded to form the Naute Reservoir (26°57'S/17°58'-18°01'E) south of Keetmanshoop.

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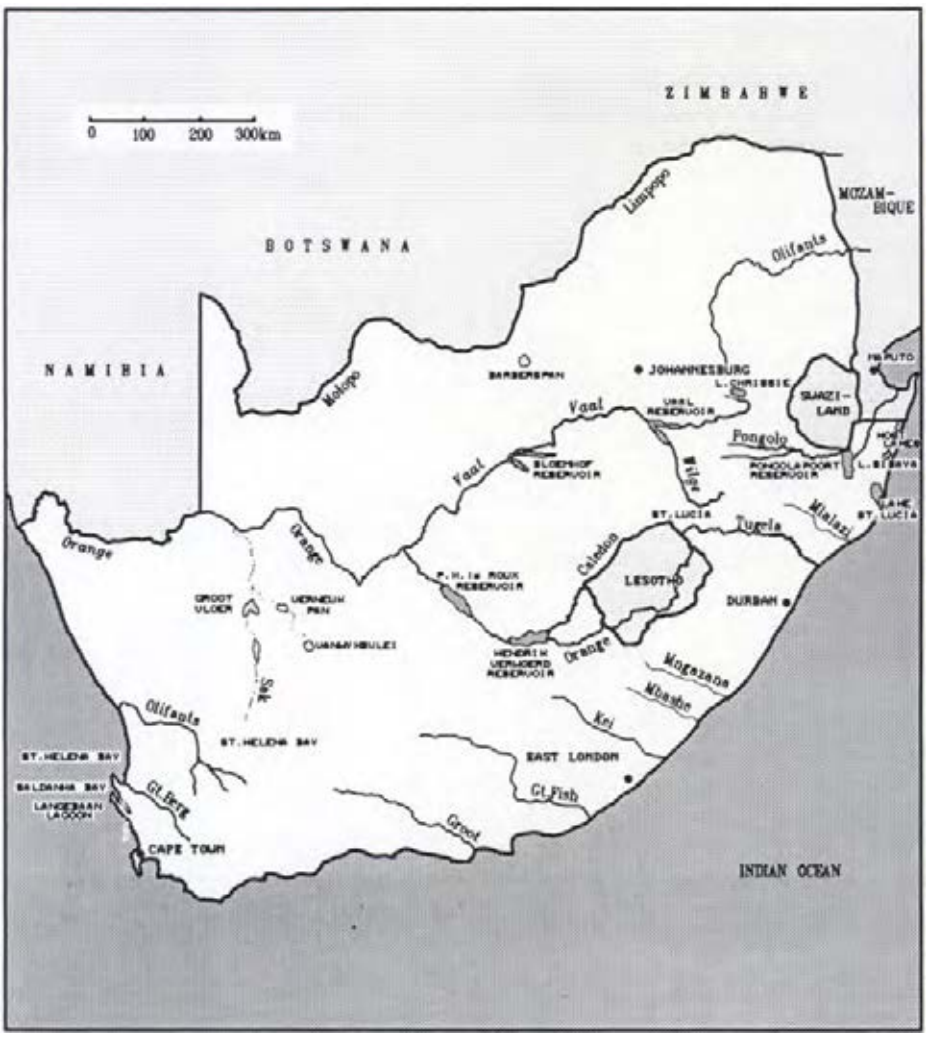

Map of South Africa

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5.7 SOUTH AFRICA

Introduction

South Africa is the second largest country in Region 5, with an area of 1 184 825 km^2. It has a population of 26 124 000 (1983) and therefore a mean population density of 22 persons/km^2. However, the population is heavily concentrated in the eastern half of the country and apart from the southern coastal strip, most of the west has a population density of 2 persons/km^2 or less. South Africa extends 1400 km from north to south, between latitudes 22°10' and 34°50'S and 1619 km from west to east, between longitudes 16°30'E (Alexander Bay) and 32°52'E (Kosi Bay). It has the longest national coastline in Africa, exceeding 3000 km. It is the only country on the continent to be washed by both the Atlantic and Indian Oceans, and these, by their opposing influences, are important determinants of its climate. Cold polar waters on the Atlantic coast bring arid conditions to the west, while the warm tropical waters of the Agulhas Current lead to reliable precipitation on the eastern and southern coasts.

There is a narrow coastal plain all around the country, widening in Zululand, in the northeast, to some 80 km. On both east and west coasts, the mountains backing the plain lead up through foothills and a series of scarps and minor plateaux, to the great central plateau discussed in the introduction to the region. There, most of the surface lies above the 1000 m contour and comprises flat or gently undulating land which slopes towards the northwest, away from the high southeastern rim formed by the Drakensberg Mountains. The interior plateau reaches its lowest levels along the borders of Botswana and Namibia, at elevations of 600-700 m asl, in the vast shallow sandy valley of the now seasonal, and sometimes perennially dry, Molopo River.

The southern coastal plain is backed by several ranges of ancient fold mountains, quite separate from the great massif which forms the central plateau. These include the Langeberg, Swartberg, Kougaberge and some ancillary ranges. They rise to heights of over 2000 m and descend, on their northern flanks, to the Great Karroo, a subsidiary plateau which intervenes between the southern coast ranges and the main escarpment of the interior plateau. In places the southern flanks of the coast ranges reach the sea, thus interrupting the coastal plain. All streams of the west coast between the Orange and Olifants Rivers are seasonal. Thereafter, along the south coast, almost all streams are perennial, although highly seasonal in their discharge. All large streams are perennial on the east coast, but towards the north, in Zululand, some small rivers which rise on the coastal plain or its immediate hinterland, are again seasonal.

Climate

For up to seven months of the year (April-October), when high pressure prevails over the interior, the country is predominantly influenced by descending divergent upper air masses that tend to circulate eastwards causing fine weather and minimal precipitation. Southwesterly and southerly winds bring rain to the southern coastal plain and mountains in winter (April-September), while southeasterly and northeasterly winds, blowing off the Indian Ocean, bring rain to the east coast during summer (October-March). The west coast and western interior is very dry, as is the Great Karroo which is in the rainshadow

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of the coast ranges. Temperatures frequently reach 40°C in the western and northern interior regions in summer, and may occasionally reach this figure in northern Natal. Frosts are common on the mountains and in the central interior during the winter. Severe hailstorms can occur over almost any part of the country in spring and summer, and have been known to kill large animals, and to decimate huge flocks of birds.

Wetlands

With the exception of the St Lucia system, there are no wetlands of great magnitude in South Africa, but because of the small total extent of wetlands in such a large and predominantly arid country, most sites are of considerable biological and national importance. Several are of international importance as the breeding sites and the southern terminals for numerous species of birds migrating between continents.

The most important and best known South African wetlands are coastal; either estuarine systems, or lakes, swamps, marshes, floodplains and pans on the long coastal plain. On the high mountains of the south and east there are extensive sponges and peat bogs, and perennial herbaceous swamps on many valley floors. On the central plateau, there are a host of seasonal pans, some endorheic lakes, and numerous artificial impoundments, with some small and very irregularly inundated floodplains.

Wetland Flora

Saltmarshes: The lowest reaches of saltmarshes are dominated by *Zostera capensis*, often with some *Spartina maritima* above this. The higher levels support such species as *Chenolea diffusa, Cyperus fastigiatus, C. marginatus, Juncus krausii, Limonium scabrum, Sarcocornia natalensis, S. perennis, Scirpus maritimus, S. triqueter, Triglochin bulbosa* and *T. striata*. *Mesembryanthemum crystallinum* occurs on salt pans of the southern and southwestern coasts.

Mangroves: Mangroves occur only on the east coast, beginning just north of East London at the Nahoon River mouth (32°59'S/28°58'E). Thereafter they occur at the mouths of most streams in Transkei, but the southernmost sites contain only *Avicennia marina* in open stands under which saltmarsh species flourish. *Bruguiera gymnorrhiza* joins *Avicennia* in the mangroves on the Mbashe Estuary (32°14'S/28°55'E) and *Rhizophora mucronata* joins the association at the Mngazana Estuary (31°42'S/29°25'E). *Hibiscus tiliaceus* is also present here, but may occur to the south. From Mngazana northwards all four species occur in the tidal forests, although *Rhizophora* is not present in all sites. In the most northern mangrove swamp, at Kosi Bay, *Ceriops tagal* and *Lumnitzera racemosa* also enter the association. *Acrostichum aureum* is found in the landward mangrove, under an open canopy, and also occurs in reed swamp where this occurs adjacent to the mangrove. A number of other species, trees and shrubs, are found on the mangrove fringes in northern Natal, all subject to periodic tidal inundation. These include some freshwater swamp forest species and some characteristic of dune or riverine forest. Among the more common are *Acacia karroo, Allophyllus natalensis, Apodytes dimidiata, Barringtonia racemosa, Brachylaena discolor, Casuarina equisetifolia, Chrysanthemoides monilifera, Erythrina lysistemon, Garcinia livingstonei, Macaranga capensis, Phoenix reclinata, Schinus terebinthifolius* and *Syzygium cordatum*.

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Coastal Freshwater Swamp Forest: Here *Barringtonia racemosa, Cnestis natalensis, Ficus burtt-davyi, F. sur, F. trichopoda, F. vogelii, Garcinia livingstonei, Hibiscus diversifolius, Macaranga capensis, Myrica serrata, Phoenix reclinata, Rauvolffia caffra, Schefflera umbellifera, Syzygium cordatum* and *Voacanga thouarsii* are characteristic species. Several woody lianes, including *Abrus precatorius, Dalbergia armata* and *Entada pursaetha* may climb in the trees, which often stand with their trunk bases submerged for many consecutive months. Other climbers include the fern *Stenochlaena tenuifolia* as well as *Capparis sp., Gloriosa superba, Rhoicissus digitata, Secamone frutescens* and *Smilax kraussiana*. Near the sea, little bushes of *Cassia bicapsularis* and patches of the coarse terrestrial fern *Acrostichum aureum* abound in open spaces between clumps of trees where *Cladium* sp., *Scirpus littoralis* and *Stenotaphrum secundatum* cover the ground. Here there are also many trailing plants, *Ipomoea* spp., a terrestrial orchid *Platylepis glandulosus* and numerous bulb plants such as *Haemanthus katherinae* and *Crinum* spp. This type of vegetation may have a transition with typical mangrove vegetation on coastal lagoons and estuaries. The naturalised herbs *Conyza bonariensis* and *C. floribunda* are locally abundant on the fringes of this vegetation.

Riverine Forest or Thicket: This is best developed in the east and is floristically very rich. Constituent species include *Acacia caffra, A. schweinfurthii, A. sieberana, Acokanthera oppositifolia, Allophyllus africanus, A. decipiens, Artabotrys brachypetalus, Balanites maughamii, B. pedicellaris, Bauhinia tomentosa, Cassia petersiana, Cassine aethiopica, Choetacme aristata, Clausena anisata, Cordyla africana, Dalbergia armata, Ficus soldanella, F. sycomorus, Hugonia orientalis, Millettia stuhlmannii, Papea capensis, Phyllanthus reticulatus, Psoralea pinnata, Rhus lancea, Sesbania sesban, Strychnos spinosa, Trema orientalis* and *Trichelia emetica*.

Reed Swamps: These are dominated by *Phragmites australis* or *P. mauritianus* depending upon site. The former species is able to tolerate moderate levels of salinity and is often present behind mangrove stands and along estuaries, and often occludes shallow coastal lakes and lagoons. *Typha capensis* frequently forms patches in the *Phragmites* swamp, and on the landward sides, reed swamps often give way to lower growing sedges e.g. *Eleocharis* spp., *Scirpus littoralis* and *S. nodosus*, or swards of *Juncus acutus* and, or *J. krausii*. A number of climbers occur in the fringes of the *Phragmites* swamps, chiefly species of *Ipomoea*. Often there are grasses around the landward fringes, e.g. *Sporobalus virginicus* in saline areas, giving way to *Stenotaphrum secundatum* and *Dactyloctenium geminatum* behind, the latter in wet and the former in drier sites.

In deeper water, outside the *Phragmites* swamp, floating-leaved and free-floating species may carpet the water. Among the former, *Nymphaea caerulea* and *N. capensis* are widespread, while *Lemna gibba* and *Spirodela* spp., are free-floating species. *Eichhornia crassipes* occurs in many systems in Natal, often fully occluding small lakes and estuaries, while *Salvinia molesta* has been identified in other systems. *Leersia hexandra* and *Ludwigia stolonifera* often form masses in the water around the banks. Below the water, and floating at its surface, there may be meadows of *Ceratophyllum demersum, Myriophyllum spicatum, Najas marina, N. pectinata, Potamogeton pectinatus, P. schweinfurthii, Ruppia marina* (near coast), *R. spiralis* and *Utricularia inflexa*.

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Papyrus Swamps: *Cyperus papyrus* is important in northern Natal where it dominates large areas subject to marked seasonal fluctuations in water level. Usually it is associated with *Phragmites mauritianus, Typha capensis* and several lower growing species.

Montane Wetlands: The high alpine sponge bogs are dominated by short mat-forming angiosperms, including both stoloniferous and rosette plants. Common species include the composites *Athrixia fontana, Berkehya multijuga, Haplocarpha nervosa, H. scaposa*, and occasionally *Helichrysum palustre*, also a grass, *Agrostis huttoniae*, sedges, *Carex* spp., *Schoenoxiphium filiforme* and *Scirpus fluitans*, a rush, *Luzulua africana*, and *Limosella capensis, L. grandiflora* and *L. longiflora* (Scrophulariaceae). Algae dominate the submerged vegetation of pools which occur over springs in the sponges, where species of *Lyngbia, Nitella* and *Spirogyra* are most important. *Aponogeton spathaceum* and *Crassula natans* are generally the only true aquatic angiosperms present, but *Limosella* spp. frequently grow in the water with floating leaves. Mosses fringe pools and occur in the ground layer of the sponge, but *Sphagnum* spp., the aquatic bog-forming mosses of the northern hemisphere, are absent. *Grimmia apocarpa* and a species of *Mnium* are most important. Around the drier margins of the bog, but still on peat soil, *Elsiea flanaganii, Eragrostis caesia, Eriocaulon baurii, Geum capense, Kniphofia caulescens, Koeleria cristata, Moraea* spp., *Ranunculus baurii, Rhodohypoxis rubella, Sebaea thodeana* and *Senecio cryptolanatus* grow densely between occasional tussocks of *Danthonia drakensbergensis. Geranium incanum, Oxalis depressa* and *Trifolium burchellianum* grow on hummocks in the bog, as well as on the periphery.

At lower elevations, the pale green and much taller *Kniphofia caulescens* grows profusely in bogs together with *Juncus glaucus* var. *acutissimus* and a number of tall sedges. *Danthonia* tussocks again characterise the margins. The vegetation of these bogs is taller than that of the surrounding grassland. Many orchids grow in these bogs, including *Brownleea macroceras, Habenaria cornuta, Holothrix incurva, Satyrium crassatum, S. macrophyllum* and *S. neglectum*, together with a variety of alpine herbs.

Tiny streamlets in the alpine zone are fringed by herbaceous communities up to 1 m high, usually dominated by the tussock grasses *Danthonia drakensbergensis* and *D. macowanii*, but with *Berkheya multijuga, Carex* spp., *Juncus exsertus, Kniphofia caulescens, Polygonum salicifolium, Rhodohypoxis rubella, Senecio achilleifolius*, and *S. cryptolanatus* between tussocks, and, in places, low woody shrubs of *Cliffortia browniana, Erica thodei, E. alopecurus* and *Euyops montanus*.

Lower down the mountains, between 2000-1600 m asl, aquatic and hygrophilous communities are numerous but usually of small size. In occasional tarns, and in open water in upland valley swamps, some algae, and the aquatic mosses *Philonotus laeviuscula* and *P. afromontana*, dominate the submerged community. *Aponogeton junceus* and *Crassula natans* occur in open water, and around the margins, in very shallow water, plants such as *Anagallis huttonii, Crassula natans, Ericocaulon abyssinicum, E. dregei, Limosella capensis, L. maior* and *Scirpus fluitans* occur, with a taller fringe of *Cyperus fastigiatus, Juncus exsertus* and *Polygonum strigosum* at the margins, gradually encroaching upon the water as sedimentation procedes. Eventually the open water surface is lost and the pool is occluded by a taller community of the grasses *Arundinella nepalensis, Danthonia disticha* and *Pennisetum thunbergii*, with the sedges *Eleocharis dregeana, Rhynchospora brownii, Scirpus ficinlodes* and *S. macer*, the rushes *Juncus*

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exsertus and *J. rostratus* and a few other herbs, e.g. *Anoiganthus breviflorus* and *Gunnera perpensa*.

Similar communities develop along foothill streams and here a wide range of other species creeps in as the community ages. These include *Anemone fannanii, Aristea angolensis, Berkheya macrocephala, Helichrysum* spp., *Calpurnia woodii, Chironia krebsii, Cyrtanthus flanaganii, Disa fragrans, Drosera natalensis, Geranium ornithopodum, Gladiolus papilio, Moraea spathulata, Rabdosia calycina, Satyrium neglectum* and *Tysonia africana*. Later hydrosere stages include tall grasses, exceeding 2 m in height, such as *Cymbopogon validus, Hyparrhenia aucta* and *Miscanthidium capense*.

On flatter sites that are only seasonally flooded, sedges dominate the vegetation, including *Ascolepis capensis, Bulbostylis schoenoides, Fuirena pubescens, Kyllinga erecta, Mariscus congestus, Pycreus oakfortensis, Scleria welwitschii* and *S. woodii*. Hygrophilous grasses follow in the succession, including *Agrostis huttoniae, A. lachnantha, Andropagon appendiculatus, A. eucomus* and *Stiburus alopecuroides*. There are also many lilies, e.g. *Agapanthus campanulatus, A. nutans, Galtonia candicans* and *Tulbaghia natalensis* together with various Iridaceae such as *Aristea woodii, Dietes vegata, Hesperantha lactea, Moraea modesta* and sometimes hypoxidaceous species, e.g. *Hypoxis acuminata, H. filiformis* and *H. gerrardii*.

Wetland Fauna

Invertebrates: The freshwater crab *Potamonautes sidneyi* is widely distributed, ranging from coastal lakes to mountain streams. In southern and southwestern estuaries *Anurida maritima, Assiminea globulus, Deto echinata, Exosphaeroma hylecoetes, Hymenosoma orbiculare, Orchestia rectipalma* and *Palaemon pacificus* are abundant in algal weed beds, while *Cyclograpsus punctatus* dominates the mudbanks and *Callianassa kraussi* is abundant in sand. This latter species also occurs in mudbanks if *Upogebia africana* is absent.

The invertebrate fauna of the mangrove clad, east coast estuaries comprises over 200 benthic species. *Solen cylindraceus* and *Tharyx marioni* occur in the anoxic mud below the low water mark of spring tides. Higher up the shore, in the mud of the *Zostera* beds, *Aglaia capensis, Alpheus crassimanus, Ceratonereis erythraeensis, C. keiskamma, Cirriformia tentaculata, Cleistostoma algoense, Clibanarius longitarsus, Dosinia hepatica, Grandidierella bonneroides, Melita zeylanica, Metapenaeus monoceros, Nassarius kraussiana, Natica* sp., *Orbinia angrapaquensis, Palaemon pacificus, Penaeus indicus, P. monodon* and *Upogebia africana* also feed there. Under the mangroves *Assiminea bifasciata, Cerithidea decollata* and *Littorina scabra* occur in vast numbers and ascend the mangrove trunks. *Sesarma catenata* and *Terebralia palustris* also occur here, the former often climbing into the trees. *Scylla serrata* is common towards the seaward face of the mangroves. *Uca annulipes, U. chlorophthalmus, U. urvillei* and *U. vocans* are found in the mangroves but are most prolific on the fringes, where *Ilyograpsus rhizophorae, Sesarma guttata* and *S. meinerti* may be abundant.

Orchestia rectipalma and *Perinereis falsovariegata* occur in the patchy algal bostrychietum on the pneumatophores of *Avicennia*. *Balanus amphitrite* and *Crassostraea cucullata* and calcareous tubeworms attach to mangrove roots, and logs embedded in the mud, almost to the limit of tidal influence. *Martesia striata* (lamellibranch) also occurs

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in estuaries, and nests of *Oecophylla* spp. and the webs of spiders, e.g. *Gasteracantha* spp., are found in the trees.

Fish: Freshwater fishes of the southwestern and southern coasts include *Barbus burgi, Galaxias zebratus* and *Sandelia capensis*. Among estuarine species there are *Argyrosomus hololepidotus, Gilchristella aestuarius, Gobius multifasciatus, Hepsetia breviceps, Lithognathus lithognathus, Liza richardsoni, Mugil cephalus, Psammogobius knysnaensis* and *Rhabdosargus globiceps*. However, several species have been introduced, e.g. *Cyprinus carpio* and *Oreochromis mossambicus*.

The fauna of eastern estuaries and estuarine lakes is richer. *Periophthalmus kalolo* occurs throughout the mangroves. *Acanthopagrus berda, Alestes imberi, Ambassis commersoni, Anguilla bicolor, Argyrosomus hololepidotus, Barbus paludinosus, B. toppini, B. trimaculatus, Clarias gariepinus, C. ngamensis, Coryphopterus multifasciatus, Ctenopoma multispinis, Eutropius depressirostris, Gilchristella aestuarius, Glossogobius giuris, Hydrocynus vittatus, Hypseleotris dayi, Labeo rosae, L. rubropunctatus, Liza macrolepis, Marcusenius macrolepidotus, Mugil cephalus, Mugilogobius durbanensis, Neobola brevianalis, Nothobranchius orthonotus, Oreochromis mossambicus, Pomadasys commersonni, Rhabdosargus sarba. Tilapia rendalli* and *T. sparrmanii* are some of the others found in Natal.

Amphibians: A number of frogs and toads have been recorded in southern coastal swamps including *Bufo pardalis, B. rangeri, Hyperolius horstocki* and *Rana grayi*, but there are rather more in the northeast. Here *Afrixalus fornasinii, A. spinifrons, Arthroleptis stenodactylus, A. wahlbergi, Bufo regularis, Cacosternum boettgeri, Chiromantis xerampelina, Hemisus marmoratum, Hylambates maculatus, Hyperolius marmoratus, H. nasutus, H. puncticulatus, H. pusillus, H. semidiscus, H. taeniatus, H. tuberilinguis, Kassina senegalensis, Leptopelis natalensis, Phrynobatrachus natalensis, Phrynomerus bifasciata, Ptychadena oxyrhynchus, Pyxicephalu adspersus, P. natalensis, Rana angolensis, R fasciata, R. grayi, R. vertebralis, R. wageri* and *Xenopus laevis* are found in wetland situations.

Amphibians also occur in montane wetlands. *Bufo gariepinus* and *Rana hymenopus* reach the summit plateau at over 3000 m asl. Others exhibit a wide altitudinal range and are found from the lower slopes up to the summit plateau. These include *Breviceps adspersus, Bufo gutturalis, Cacosternum boettgeri, Heleophryne natalensis, Kassina senegalensis, Phrynobatrachus natalensis, Pyxicephalus natalensis, P. adspersus, Rana angolensis, R fasciata, R. grayi* and *R. vertebralis*. Typically these species occur close to water, or damp swampy ground.

Reptiles: *Acontias plumbeus, Brachypodion pumilum, Crocodylus niloticus, Pelosios sinuatus, Varanus exanthematicus* and *V. niloticus* occur in the northern coastal wetlands. *Lygodactylus capensis* occurs in southern reed swamps and the terrapin *Pelomedusa subrufra* occurs from the Cape northwards. Common snakes in coastal wetlands include *Aparallactus capensis, Crotophopeltis hotamboeia, Lycodonomorphus laevissimus, L. rufulus, Naja melanoleuca, Natriciteres variegata sylvatica, Philothomnus angolensis, P. hoplogaster, P. irregularis, P. natalensis* and *Python sebae*, while arboreal snakes found in swamp forest trees include *Dasypeltis scabra, Dendroaspis angusticeps, Philothomnus semivariegatus* and *Thelotornis capensis*. Some species range high into the mountains, favouring damp locations and feeding very largely upon amphibians, e.g. *Lycodonomorphus rufulus, Lycophidion capense* and *Philothamnus natalensis*.

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Birds: Birds associated with South African wetlands, and fairly widely distributed, include *Actophilornis africanus, Anhinga anhinga, Ardea cinerea, A. goliath, A. melanocephala, A. purpurea, Arenaria interpres, Bubo africanus, Bubulcus ibis, Butorides striatus, Calidris alba, C. ferruginea, C. minuta, Ceryle rudis, Charadrius marginatus, C. pecuarius, C. tricollaris, C. hiaticula, Corythornis cristata, Egretta garzetta, E. intermedia, Fringillaria capensis, Fulica cristata, Gallinula chloropus, Glareola pratincola, Haematopus moquini, Halcyon senegalensis, Haliaeetus vocifer, Himantopus himantopus, Hoplapterus armatus, Hydroprogne caspia, Ixobrychus minutus, Limnocorax flavirostris, Megaceryle maxima, Nycticorax nycticorax, Pelicanus onocrotalus, Phalacrocorax africanus, P. capensis, P. carbo, P. coronatus, P. neglectus, Phoeniconaias minor, Phoenicopterus ruber, Platalea alba, Plegadis falcinellus, Philomachus pugnax, Porphyrio porphyrio, Recurvirostra avosetta, Scopus umbretta, Scotopelia peli, Speniscus demersus, Squatarola squatarola, Stephanibyx coronatus, Sterna bergii, Tachybaptus ruficollis, Threskiornis aethiopicus, Tringa nebularia* and *Tyto capensis.*

Many bird species occur in the mountains, the majority at lower elevations where habitats are more diverse. Species commonly seen in mountain swamps include *Anthropoides paradisea, Ardea melanocephala, Asio capensis, Bubo africanus, Bubulcus ibis, Burhinus capensis, Buteo buteo, B. rufofuscus, Circus ranivorus, Elanus caeruleus, Francolinus levaillantii, Geronticus calvus, Hagedashia hagedash, Milvus aegyptius, Numida meleagris, Scopus umbretta* and *Tyto alba.*

Mammals: Mammals found in southern and southwestern coastal swamps include *Aonyx capensis, Atilax paludinosus, Felis caracal, F. lybica, Genetta tigrina, Herpestes ichneumon* and *Paplo ursinus. Mirounga leonina* enters many estuaries. Other small mammals found on coastal floodplains and vlei margins include *Crocidura flavescens, Myosorex varius, Otomys irroratus* and *Rhabdomys pumilio.* The first 6 of these also occur in northern wetlands.

Cercopithecus pygerythrus is common in the canopy and on the ground in mangroves and freshwater swamp forests, which are both also frequented by *Cephalophus monticola, Redunca arundinum* and *Tragecephalus scriptus* in parts of Natal. *Dasymys incomtus* and *Otomys angoniensis* are found throughout the northern wetlands, including tidal swamps. Other mammals found in northern wetlands include *Aepyceros melampus, Canis mesomelas, Cephalophus natalensis, Cercopithecus albogularis, Crocidura cyanea, Cryptomys hottentotus, Cynictis penicillata, Felis serval, Hippapotamus amphibius, Ictonyx striatus, Lutra maculicollis, Neotragus moschatus, Orycteropus afer, Otomys irroratus, Panthera pardus, Pellamys fallax, Potamochoerus porcus, Praomys natalensis, Proteles cristatus* (St Lucia), *Rattus rattus, Rhabdomys pumilio, Sylvicapra grimmia, Thryonomys swinderianus, Tragelaphus angasi* and *Vulpes chama.*

Mammals associated with montane wetlands include *Aonyx capensis, Atilax paludinosus, Genetta tigrina, Ichneumia albicauda, Lutra maculicollis, Otomys irroratus* and *Otomys sloggetti* (up to 3000 m asl). *Rhabdomys pumilio* and *Redunca arundinum* frequent the valley swamps, while *Tragelaphus scriptus* and *Sylvicapra grimmia* are locally common in streamside thickets.

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List of Wetlands Described

1. Tidal Wetlands
   (a) Minor Systems
   (b) The Kosi Lake System
2. Coastal Lakes & Swamps
   (a) Minor Systems
   (b) The St Lucia Lake System
   (c) Lake Sibaya
3. Riverine Floodplains & Swamps
   (a) Minor Systems
   (b) The Pongolo River Floodplain
   (c) The North Mosi Swamp
4. Lakes & Pans of the Interior
   (a) Minor Pans
   (b) Barberspan
5. Montane Wetlands
6. Artificial Impoundments
   (a) Hendrik Verwoerd Dam
   (b) Vaal Dam
   (c) Bloemhof Dam
   (d) The P.K. le Roux Dam
   (e) Pongolapoort Dam

1. Tidal Wetlands

(A) MINOR SYSTEMS

General: Small tidal wetlands occur at the mouths of many streams and rivers and tidal swamps or marshs occur in every estuary, all of which are listed with brief details of catchment size, run-off, human impact and current utilisation by Noble & Hemens (1978), while the 70 estuaries of Natal are dealt with in rather more detail by Begg (1978). The large number of very small sites precludes an individual account of each being given here.

Herbaceous saltmarsh vegetation occupies the intertidal zones of the southern and southwestern coasts, while on the warmer eastern coasts, influenced by the Mozambique Current, mangroves occur. The most southerly stand is at the mouth of the Nahoon River (32°59'S/28°58'E). This is a sparse monospecific stand of *Avicennia marina*, but the mangrove association becomes richer and more complex in passing northwards, as indicated in the introduction. Ward & Steinke (1982) give a brief account of the distribution and approximate areas of mangrove vegetation in the country.

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On the east coast streams tend to be deflected by the powerful longshore drift, and their lower reaches tend to become long lagoons parallel to the sea but separated from it by dune covered spits. In consequence the mouths of most seasonal streams are closed by sand bars in the dry season. However, if the stream mouth is generally open and its estuary or lagoon is tidal, its shores tend to be colonised by mangroves. Upstream the tidal woodland may grade into freshwater swamp forest, while to landward of the mangroves there may be a reed swamp. This in turn may grade into a floristically diverse herb marsh at its landward fringe, or into bare mudflats, or a saline herb field, depending upon local levels of soil salinity.

Tidal marshes occur at the mouths of the Orange River (28°39'S/16°27'E) and Olifants River (31°43'S/18°11'E). The mouth of the Orange is largely closed by a bar and the lagoonal area behind it is flushed regularly through a narrow mouth by the tides. When high floods come downstream the bar is breached in many places and the small saltmarshes are inundated by freshwater. The Olifants River has a narrow estuarine section up which tides penetrate for 32 km, periodically flooding the peripheral marshes. The small intervening streams between the Orange and the Olifants are not perennial and they do not support important wetlands. A small saltmarsh/salina system occurs farther south at the mouth of the Verloren Lagoon (32°23'S/18°20'E) which is often closed. The system is fed by a small, but perennial rivulet. When the mouth is open the narrow lagoon and estuary, and sometimes the lake into which the estuary widens upstream, become tidal. Here there are about 1000 ha of wetland, including the lake and its fringing reed swamps, and a valley swamp along the lower reaches of the Verloren rivulet. Grindley *et al.* (1980) give an account of this system.

Immediately to the south, saltmarshes, reed swamps and salt pans occur on the estuary and floodplain of the Great Berg River (32°46'-32°54'S/18°09'-19'E) covering a total of some 5000 ha. The Great Berg River loses only 1 m in altitude over the last 50 km of its course, meandering on a narrow floodplain. During high water in winter the river is turbid and fresh almost to its mouth, where salinities then vary from 2-6‰, with temperatures of 11-15°C. By contrast, in summer, when flow is reduced and sea water enters the estuary, salinities always exceed 25‰ at high tide, and frequently reach 35‰, while temperatures reach 27°C. The river is tidal for 70 km, and saline influence is felt at least 50 km upstream. Surface salinities of 9‰ were recorded 45 km upstream in February 1979. Heavy rains, combined with high tides, flood the reed swamps that fringe the river, as well as a series of temporary salt pans along the edges of the floodplain. Inundation of the pans is altogether a much more temporary event than inundation of the *Phragmites* and *Juncus* swamps. These are more than 1 km wide in places, but alternate from one side of the river to the other, upstream.

Another substantial wetland, covering 7252 ha, is situated at Langebaan Lagoon (33°04-33°13'S/18°03'E). The lagoon is an open tidal sea water lagoon, oriented SE-NW, which opens to the southern shore of Saldanha Bay. It is 15 km long, up to 3.7 km wide and reaches 6 m in depth. Some 60% of its area is open water, 30% is intertidal saltmarsh, and 10% is herbaceous swampland. Numerous muddy islands are emergent at low tide. The lagoon is separated from the Atlantic Ocean on the western side by a stony spit of land about 1.5 km wide which rises towards the mouth at the northern end, to two hills 188 and 192 m high. Along this side the shores are steep, with deep water

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close inshore. By contrast, the eastern, 'inland', shore is flat and sandy and fringed by low dunes. Here there is a broad intertidal zone, in one place 2 km wide, while behind the dunes are some salt pans, flooded only by spring high tides. A seasonal stream enters the head of the lagoon in the south, through a reed/sedge swamp. Two high islands, Meeuw and Schaapen, are situated in the mouth of the lagoon which is 1.7 km wide. Maximum tidal amplitude is reduced from 1.7 m at the mouth to 1.4 m at the head of the lagoon, and currents of 1 m/sec are generated at the mouth on the ebb tide. The lagoon hinterland is arid, bleak and windswept.

In passing eastwards along the south coast, small, sometimes very small, tidal saltmarshes are found in the Palmiet, Kleinmond, Uilskraal, Heuningnes, Bree, Duiwenhoks, Kafferkuils, Gouritz, Klein Brak, Groot Brak, Kaaimans, Touw, Swartvlei, Goukamma, Keurbooms, Elandsbos, Storms, Klipdrif, Krom, Gamtoos, Swartkops, Sundays, Bushmans, Kowie, Fish, Keiskamma, Ngqinisa, Kiwane, Gxulu and Buffalo Estuaries. Some of these are not permanently open to the sea including the Gamtoos, Goukamma, Swartvlei, Touw, Kaaimans and Heuningnes estuaries.

Farther north, mangroves and a saltmarsh occur at the Nahoon River mouth, and in passing up the coast towards Natal, trees become an increasingly important feature of tidal marshes. Not all of the host of streams reaching the Transkei and Natal coasts carry mangroves however, and where they do the stands are very small, some less than a hectare. Many carry only *Avicennia marina*.

The first well developed mangrove swamp is in the Mngazana Estuary (31°42'S/29°25'E) which has a total wetland area, including open water, of 260 ha. The Mngazana River, some 150 km long, drains a small catchment (c. 350 km^2) in the coastal hills of Transkei. The estuarine section of the river is about 6 km long and increases in width from 40 to 400 m in proceeding downstream, but narrowing again to 50 m at the mouth. Mean spring tidal amplitude at the mouth is 1.5 m, decreasing to 70 cm at the weir which now forms the head of the estuary. The river is perennial and the mouth is permanently open, being sheltered by a rocky promontory on the south side. Water depth increases from 30 cm at the head of the estuary to a maximum of 2.5 m near the mouth. Immediately behind the mouth the lagoon is 400 m wide, with several shifting mudbanks, and in this region the river receives three small tributaries. The estuarine part of the system comprises a total of 110 ha of open water and about 150 ha of peripheral mangrove and saltmarsh communities. The gently shelving shores of the lagoon, much of a large mud island, and the tributary waterways, are densely fringed by mangrove swamps with broad saltmarshes on higher intertidal land. *Avicennia marina, Bruguiera gymnorrhiza* and *Rhizophora mucronata* are the arborescent species. *Zostera capensis* and then *Halophila ovalis* occur in front of the mangroves in progressively deeper water, while *Chenolea diffusa, Cotula coronopifolia, Falkia repens, Samolus porosus, Sarcocornia natalensis, S. perennis* and *Triglochin bulbosa* occur on the adjacent saltmarshes. *Paspalum distichum* occurs on elevated patches in the mangrove, with fringes of *Sporobolus virginicus* and then *Stenotaphrum secundatum* around the landward margins of the saltmarsh. Riverine mangroves, chiefly *Avicennia marina* and *Hibiscus tiliaceus*, extend upstream for over 5 km, although in the upper reaches they are not continuous, occupying only the prograding mudflats on meander bends away from the current. Along the river,

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Cyperus textilis, *Phragmites australis* and *Scirpus litoralis* grow on the banks behind the mangroves.

The invertebrate fauna is quite rich, over 200 benthic species having been recorded, while 62 species of fish have been collected from the estuary, including many of those cited in the introduction as being present in east coast estuaries. Some species are present all the year, but others are seasonal visitors. A list of all recorded fish is given by Branch & Grindley (1979). The avifauna is not well described, but many piscivorous species occur here, including herons, fish eagles and kingfishers. This estuary is at present little disturbed.

In passing northwards again, many small streams are seasonal and many have no important tidal wetlands. Where they do occur, mangrove stands are very small and most are monospecific. There is a mangrove swamp at Sipingo, just south of Durban (29°53'S/31°00'E), while the once extensive swamps in Durban Bay have very largely been cleared. A little over 15 ha remain today. Farther north there are mangroves in the estuaries of the Mgeni (29°48'S/30°02'E) and Mlalazi (28°57'S/31°48'E) Rivers, in Richards Bay, at the Mfolozi River mouth (28°25'S/32°27'E), in the St Lucia (28°24'S/32°27'E) and Mgobezeleni (27°32'S/32°40'E) Estuaries, and in the Kosi Lake system (26°50'-27°11'S/32°38'-32°53'E).

The mouth of the Mlalazi River at Mtunzini has been deflected northwards for 4 km between high forested sand dunes. The mouth has not closed during the past 35 years, but did so several times in the first half of the century, eventually leading to high water levels in the lagoon which killed all mangrove vegetation before the bar was overtopped and breached. Thus the present mangrove stands are comparatively young, *Avicennia* having first been noticed in 1940. That mangrove vegetation previously occurred in the estuary is evident from buried mangrove stumps and oyster beds in several sites upstream of the present lagoon. The river drains a catchment of some 450 km^2 with an estimated mean annual run-off of 139 million m^3 giving a mean discharge rate of 4.5 m^3/sec. However, during a cyclone in February 1984, when 550 mm of rain fell in 48 hours, the discharge rate is estimated to have approached 1600 m^3/sec. The lagoon behind the mouth is 75-280 m wide, 1-3 m deep at high spring tide, has an open water surface of 90 ha and contains numerous emergent mudbanks. In places, dune forest reaches the water's edge, in others the lagoon is fringed by mangroves with a narrow reed swamp behind. Elsewhere mangroves are backed by bare mudflats and saltmarshes where summer temperatures reach 50°C on the soil surface and 35°C at 5 cm depth. On the coastal plain immediately abutting the dunes, the river is flanked by a short swampy floodplain, containing, on the north shore, a small endorheic lake. Mean annual rainfall is close to 1100 mm, and winds are predominantly from the SE and NE. In total there are some 270 ha of wetland and open water.

The mangroves comprise *Avicennia marina* and *Bruguiera gymnorrhiza*, but with *Casuarina equisetifolia*, *Mimusops caffra* and *Sideroxylon inerme* growing at the water's edge, in some quite regularly tidal sites on the lagoon. Several transitional species occur on the fringes of the mangrove and *Phragmites australis* occurs as thin fringes along parts of the river channel, occludes some backwaters, and dominates the reed swamp. *Sporobolus virginicus* and then *Stenotaphrum secundatum* occur on the landward margins of mangrove swamps along the lagoon. Mangroves also grow along watercours-

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es through the saline mudflats where typical saltmarsh species are dominant. Swampy freshwater parts of the floodplain support a surprisingly rich flora, with numerous clumps of trees and intervening high tangles of herbs as indicated in the introduction.

Hill (1966) lists 156 invertebrates and 58 fish in the system, including *Carcharhinus leucas*. He gives information on their distribution and ecology, but Begg (1978) suggests that the fauna has been impoverished since that time, and indeed, in 1971 Hemens found only 15 fish to be present, but this figure probably underestimates current diversity.

Several frogs, including tree frogs, occur on the swampy parts of the floodplain. *Crocodylus niloticus* is uncommon. Over 50 species of birds occur in the system including *Ardea goliath*, *Glareola pratincola*, *Haliaeetus vocifer* and *Sterna bergii*. Vervet monkeys are common both in the canopy and on the ground in the mangroves, while various buck and duiker visit them from the dune forest and there are resident rodents in the peripheral wetlands.

Originally Richards Bay was a shallow coastal lagoon at the mouth of the Mhlatuze River, with an open water area of about 2800 ha. It also received several minor streams and the overflows of Lake Cubhu (400 ha) to the southwest and Lake Mzingazi (970 ha) to the northeast. It was converted to a deep water harbour in the 1970s, when the southern part of the lagoon was separated from the northern part by an artificial berm. The Mhlatuze River has been canalised and discharges into the southern section, and thence to sea via an artificial mouth. A large area of peripheral swamp land has been drained for industrial and residential use around the northern part of the bay, but the southern half of the bay has been declared a wildlife sanctuary. Nevertheless, it is rapidly silting up and being invaded by mangroves. Small areas of freshwater swamp forest and papyrus swamp persist along the southern shores, and another much reduced area of freshwater swamp forest occurs along the lower reaches of the Mzingazi River where it enters the north of the bay. Mean annual precipitation exceeds 1325 mm over the system, 80% falling during the summer, October-March. Summers are hot, winters warm and dry.

The St Lucia Estuary is 20 km long and connects Lake St Lucia (see section 5.7.2b) with the sea. Mean annual precipitation is 1200 mm at the estuary mouth. Annual rainfall variations can be dramatic, e.g. 2057 mm in 1925 but only 530 mm in 1926. The estuary mouth, about 100 m wide, used to close periodically, but is now kept open by dredging. The St Lucia wetlands occupy some 66 000 ha, but only the estuary is regularly tidal. Forests of *Avicennia marina* and *Bruguiera gymnorrhiza* flank the estuary, and also the vicinity of the Mfolozi River mouth immediately to the south.

Human Impact & Utilisation: Many systems are polluted by sewage and some carry industrial wastes. Others have been altered for harbour development, e.g. Saldanha Bay and Richards Bay, and yet others have been altered by the construction of marinas and tourist facilities. The systems most remote from centres of population have in general survived best, but a special problem along the Natal coast is that of siltation caused by bad agricultural practices in the hinterland.

Conservation Status: Systems which enjoy some measure of protection on the east coast are the Mgeni, Mgobezeleni, Mlalazi and St Lucia Estuaries, and part of Richards Bay. On the south and southwestern coasts a number of small systems are protected and Langebaan Lagoon is a crayfish sanctuary.

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(B) THE KOSI LAKE SYSTEM

Location: 26°50'-27°11'S/32°38'-32°53'E
Area: 18 550 ha (c. 4550 ha open water + c. 14 000 ha swampland)
Altitude: 0-5 m asl
Nearest Towns: Ingwavuma (92 km WSW); Durban (363 km SW)

General: The Kosi Lakes lie on the sandy Maputaland coastal plain, some 470 km north-east of Durban. They comprise a series of interconnected, and roughly circular lakes, which open to the Indian Ocean via a shallow estuary near the northern end. They are separated from the ocean by a strip of forested sand dunes 600-2000 m in width and numerous sandy mudbanks, emergent at low tide, occur in the lower part of the system. The total catchment has been estimated as 500 km^2, with the northernmost part draining into Lake Zilondo (Zilonde) in Mozambique. The lakes are fed by four small coastal streams. The largest of these, the Sihadla, rises to the south in the Mtombeni Pans and drains some 13 000 ha of swampy land before entering the southernmost lake. The system was once the estuary of a much larger river, almost certainly the Ingwavuma. Mean annual precipitation over the lakes and much of the catchment is in the region of 950 mm and the climate follows the regional pattern of hot wet summers and cool dry winters.

Hydrology & Water Quality: The small streams drain through reed swamps and clean sands before entering the lakes and bring very little silt with them. The mouth of the estuary is usually open and the system is fully tidal below Lake Mpungwini, but the dimensions of the mouth vary with every tide, its width altering from 5-100 m. Tidal range in the lower part of the estuary is 75 cm at spring tide. Levels at low neap tide are lower than at low spring tide, because water which enters on the spring flood tide does not all escape on the succeeding ebb tide. In August 1965 the mouth closed altogether, and water levels in the system began to rise, a total of about 30 cm in five months. At the beginning of January 1966, during cyclone Claude, 640 mm of rain fell in the catchment and water rose to 1.6 m above normal spring tide level. The mouth was artificially breached 2 weeks later. Much of the peripheral vegetation, including most of the mangrove forest, was killed by the long-term flooding. Maximum water depths, with the mouth open, are 31 m in Lake Nhlange, 18 m in Lake Mpungwini, 8 m in Lake Makhawulani, but only 3 m in the estuary. Lake Amanzimnyama at the southern extremity, farthest from the sea, is very shallow with a maximum depth of 2 m.

The waters are clear and Secchi transparencies of 7.0 m have been obtained, while readings of 3-4 m are the norm. The waters of the lower tidal basin have chemical characteristics similar to sea water, but on occasions during the summer, salinities have been found to fall below 10‰. Lake Mpungwini has a sharp halocline and thermocline at 10 m, the bottom water being highly saline, with a proportional ionic composition similar to that of sea water. Lake Nhlange is not similarly stratified, and is predominantly a freshwater lake, with a salinity range of 0.9-5.6‰. Here the water has an ionic composition different from sea-water. Lake Mpungwini is meromictic, but Lake Nhlange appears to be well mixed. Because of strong N-S winds, the upper waters of Lake Mpungwini show a complex pattern of temperature stratification in summer, but in winter the deep lakes tend to be homothermal. Surface temperatures in the deep lakes range from 19°C in winter to 30°C in summer in open waters, but may exceed 40°C in the shallows in summer. Dissolved oxygen concentrations vary between 7.6-8.6 mg/l at

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the surface and 7.0-7.7 mg/l at 10 m depth, but below this depth in Lake Mpungwini, the bottom waters become anoxic in winter and may contain hydrogen sulphide. Ionic concentrations show regular seasonal changes in the upper waters of Lake Nhlange. Here, principal ion concentrations tend to rise from minima in winter to maxima in summer, and figures for 1967, expressed in mg/l, are sodium 1846-2450; potassium 4-5; calcium 53-84; bicarbonate 121-144; sulphate 209 steady; and silicate steady at 7. Nitrate concentration rose from 52-63 µg/l, while orthophosphate remained steady around 19 µg/l.

Flora & fauna: The shores of the lower tidal basin, the emergent islands, and parts of the shores of Lakes Mpungwini and Nhlange are fringed by tidal forest, comprising *Avicennia marina, Barringtonia racemosa, Bruguiera gymnorrhiza, Ceriops tagal, Hibiscus tiliaceus, Lumnitzera racemosa* and *Rhizophora mucronata*. *Bruguiera gymnorrhiza* is the most important of these, having been best able to regenerate after the 1966 flooding, and some specimens on Uhkalwe Inlet now exceed 18 m in height. *Lumnitzera* and *Hibiscus* occur on the most elevated sites, often growing with *Acrostichum aureum, Caesalpinia bonduc* and *Chrysanthemoides monilifera*. Saltmarshes occur at the back of the mangrove on the seaward (eastern) side of the lower tidal basin. *Barringtonia racemosa-Hibiscus tiliaceus* forest fringes much of Lake Nhlange, particularly the southern and western shores, and interdigitates with other species in the upper basin. Saltmarsh and reed swamps occur along the streams connecting Lake Zilondo with the estuarine basin, and along the channel between Lake Nhlange and Lake Amanzimnyama. On the western shore of the system, fresh or brackish water swamp forest occurs behind the mangroves on Lake Nhlange, and along most drainage lines entering the system on the landward side. It forms a riparian belt 1 km wide and 7 km long on the Nswamanzi Stream which enters Lake Nhlange. Here, in addition to the typical species, *Raphia australis* is present forming perhaps the southernmost natural population of this species. Two other rare species, the terrestrial orchid *Platylepis glandulosa*, and the climber, *Tiliacora funifera*, occur in this forest, again at the southern limits of their distributions.

Phragmites swamps cover 10 000 ha along the Sihadla River, with *Cyperus papyrus* as an important associate. *Phoenix reclinata* and *Hyphaene natalensis* occur on the fringes of the reed swamps, and on more elevated patches in them. Various floating species occur in the bays and inlets, especially *Nymphaea* spp., but the surface waters of the lakes are free of vegetation. Submerged plants are also confined to sheltered bays and inlets and comprise a mixture of marine and freshwater species including *Ceratophyllum demersum, Najas marina, Potamogeton pectinatus, Ruppia* spp., *Thalassodendron ciliatum, Zostera capensis* and numerous algae.

The sand prawn, *Callianassa kraussii*, is the major infaunal organism. Penaeid prawns are not abundant in the estuary, reflecting its low nutrient status. The mangrove fauna reflects the fact that the substratum is predominantly sandy. Malarial mosquitoes occur in the swamps, as do the vectors of human bilharzia, *Bulinus africanus* and *Biomphalaria pfeifferi*.

Blaber (1978) listed 133 fish species in the Kosi system. Of these 85 were marine species found in the lower estuary, 39 were resident estuarine species which penetrated to non-tidal areas, and 9 were freshwater species. Apart from birds, other vertebrates have

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not been intensively studied here. However, frogs and toads abound in the streams and reed swamps. *Crocodylus niloticus* is uncommon, but occurs in Lakes Zilonde and Amanzimnyama, while *Varanus niloticus* is common throughout. Snakes also occur throughout the system, but collected species from the wetlands and beaches include only *Amblyodipsas microphthalma, Boaedon fuliginosus, Dispholidus typus, Leptotyphlops distanti, Philothamnus hoplogaster* and *Psammophis phillipsii*. Of more than 250 birds in the system, most of which were listed by Tinley (1976), the majority are associated with the swamp and dune forests. Perhaps a third, some 85 species, are specifically associated with the open water, beaches or reed swamps. Among mammals, *Hippopotamus amphibius* occurs in the system, a few individuals in the estuary, but most on the upper lakes. The water mongoose, *Atilax paludinosus*, is comparatively common as are various rodents.

Human Impact & Utilisation: The lake and swamp system is still relatively undisturbed as the area is not easily accessible. The local population was estimated as 80 000 in 1968, and the estuary provides a source of fish for these people. Large permanent fish traps, with long guide fences, have been built in the lower tidal basin, but lines and spears are also used, both from the banks and favourite perches in mangrove trees. Fishing with seine nets is prohibited but the practice occurs and is increasing. Pesticide residues have been found in the sediments of the tidal lakes and in the food chain, e.g. 860 µg DDT/kg *Mugil cephalus* liver. This pollution arises from malaria control operations. Only the insides of habitations are sprayed, the DDT then supposedly not entering the run-off, but it appears that preparative procedures have been faulty and have permitted escapes. The waters of the system are not polluted by faecal matter.

Conservation Status: The coastal dunes and lakes fall within the Coastal Forest Reserve established in 1952. The swamps along the Sihadla River are unprotected, and there have been proposals to drain them and bring the area under agriculture, which would be enormously detrimental to the wetland system. Proposals to establish a deep water harbour in the system, possibly by opening Lake Nhlange directly to the sea, are recurrent. Any such scheme would undoubtedly prove disastrous to the wetland ecosystem.

2. Coastal Lakes & Swamps

(A) MINOR SYSTEMS

General: On sandy beaches all around the coast of South Africa, numerous minor streams terminate in brackish lagoons among the coastal dunes, separated from the sea by sand bars. In such places, water losses from evaporation and seepage through the bar may keep pace with influxes, so that the water levels remain fairly constant, at least during dry seasons. Such lagoons are usually fresh or lightly brackish and swampy areas frequently develop along their flanks, and may extend several kilometres upstream from the lower end of the lagoon. However, during wet seasons, or following unseasonal storms in the catchment, the lagoons may rise and their flood waters may overtop the bars. Alternatively exceptionally high tides generated by storms at sea may breach the bars. In either event, the dammed up waters pour out, scouring the banks of the lagoons and disturbing their vegetation. The frequency with which such discharges occur in any given lagoon is a major factor in determining its morphometry, the composition and

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disposition of its peripheral swamps, and its fauna. Increased siltation, attendant upon intensive agricultural practices in the hinterlands, is accelerating the encroachment of vegetation into these streams and lagoons, especially along the Natal coast. As the lagoon floors rise so the waters spread, developing new lakes.

Dense beds of *Phragmites australis*, up to 4 m high, develop around the peripheries of these lagoons, where they are not strongly affected by the currents generated during periodic discharges. *Nymphaea* spp. occur in some lagoons and *Eichhornia crassipes* may occlude the deepest water. There are often tangles of *Leersia hexandra* and other aquatic species, e.g. *Ludwigia* sp., where deep water lies close to the banks. There are numerous submerged aquatics including *Najas marina, N. pectinata, Ruppia maritima* and *R. spiralis* in addition to those listed in the introduction, and on open fringes there are swards of grass or sedge species. However, lagoons in Natal are usually fringed by trees. Reeds tend to invade the open water as siltation proceeds, in many cases eventually filling the lagoon. In Natal, if the systems are not regularly flushed by high floods a swamp woodland develops, as trees become established in the reeds.

A gradation exists between lagoons which are fully open and fully closed. Some are mostly open and support tidal wetlands and have been dealt with in the preceding section. Others are mostly closed and are essentially non-tidal systems, many of these not becoming tidal even when their bars are breached. These are dealt with here. Yet others have lost connection both with the sea and the streams that once fed them, so that all around the coast, but especially in Natal, there are endorheic lakes, ponds and swamps which originated from estuaries or lagoons. The number of small sites is very large, but it includes Botriviervlei (34°20'S/19°06'E), Kleinriviersvlei (34°25'S/19°22'E), De Hoop Vlei (34°31'S/20°23'E), Salt River Marsh (34°29'S/20°24'E) and Groenvlei (34°00'S/22°50'E) on the south coast.

Sites on the east coast include the lagoons of Zolwane (31°04'S/30°12'E), Kandandlovu (31°00'S/30°16'E), Mpenjati (30°58'S/30°17'E), Umhlangankulu (30°57'S/30°18'E), Kaba (30°56'S/30°19'E), Zotsha (30°47'S/30°25'E), Ntshambili (30°38'S/30°33'E), Mhlungwa (30°33'S/30°35'E), Kwa Makosi (30°31'S/30°36'E), Fafa (30°27'S/30°39'E), Sezela (30°25'S/30°41'E), Mahlongwana (30°14'S/30°48'E), Mgababa (30°09'S/30°50'E), Msimbazi (30°08'S/30°51'E), Mhlanga (29°42'S/31°06'E), Mdloti (29°38'S/31°08'E), Mhlali (29°27'S/31°16'E), Mdlotane (29°21'S/31°22'E), Zinkwasi (29°16'S/31°27'E), Nyoni (29°08'S/31°36'E) and Siyai (28°58'S/35°46'E).

Flora & Fauna: See introduction.

Human Impact & Utilisation: Many sites have been seriously degraded by inputs of sewage, by enhanced siltation and by residential and tourist developments. Road and rail bridges across others have impeded drainage.

Conservation Status: Some of the northern lagoons are enclosed by dense dune forest or dune scrub, and these tend to be difficult, and in some cases impossible to reach by road. Thus, even if not protected by legislation, these systems enjoy a measure of protection by virtue of their isolation, but in Cape Province, systems of this type tend to lack trees and are seldom separated from the sea by high dunes. Most of them are easily accessible to the public and many have been despoiled.

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(B) THE ST LUCIA LAKE SYSTEM

Location: 27°22'-28°28'S/32°20'-32°34'E (total system)
Area: c. 33 000 ha (open water) + c. 33 000 ha (swampland).
Altitude: 0-5 m asl
Nearest Towns: Mtubatuba (20 km W); Durban (206 km SW)

General: Lake St Lucia lies on the Maputaland Coastal Plain and drains to the Indian Ocean through a 20 km long estuary. The estuary mouth, about 100 m wide, used to close periodically, but is now kept open by dredging. The St Lucia drainage system is the largest estuarine system in South Africa, and with associated swamps has a total wetland area approaching 66 000 ha. The maximum length of the lake is 42-45 km, depending upon water levels, and the maximum width 15 km. The length of the shoreline varies from 300-400 km reflecting seasonal variations in the size of the lake. The floor of the lake comprises deep mud and lies between 1.0-2.5 m below sea level, while the water surface is usually close to mean sea level. Water levels in the lake have varied from 0.6 m below sea level to 1.06 m above sea level (1951-1956). However in 1984, after intense precipitation in the wake of cyclone Demoina, the surface level in the lower part of the estuary rose 16 m. Storms of this nature appear to occur in the region about 3-4 times a century. Summers in the region are hot and comparatively wet, from October-April, and winters are warm and dry, from May-September. Mean annual precipitation is 1200 mm at the estuary mouth, but it decreases progressively in passing inland to 625 mm at the western extremity of the lake. Annual rainfall variations can be dramatic, even at the mouth, e.g. 2057 mm (1925) and 530 mm (1926).

The Mkuze River drains the South Mosi Swamp (c. 3000 ha) and crosses an extensive floodplain with numerous pans, before it enters the lake at its northern end through the Mkuze Swamp. This lakehead swamp is an integral part of the system, but is poorly understood. It was once a northern extension of St Lucia Lake which became shallow enough to support rooted and floating vegetation, including vast monospecific stands of *Cyperus papyrus*. A natural bar at the southern end of the swamp inhibits the intrusion of saline water, permitting freshwater fishes and plants to flourish. There are four stretches of open water in the swamp: Ndlaka, Demezane, Mbazwan and Butterfly. Where the Mkuze River enters the swamp there is a delta which contains four open lakes: Mpempe, Ntshangwe, Mdlanzi and Tshanetsha, forming an ecosystem hydrologically separated from the main Mkuze Swamp by two dry sections at the toe of the delta. A channel was once excavated from the Mkuze River near Mpempe Pan to a point near Demezane Pan in an attempt to introduce more freshwater to Lake St Lucia. This channel has now closed and no attempts are planned to re-open it; the probable deliterious effect on the Mkuze swamps would seem to outweigh any advantage that might be gained by reducing the salinity of the northern end of Lake St Lucia. Patches of land with an elevation exceeding 5 m asl occur in the Mkuze Swamp.

The South Mosi Swamp is the most northerly and westerly part of the system. It lies in a long depression, oriented N-S, in an old dune field and is approximately 30 km long at high water, with a maximum width of just over 1 km. The most southerly part of the St Lucia system is the swampy lower floodplain of the Mfolozi River. The bar at the mouth of this latter river, with the second largest catchment in Natal, is northward pointing, and at times the Mfolozi has poured its waters into the lower part of the St Lucia

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estuary. However, it now has a mouth about 1.5 km south of the St Lucia mouth, but the two systems are connected by a canal some little distance inland. The object of this is to channel Mfolozi water into the St Lucia system at times of high salinity. The lake and floodplains are separated from the Indian Ocean by high densely forested sand dunes, which reach 180 m asl at Maphelana. The combined St Lucia/Mkuze/Mfolozi system provides a range of habitats beside the aquatic one, including islands, mudflats, reed swamps, papyrus swamps, open grasslands, freshwater swamp forest, tidal swamp forest, coastal dunes, riparian communities, and freshwater pans and beaches.

Hydrology & Water Quality: Water enters St Lucia Lake from four principal rivers, contributing an estimated mean annual total of 295 million m^3. The Mkuze River, which enters the lake at its northern extremity, through the Mkuze Swamps, contributes 56% of the annual riverine inflow, while the other rivers each contribute some 24 million m^3, and seepage from the wet eastern shore a further 46 million m^3. Direct precipitation accounts for a further 268 million m^3, while evaporation takes an estimated 397 million m^3. Estimates of the total water storage capacity of the system vary between 295 and 322 million m^3. Since the lake is at sea level, and in a normal year influxes exceed evaporation, water overflows to the sea. However, in drought years there may be a net influx of sea water. Spring tide range at the mouth is 1.9 m, falling to 15 cm at the head of the estuary, but persistent winds generate seiches of 30-45 cm on the lake. Wind direction is predominantly from the NE or SW, parallel to the long axis of the lake.

Current annual silt accumulation in the lake has been estimated at 1-2 million m^3/yr, which is thought to be two to three times greater than the mean rate over the past 5000 years, and to be due to the acceleration of erosion in the hinterland by agricultural practices. However, sedimentation rate is clearly subject to large scale variations. Cyclonic storms, two of which occurred in 1984, may cause the deposition of more silt in a few days than would normally occur in a decade. The mean annual discharge of the Mfolozi River has been estimated as 729 million m^3 (Begg, 1978), while its coastal tributary, the Msinduzi, which joins it on the southern side of the floodplain, contributes a further 89 million m^3. The Mfolozi River is notorious for catastrophic floods, during which it deposits millions of m^3 of silt on the floodplain and cane fields.

Salinity varies from place to place in the lake, and from season to season and year to year. In a wet period, there is a salinity gradient from the head of the lake to the estuary. At such times salinity falls to 5.0‰ in False Bay and is generally about 25‰ at the head of the estuary. Following the drainage of the Mfolozi Swamps for agriculture in 1951, siltation closed the St Lucia estuary, and the Mfolozi River mouth migrated south to its present position. The St Lucia mouth remained closed for 5 years, until 1956, during which time an extreme salinity of 116‰ was attained. The southern part of the lake and the narrow estuary are the most stable parts of the system with regard to salinity. Salinity is normally close to 35‰ in the lower part of the estuary. Water temperatures range from 17°C in July to 29°C in January.

Flora & Fauna: Much of the lakeshore is fringed by *Phragmites* swamp with some *Cyperus papyrus*, the latter species more common in the north. At times of high salinity the reeds are reduced in vigour, or die back. *Juncus kraussii* and *Scirpus* spp., which always occur in patches, then become more prominent, and salt tolerant grasses such as *Sporobolus virginicus* and *Stenotaphrum secundatum* spread on the margins. The

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St Lucia reed swamps are contiguous with those of the Mkuze River in the north and those of the Mfolozi River in the south. The Mkuze Swamp (12 000 ha) at the head of the lake is a dense *Cyperus papyrus-Phragmites mauritianus* swamp, protected from incursions of saline water by a natural bar. In the south a further 2500 ha of reed swamp occupies most of the lower floodplain of the Mfolozi River. The isolated Mosi Swamp is predominantly occupied by a *Cyperus papyrus-Phragmites mauritianus-Typha latifolia* association with substantial areas of open water.

Freshwater swamp forest, with a closed canopy up to 28 m high, occurs in a discontinuous belt up the eastern shore of the lake, and in small patches on the Mkuze River, in the Mosi Swamp, and on both sides of the Mfolozi Floodplain. Thickets of *Allophyllus decipiens, Ficus capreifolia, F. verruculosa* and *Kraussia floribunda* grow around the margins. A thin strip of unique forest, seasonally flooded and containing *Ficus trichopoda, F. vogelii, Inhambanella henriquesii, Manilkara discolor, Podocarpus falcatus, Schotia brachypetala* and *Spirostachys africana* occurs between the herb swamp at Mosi, and the surrounding sand forest. Riparian forest, subject to seasonal inundation, with dominant *Acacia xanthophloea* and *Ficus sycomorus*, grows along much of the Mkuze River north of the lake head swamp. It also fringes the pans in this area. Beneath the trees, the zone between high and low water is covered by dense swards of *Cynodon dactylon*.

129 invertebrate species have been recorded from the St Lucia System (Day *et al.*, 1954). A comprehensive survey of the benthic fauna is given by Boltt (1975b). The most abundant species is the small gastropod *Assiminea africana*. Most benthic organisms in the system can tolerate salinities of up to 55‰ and when this concentration has been exceeded recolonisation is effected by planktonic larvae brought into the lake by wind induced water movements. The system is important as a nursery for penaeid prawns and is, for the dominant species, *Penaeus indicus*, the largest reserve in South Africa. However, during periods of low salinity *Macrobachium equidens* may become the most numerous species.

108 species of estuarine fishes are listed by Whitfield (1980) as occurring in the St Lucia System, and at least 13 freshwater species occur in the northern part of the lake and its tributary streams. Various sharks occur in the lower estuary, but *Carcharinus leucas* and *Pristis pectinatus* penetrate the whole system. Gravid females of *Carcharinus leucas* frequently give birth to their young in the system. Some species e.g. *Elops machnata* and *Mugil cephalus* are not adversely affected by high salinity phases, and *Oreochromis mossambicus* has been observed to breed in a salinity of 116‰. Several species of the lake fish fauna have wide salinity tolerances; 10 species have upper tolerance limits of 65-70‰, while 32 species have lower tolerance limits of 1-3‰ (Whitfield, 1977).

Amphibians abound in the reed swamps and watercourses, and on pan margins. Crocodile breeding places are protected, and crocodiles show marked migratory patterns from summer breeding places to winter basking grounds. The total *Crocodylus niloticus* population probably exceeds 600, and the species is quite numerous in the Mkuze Swamp where counts are difficult to make. Several snakes occur in the wetlands, including most cited in the introduction. In addition *Bitis gabonica*, which is rare in southern Africa, occurs in the swamps and pans around the lake. Another snake at the southern limit of its distribution is *Amblyodipsas microphthalma*. This is a burrowing species which

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frequents the reed swamps and mangroves. *Naja melanoleuca* occurs in the area and has been observed to feed on fish. Other reptiles include *Acontias plumbeus, Lygodactylus capensis, Pelomedusa subrufa, Pelusios sinuatus, Varanus exanthematicus* and *V. niloticus.*

Some 340 species of birds are associated with the St Lucia Lake System which is renowned for its pelicans and flamingoes. It is a recognised breeding ground for about twenty aquatic species including *Anastomus lamelligerus, Ephippiorhynchus senegalensis, Mycteria ibis, Pelecanus onocrotalus* and *P. rufescens.* It is one of only two breeding places in South Africa for *P. onocrotalus.* Other rare species are *Apalis ruddi* and *Batis fratrum.* During high salinity phases most of the birds migrate away from St Lucia and cease breeding (Whitfield, 1977).

Numbers of *Hippopotamus amphibius* have increased over the last twenty years to about 700. They are found mainly along the eastern shores where they are said to play an important role in carving channels through the swamps, modifying the drainage lines and releasing large quantities of plant detritus into the lake in their faeces. Antelopes such as *Aepyceros melampus, Neotragus moschatus, Redunca arundinum* and *Tragelaphus angasi* are also common on the eastern shore, the first two especially favouring swamp and riparian forest habitats. *Syncerus caffer* and *Diceros bicornis* have recently been introduced to the eastern shore of the lake. Among rodents, *Otomys angoniensis* and *Pelomys fallax* are common throughout the system, while *Dasymys incomtus* is less so. *Crocidura* spp. occur around pans on the floodplains, and a fruit bat, *Epomorphus wahlbergi,* roosts in swamp and riparian forests throughout the system. Endangered species protected in the system include *Cephalophus natalensis, Cercopithecus albogularis, Crocodylus niloticus, Diceros bicornis, Felis serval, Manis temminckii* and *Neotragus moschatus.*

Human Impact & Utilisation: Agricultural practices in the catchments have been deleterious to the system. Major problems are siltation, and altered drainage patterns which have led to increased salinity. Attempts to lower salinity by dredging and building channels have not been successful and have themselves had further adverse effects upon the system. The more remote northern areas of the Mosi and Mkuze Swamps have been little disturbed. The principal human impact has been on the lake itself, and on the floodplain of the Mfolozi River.

Conservation Status: The water in the lakes and channels and a 1 km wide strip of land along the banks has been declared a Nature Reserve. St Lucia Park, established in 1939, has an area of 12 545 ha. St Lucia Game Reserve, which was established in 1897, covers a further 36 826 ha on the eastern shore and around the north and northwest of the lake, including much of the Mkuze Swamp. Upstream sections of the Mkuze River, including some floodplain areas are protected in the Mkuze Game Reserve, established in 1912, with a total area of 25 091 ha. The False Bay Nature Reserve, established in 1954, on the extreme western shore of the lake covers 2247 ha. Angling is permitted under license in certain areas in St Lucia Park, but the flora and fauna are otherwise protected in the reserves. Boating is permitted on the lake, and there are two small permanent camps for visitors on the western shore. Much swampland between the lake and the coastal dunes is a prohibited area under military control, and is thus also effectively protected. To the

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south, on the Mfolozi Floodplain, an important area of freshwater swamp forest, and some adjacent duneland, is fully protected in Maphelana Nature Reserve.

(C) LAKE SIBAYA

Location: 27°22'S/32°42'E
Area: 9500 ha (lake + peripheral swamps)
Altitude: c. 20 m asl (lake surface)
Nearest Towns: Ubombo (54 km WSW); Durban (307 km SSW)

General: Lake Sibaya is an endorheic lake lying immediately to landward of high and densely forested sand dunes on the coastal plain of northern Natal. In places the sea approaches to within 1 km of the eastern shore of the lake, from the narrow sandy beach of which the dunes rise steeply. The lake was once an estuary, and the three arms which run north, west and south from the main basin indicate the former positions of tributary rivers. The main basin is 8.5 km long and 6 km wide and a maximum depth of 43 m was determined at high water in 1977. At this time the surface was some 23 m above, and the lowest point of the lake bed 20 m below, mean sea level. The lake then had an estimated open water area of 7750 ha with a storage capacity of 981 million m^3. A series of marshy depressions around the periphery, principally along drainage lines, provide a further 1750 ha of wetland. Stream flow into the lake is negligible for much of the year, and the peripheral marshes tend to trap what little silt is carried into the system. The total catchment for the system is estimated as 530 km^2. Summers are hot and wet, while winters are cool and dry. Mean annual precipitation is 1030 mm, over 40% falling in January-March. Prevailing winds are from N and S with normal maximum velocities of 31 km/hr. Much higher velocities are reached during occasional cyclonic storms.

Hydrology & Water Quality: Mean annual evaporation from the lake surface has been estimated as 1420 mm. This exceeds direct precipitation, and the level of the lake surface fluctuates by as much as 4 m over time periods of a few years, depending on stream and groundwater inflow, and seepage to the sea. The former has been estimated as 21 million m^3/yr and seepage at 1-4 million m^3/year.

The main body of lake water, which is well mixed by winds and not markedly stratified, experiences annual temperature fluctuations of up to 10°C, with a range of 18-28°C. However, shallow peripheral water may be heated to 41°C in summer and may cool to 13°C in winter. The water is clear with a mean Secchi depth of 3.2 m, and in the absence of regular stream inflow, siltation is minimal. pH is almost constant, at 8.2-8.3 throughout the year, while dissolved oxygen concentration ranges from 7.0 mg/l at 30 m depth to about 7.6 mg/l at the surface in summer. The principal ionic concentrations, in mg/l, estimated in the winter of 1967 were sodium 86.1; potassium 7.3; calcium 27.5; magnesium 9.0; bicarbonate 135.8 and chloride 131.3. Nitrate and phosphate concentrations were close to 30 and 55 µg/l respectively.

Flora & Fauna: During periods of normal water level, the sheltered shores of the lake, principally those of the main arms, are fringed by a tall reed swamp with some papyrus and the typical associates. *Ceratophyllum demersum* is the most important macrophyte in the arms of the lake, while *Myriophyllum spicatum* dominates the main basin. The shallow inshore terraces of the main basin are too windswept for the development of macrophyte beds, but support algal communities. During the exceptionally high water

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of 1977, when the lake rose many metres, the emergent macrophytes were overtopped and destroyed, and the fringe forest of *Acacia karroo*, along the sandy beach adjacent to the dunes was also killed.

The invertebrate fauna is still not very well known, but a variety of benthic organisms are found in the lake, principally Crustacea and Mollusca. The crustacean component is dominated by small burrowing and tube dwelling amphipods and tanaids, mostly of estuarine affinity, but the marine crab *Hymenasoma orbiculare*, the freshwater crab *Potamonautes sidneyi*, and a freshwater shrimp, *Caridina nilotica*, are common. The molluscs are typical freshwater forms and include the intermediate snail hosts for human bilharzia.

The fish fauna, comprising 18 species, is dominated by cichlids and gobiids. Five species (*Croilia mossambica, Gilchristella aestuarius, Glossogobius giuris, Hepsetia breviceps* and *Silhouettea sibayi*) have marine affinities and reflect the estuarine origin of the lake. Fishes are largely confined to the shallow inshore regions of the lake where vegetation is dense. Only 3 species frequent the bare sandy terraces, *Clarias gariepinus, Glossogobius giuris* and *Oreochromis mossambicus*. *Gilchristella* and *Hepsetia* are the only species regularly found in the pelagic zone. The peripheral pools and swamps are inhabited by cichlids (*Pseudocrenilabrus philander, Tilapia* spp.), catfishes (*Clarias gariepinus, C. theodorae*), topminnows (*Aplocheilichthys katangae, A. myaposae*), and the climbing perch, *Ctenopoma multispinis*. Bruton (1980) gives an account of the ecology of fishes in the lake.

Twenty-two species of frogs and toads have been recorded from Lake Sibaya, and of these 20 are tropical forms near the southern limits of their distributions. Only *Rana f. fasciata* and *Xenopus l. laevis* are temperate forms. All species are associated with the densely vegetated swamps and bays, and only *Xenopus* spp. venture into open water. A check list of anurans is given by Bruton (1980). Eight reptiles (*Crocodylus niloticus, Lycodonomorphus r. rufulus, Natriciteres variegata sylvatica, Philothamnus i. irregularis, Philothamnus hoplogaster, Python sebae* and *Varanus niloticus*) are closely associated with the wetland system, but a further 39 species occur in immediately adjacent habitats.

Sixty-two of the 279 bird species recorded in the area are closely associated with the wetlands, but great concentrations of birds do not occur here. Important piscivores are *Anhinga rufa, Ardea goliath, A. purpurea, Casmerodius albus, Ceryle rudis, Corythornis cristata, Haliaeetus vocifer, Larus cirrocephalus, Megaceryle maxima, Phalacrocorax africanus* and *P. carbo*. A check list of birds is given by Cyrus *et al.* (1980).

The mammals closely associated with the lake are *Atilax paludinosus, Dasymys incomtus, Hippopotamus amphibius, Ichneumia albicauda, Otomys irroratus* and *Redunca arundinum*.

Human Impact & Utilization: The lake has always been the principal source of potable water for the local people, and it has always been fished by them. Spears and nets are used throughout the year, but most intensively in the summer when large numbers of breeding *Clarias gariepinus* and *Oreochromis mossambicus* are taken. Boats are not used, apparently because of a fear of the depth of the lake, and the dangers posed by crocodiles and hippopotamuses. Some 400 indigenous people depend on the lake, which is isolated and seldom visited by outsiders. However, Mseleni Mission Hospital, with a further 300 inhabitants, also depends upon lake water. Crops are grown around the lake

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area by the indigenous people, but wild fruits and vegetables are also important to them. Part of the catchment has been planted with exotic pines and *Casuarina equisetifolia*. Because of its inaccessibility the system is virtually unspoiled, but this could change with the rapid expansion of the KwaZulu population, when the system may have to be managed in a sophisticated way to provide both water and protein for a much larger local population. Because of its endorheic nature the lake will be particularly susceptible to pollution by agricultural fertilisers and pesticides.

Conservation Status: The eastern shore of the lake is included in the Coastal Forest Reserve proclaimed in 1952. The rest of the system is unprotected, but it has been suggested that it should be included in a proposed Maputaland National Park.

3. Riverine Floodplains & Swamps

(A) MINOR SYSTEMS

General: In the north there is a small floodplain along the Limpopo River where it forms the border with Botswana, and another, with a series of associated pans, in the vicinity of Pafuri (22°27'S/31°20'E) where the borders of Zimbabwe, Mozambique and South Africa meet. In the central west there is a small floodplain on the Orange River in the vicinity of Upington (28°27'S/21°15'E). Farther downstream, a number of pans and vleis, some very large, lie in a system tributary to the Orange. Here the Sak River and its tributaries, all temporary watercourses, rise on the Roggeveld some 300 km NE of Cape Town and drain to the Orange River. Mean annual precipitation over the catchments is very variable; in some years the river barely flows, while in others it floods the pans and vleis. The largest of these are Groot Vloer (29°43'-30°14'S/20°27'-20°39'E), Verneuk Pan (29°57'-30°04'S/20°54'-21°15'E) and Vanwyksvlei (30°25'S/21°48'E).

The floodplain of the Great Berg River on the SW coast has been dealt with in section 5.7.1a, as a tidal system. However, while the tide penetrates some 70 km upstream on that river, flooding of the peripheral land is almost entirely due to the river borne flood, although it may be exacerbated by high tides. Another floodplain occurs on the Touw River in the southern Cape Province (33°59'-34°00'S/22°35'-22°50'E). Here the Touw River, rising in the Outeniqua Mountains, reaches the sea via the Wilderness Lagoon. Immediately upstream of the mouth it is connected by meandering streams to three small marshy lakes, Eilandvlei, Langvlei and Rondevlei which in total provide some 500 ha of open water. At times the Touw rises to flood these lakes and some peripheral land. Soutriviervlei (32°20'-32°33'S/22°52'-23°05'E), another marshy area, is situated at the confluence of the Salt River and one of its tributaries, east of the town of Beaufort West.

(B) THE PONGOLO RIVER FLOODPLAIN

Location: 26°45'-27°30'S/32°20'-32°33'E
Area: c. 13 000 ha
Altitude: 40-60 m asl
Nearest Towns: Ubombo (15 km S); Durban (288 km SSE)

General: The Pongolo River has a catchment of 8000 km^2 and descends eastwards from the central plateau. Having traversed a narrow gorge in the Lebombo Mountains it winds

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northwards across the Makatini Flats to a confluence with the Usutu River. It develops a floodplain on the flats which merges with that of the Usutu River in Mozambique. The floodplain incorporates a series of shallow pans separated from the river by low levées. The pans have a total area of some 2600 ha while the floodplain *per se*, occupies a further 11 000 ha at peak flood levels. The floodplain lies on alluvium of Tertiary and Recent origin. Mean annual precipitation is in the region of 520 mm, while mean class A pan evaporation is 2388 mm. Summers are hot, with a mean monthly maximum of 40.3°C in January, and winters are cool with a mean monthly minimum of 2.3°C in June. Mean annual maxima and minima are 28.7 and 15.8°C. Mean monthly humidity ranges from a maximum of 86% in January to a minimum of 39% in July. Prevailing winds are from S to SE in the first half of the year and from N to NE in the second half of the year. Winds are generally light, with a mean maximum velocity of 10 km/hr in September.

Hydrology & Water Quality: In September and October some rain falls in the catchment and on the plain, but the river is low, and only occasionally do pans with the lowest levées receive water at this time. Consequently pan water levels continue to fall, but water temperatures begin to rise. In summer a marked increase in rainfall results in major floods with a peak in February, when, in an average year, all the pans fill and the entire floodplain is inundated. In April rainfall and floods lessen leaving the pans at maximum retention levels, but most of them lose connection with the river. In the winter months there is little rainfall and lower temperatures prevail. Evaporation causes water levels in the pans to fall progressively. Water which seeps into some of the pans from the soil is unusually saline. This serves to raise the concentration of salts in the already brackish panwater. The mean annual flow of the Pongolo River at Golela is 1082 million m^3. An all time maximum flow of 3295 million m^3 was recorded in 1938/39 with a minimum of 309 million m^3 in 1930/31. Annual variations are not only great, as indicated, but also common; the annual flow can be expected to be less than 690 million m^3 once in every 4 years. About 70% of the total flow usually occurs between November and March, with the greatest volume (17.5%) in February. Although the flow rate is generally lowest from June-September, floods have been recorded during these months, as a consequence of cyclones. The fourth highest flow ever recorded, 563 million m^3/month occurred in July 1963. Detailed records of river flow for the period 1929-1972 are given by Heeg & Breen (1982).

The sediment load is low and has been estimated at 2.1 million m^3/yr, approximately 0.15% of the total volume flow. The river is now dammed at Pongolapoort and outflow to the floodplain is controlled. The dam has a wall height of 69.8 m, a total storage capacity of 2500 million m^3 giving a mean assured annual yield of 862 million m^3. The quality of pan water varies markedly from pan to pan and from time to time, a matter discussed by Heeg & Breen (1982).

Flora & Fauna: Several distinct vegetational types occur on the floodplain. A riparian forest dominated by *Ficus sycomorus* and *Rauvolfia caffra* with associated *Syzygium guineense* and *Trichilia emetica* occurs on the levées in strips up to 100 m wide, though in most places only narrow fringes now remain. Along seasonal stream banks the trees comprise mainly *Acacia robusta, Schotia brachypetala* and *Spirostachys africana*. On the fringes, in sites only irregularly flooded, an *Acacia xanthophloea-Dyschoriste depressa* community forms a narrow belt with occasional *Ficus sycomorus* and *Trichilia*

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emetica. At lower levels where inundation is regular, a *Cynodon dactylon* grassland prevails. Marshy areas are dominated by a *Cyperus fastigiatus-Echinochloa pyramidalis* community, while the wettest sites support reed and papyrus swamps. Papyrus is most abundant at the northern end of the floodplain, especially in the Ndumu Game Reserve; it occupies permanently flooded sites where water levels fluctuate seasonally. *Phragmites australis* prevails throughout the floodplain in swampy depressions while *P. mauritianus* predominates along river banks, pan margins and inlet-outlet channels. In pans where permanent, or semi-permanent water occurs, there are permanent and seasonal hydrophyte communities. Permanent communities contain *Trapa bispinosa* and *Nymphaea* spp., while the seasonal communities principally comprise *Potamogeton crispus* and *Najas pectinata*. A detailed vegetational map, compiled by Furness, is included in an account of the system by Heeg & Breen (1982).

The pans serve as a breeding habitat for all the important species of fish found on the floodplain, many of which are stimulated to spawn by the rising flood. Spawning occurs chiefly in shallow waters, where the juveniles are protected from predatory fish. A few species, such as *Oreochromis mossambicus* and *Tilapia rendalli*, which are nest builders and which show parental care for their young, do not exhibit a flood-dependant spawning pattern, but breed with the onset of rising temperatures. A number of rare fish also occur here, including *Redigobius pongolensis*, once thought to be endemic to the system. A check list of 50 species belonging to 15 families is given by Heeg & Breen (1982).

Frogs, toads and snakes abound on the floodplain. Most of the snakes cited in the introduction for northern swamps are present. Other reptiles include *Crocodylus niloticus, Mabuya striata, M. varia, Varanus exanthematicus* and *V. niloticus*. A large number of bird species utilise the floodplain, either as a breeding or feeding habitat, including 15 listed as endangered in the South African Red Data Book. These are *Anastomus lamelligerus, Ardea goliath, Ardeola rufiventris, Ciconia ciconia, C. episcopus, Gorsachius leuconotus, Haliaeetus vocifer, Hemiparra crassirostris, Hydroprogne caspia, Microparra capensis, Pelecanus onocrotalus, Phoeniconaias minor, Phoenicopterus ruber* and *Scotopelia peli*. Species which occur in large numbers (counts of over 8000 birds on a single pan) include *Dendrocygna viduata* and *Bubulcus ibis*. Cyrus *et al.* (1980) give a check list of birds found on the floodplain.

Among mammals *Hippopotamus amphibius* is present in substantial numbers and *Loxodonta africana* still enters the area from Mozambique, at least 50 immigrants having been sighted in a single aerial survey in 1980. However, the populations of large game animals, so abundant in Maputaland until the turn of the century, have now been eliminated, except in the reserves. Wahlberg's epauletted fruit bat, *Epomorphus wahlbergi*, roosts in the riparian forests.

Human Impact & Utilisation: At present the local people fish the river and pans quite intensively, using baskets, palisade traps, gill-nets and rods, and fish is an important local source of protein, as also are ducks, taken while feeding on the pans. Fish and hippopotamus meat is dried, and fish have recently (1980) begun to be sold commercially. The floods deposit alluvium over the floodplain each year, and much annually enriched land is cultivated for the production of crops. In other places the highly productive *Cynodon dactylon* lawns which develop naturally, provide excellent grazing for cattle. Local plants are utilised for food, the tubers of waterlilies and water chesnuts (*Trapa natans*) are harvested, as are the

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fruits of *Landolphia kirkii*, *L. petersiana* and *Strychnos madagascariensis* which grow in woodlands on the margins of the floodplain. The fermented sap of *Hyphaene natalensis* is widely drunk. At present local people live in harmony with the floodplain, except insofar as they destroy riparian forest for their practice of shifting cultivation.

The operation of the Pongolapoort Dam nevertheless poses the greatest threat to the floodplain and influences it more fundamentally than does the indigenous population. Its major direct effect is the attenuation of the seasonal floods. Research on this, and other floodplains, has shown that key floodplain ecosystem processes are dependent upon periodic flooding and drying out. Here primary production, decomposition by micro-organisms, the migration, reproduction and growth of fish, the seasonal development of *Cynodon dactylon* lawns which provide grazing for ungulates, and the seasonal growth of the riparian forest are all dependent upon the natural regime. Interference with the seasonal flood must inevitably interfere with these processes.

The Pongolapoort Dam is situated at the head of the floodplain, and the lake extends back into Swaziland. It was constructed principally to supply water for the irrigation of the Makatini Flats, the soils of the region being suitable for intensive agriculture, as trials at the Makatini Agricultural Research Station have shown. There can be little doubt that plans to carry out intensive agriculture on the Makatini Flats will be deleterious to the ecology of the Pongolo River Floodplain and to the livelihood of the large indigenous population it now supports. These people will be doubly disadvantaged by the irrigation schemes proposed. They will doubtless be displaced by the agriculture since they live on the Makatini Flats, and are dependent upon the floodplain which is being degraded. It seems unlikely that any benefits which the presently proposed irrigation schemes will bring to the indigenous population will outweigh the disadvantages attendant upon the destruction of their homesites and way of life, although it will bring paid employment to a proportion of them. There is also the fear that intensive agriculture will lead to increased silting, as has been the experience elsewhere in Natal. By contrast, fish farming on the floodplain seems to have considerable potential, the soils in certain areas being better suited to aquaculture than agriculture.

Conservation Status: Part of the northern end of the floodplain, including 4047 ha of wetland, are protected within the Ndumu Game Reserve. The Great Usutu River forms the northern border of the reserve and also the national boundary. Shokwe and Banzi pans, included in the reserve, are more properly associated with the Usutu than the Pongolo. The Pongolo Nature Reserve, of 6222 ha, at Golela, abuts the river near Pongolapoort and includes 400 ha of water surface.

(C) THE NORTH MOSI SWAMP

Location: 26°50'-27°13'S/32°29'-32°38'E (in South Africa)
Area: c. 15 000 ha (in South Africa)
Altitude: 34-45 m asl (in South Africa)
Nearest Towns: Ingwavuma (58 km NE); Durban (335 km SW)

General: The North Mosi Swamp occupies a series of N-S oriented depressions between lines of stranded sand dunes on the Maputaland Coastal Plain. Part of the swamp is in Natal and part in Mozambique. It is an isolated undisturbed low lying area of impeded or sluggish drainage, characterised by extensive reed swamps on sandy alluvial soils,

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and it marks the site of river flow during more pluvial phases of the recent past. It is a long narrow swamp, reaching a maximum width of 10 km in South Africa, but widening to more than this in Mozambique. The swamp extends more than 45 km over the border into South Africa at high water. Little is known of the hydrology of the area, and there have been no detailed botanical or zoological surveys. It is situated 25 km inland (west) of the coast at Kosi Bay, and approximately 25 km east of the Pongolo River Floodplain. The area is sparsely populated.

Flora and Fauna: The wetland is principally herbaceous and has few trees, except on elevated sand ridges. The swamps proper are dominated by *Phragmites mauritianus* and *Cyperus papyrus* with the typical spectrum of associates. *Hyphaene natalensis* grows on some of the sand ridges and *Phoenix reclinata* on the sides of some swales. Adjacent pans are fringed by *Acacia xanthophloea* and low bushy *Ficus* spp., *Afzelia quanzensis* reaches its extreme southern distribution on the sand ridges here. The fauna has not yet been well described, but most of the amphibians, reptiles and small mammals cited in the introduction are present. The avifauna is prolific, but poorly known.

Human Impact & Utilisation: Virtually none. The area is very remote and it must be among the least disturbed of all wetlands on the East African seaboard.

Conservation Status: The northern part of the swamp, adjacent to the Mozambique border, lies in the 29 878 ha Tembe Elephant Park, established in 1983. There are no visitor facilities but a rustic camp is planned. Several endangered species, or species in need of conservation are protected in the reserve, which includes a great deal of wetland. These are *Hippopotamus amphibius, Loxodonta africana, Neotragus moschatus, Redunca arundinum* and *Sylvicapra grimmia*. The elephants, numbering perhaps 120-130 individuals, are the last natural herd in KwaZulu, and they migrate freely, to and fro, across the border with Mozambique.

4. Lakes & Pans of the Interior

(A) MINOR PANS

General: There are close to 180 endorheic pans and lakes in the interior of South Africa, all mapped by Noble & Hemens (1978). Many lie along the Orange River and its tributaries as they cross the central plateau. Others are situated towards the northern central borders, towards the Nossop and Molopo Rivers, and some in the eastern Transvaal, close to the border with Swaziland. Most pans are filled by a combination of direct precipitation and irregular streamflow. Such pans may dry out completely and may remain dry for several consecutive years during dry cycles, but others, especially the larger ones are semi-permanent. It is believed that some arose as a consequence of animal and wind erosion, but the origin of most is uncertain.

Salt pans are mostly dry but usually contain perennial pools. They are alkaline and highly saline and their flora is restricted to a few salt tolerant species of algae. Their faunas contain temporary water forms like phyllopod crustaceans. Other pans are also usually dry, but their vegetation includes higher plants, usually salt tolerant grasses. Grass pans are seasonal and dry up in winter, but are flooded in summer. They are covered by a dense growth of hygrophilous grasses, often with an admixture of sedges. Alternatively

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pans may be dominated by sedges. These have a richer flora and are only ever lightly brackish. Reed pans are generally occluded by *Phragmites* and hold water for most of the year. They often contain a rich hydrophyte flora. The largest pans are semi-permanent and are bigger and deeper. They are often fringed by emergent vegetation and contain beds of submerged plants such as *Potamogeton* spp.

Lake Chrissie (26°20'S/30°13'E) occupies about 1046 ha (open water) and is situated near Ermelo in the SE Transvaal at an altitude of 1660 m asl. It is the largest of the endorheic pans, being 6 km long and more than 2 km wide. It is semi-permanent but may dry almost completely once in every 10 years. There are sparse reeds and sedges on the banks, and dense beds of *Potamogeton* in the water, and a fish, *Barbus anoplus*, is present. There are a number of smaller pans close by, the largest being Eilandsmeer (26°20'S/30°19'E) which covers 530 ha some 1679 m asl, and Lake Banagher (26°20'S/30°18'E) of 132 ha at 1660 m asl. Both these latter pans are virtually devoid of higher plants. Both are a few metres deep and both are unprotected.

(6) BARBERSPAN

Location: 26°35'S/25°35'E
Area: 3086 ha
Altitude: 1348.5 m asl (water surface at high water)
Nearest Towns: Lichtenberg (68 km NE); Johannesburg (241 km ENE)

General: This the largest and best known pan. It is a shallow, perennial, alkaline lake, with some 1750 ha of water surface at maximum high water. It measures 5 km in length by 2.5 km in maximum width, and lies near to the commencement of the fossil course of the Hart's River, which can be traced northwards by the occurrence of a series of similar, but smaller, pans for a further 45 km. The system is essentially endorheic, but Barberspan is connected to the next pan in the series, Leeupan, into which it overflowed in 1943 and 1967, through a shallow channel. Water has been prevented from pushing past Leeupan this century by a limestone obstruction; thus all water entering these two pans is lost by seepage or evaporation. The channel connecting these two pans is 1342 m asl. The two lakes dried completely in 1913, but since water from the Hart's River was artificially diverted into Barberspan in 1918, by the construction of a channel, this has never recurred. In the drought of 1933 the water surface of Barberspan shrank to 275 ha, mostly less than 50 cm in depth, but between 1965 and 1970 the pan was full with maximum depths of 3-9.5 m. The soils of the pans are calcareous, but sandy in parts. They have developed as shallow depressions in thin limestone rocks overlying an ancient volcanic series.

Summers in the region are hot, with mean monthly maxima for January of 30°C (40°C absolute maximum), and winters are cool and dry with a mean monthly minimum of 0°C for June (absolute minimim -6°C). Prevailing winds are from the north and severe dust storms occur in the area. Limestone dust from the pans has been blown into small hills at the southern sides of the pans and for Barberspan and Leeupan respectively these measure 24.4 m and 23.2 m in height. Mean annual rainfall is 557 mm at Barberspan. The highest monthly mean is for January (120 mm) and the lowest is for June (0 mm). The wettest month on record is January with total falls of 320 mm. Mean annual evaporation from the lake surface is estimated at 1812 mm.

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Water Quality: Water temperatures vary in a normal year, from an absolute minimum of 9.5°C in June to an absolute maximum of 27.8°C in January, with a mean summer temperature of 19.2°C. The water is reasonably clear with Secchi depths of 40 cm in the central basin in summer and 1.3 m in winter. The pH range is between 8.2-9.8 with a mean figure of 9.4.

Flora & Fauna: The aquatic vegetation is dominated by *Potamogeton pectinatus*, but several smaller and fully submerged species occur on the lake bed, including *Ceratophyllum demersum*, *Lagarosiphon* and *Ludwigia* spp. Dense swards of *Panicum repens* grow on lake margins where inundation is shallow at high water, providing cover for birds during times of flood. *Juncus*, *Cyperus* and *Eleocharis* spp. are also found around the lake edge in shallow water. Away from the shore these latter species grade into a grassland dominated by *Themeda triandra* with several associated species of *Aristida*, *Eragrostis* and *Setaria*. Limestone outcrops on the lakeshore are covered by lawns of *Cynodon dactylon*.

The invertebrate fauna is poorly known. No live molluscs were found during surveys in 1967 and 1972, but old shells of *Anisus*, *Barnupia*, *Bulinus tropicus* and *Limnaea* were found. The largest arthropod was *Potamon potamon*. However, 10 fish species have been identified in Barberspan; *Barbus anoplus*, *B. holubi*, *B. paludinosus*, *B. trimaculatus*, *Clarias gariepinus*, *Cyprinus carpio*, *Labeo capensis*, *L. umbratus*, *Tilapia sparrmanii* and *Pseudocrenilabris philander*.

Among the reptiles *Pelomedusa subrufa* is common in Barberspan and preys upon young waterfowl. Skinks, lizards and geckos are uncommon, but those identified are *Abelepharus wahlbergi*, *Mabuya capensis*, *Nucras taeniolaia ornata* and *Pachydactylus capensis*. Snakes are moderately abundant and include *Bitis arietans*, *Causus rhombeatus*, *Crotaphopeltis hotamboeia*, *Dasypeltis scabra*, *Hemachatus haemachatus*, *Lamprophis aurora* and *Naja nivea*. Other reptiles include *Geochelone pardalis* and *Psammobates oculifer*.

Barberspan is best known for its avifauna, some 347 species of birds, mostly waterfowl, having been recorded on it. These include very many of those cited in the introduction. Birds have been ringed at the sanctuary in the NE corner of Barberspan since 1959 and a comprehensive list of species is given by Milstein (1975).

Large mammals protected in the system are *Alcelaphus buselaphus*, *Antidorcas marsupialis*, *Connochaetes gnou*, *Damaliscus dorcas phillipsi*, *Equus burchelli* and *Raphicerus campestris*. Small mammals have not been studied intensively but many of those indicated in the introduction are present. *Erinaceus frontalis* and *Poecilogale albinucha* are endangered species which are protected here.

Human Impact & Utilisation: This has been minimal since the creation of the Barberspan Nature Reserve. Tourist density is not high and interference with the ecosystem by visitors is negligible.

Conservation Status: Barberspan and Leeupan are situated in the Barberspan Nature Reserve, established in 1954.

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5. Montane Wetlands

General: Wetland vegetation occurs in sponge bogs which develop over springs and below seepages at all altitudes. It also occurs in mountain valleys where the flow of perennial streams is impeded and water is stored in depressions and behind obstacles, giving rise, over the country, to innumerable valley swamps. These are best developed in wide valleys, on gently sloping floors. These wetland types occur all along the southern and eastern mountain ranges where precipitation is heavy. The flora of these wetlands, most of which tend to be on acid peaty soils, is rather similar, but dependant upon altitude. Sponges are raised peat bogs and have remarkable water storage capacities, such that even when there has been no rain for 5 months, water may continue to flow from a high altitude sponge, providing the headwaters of a stream, upon which, lower down, a village will depend. Such is the situation along much of the Drakensberg Range in Natal, Swaziland and the Eastern Transvaal.

Flora & Fauna: See introduction.

Human Impact & Utilisation: Apart from forestry projects the higher mountains are now little affected by man. Cattle are kept off the high slopes which are burnt in a controlled fashion by the various authorities to prevent the accumulation of dry matter. This, if permitted to accumulate, produces very hot fires which are extremely deleterious to the vegetation, and which promote erosion. Thus it is considered prudent to have occasional controlled burns. Little thought appears to be given to the effect of burning upon the fauna, and of course, burning prevents the establishment of woody species. In places, the foothills are heavily overgrazed, e.g. in parts of Natal, and these places are subject to very high rates of erosion. Here bogs, streams and pools are heavily utilised by cattle and their banks are trampled down. Under these circumstances many bogs have dried or are in the process of doing so. Many lower valley swamps have been drained, and others have disappeared in small impoundments.

Conservation Status: Large areas of sponge vegetation lie in Mountain Catchment Reserves and State Forest Reserves of the Directorate of Forestry. These are situated all the way along the mountain crests from the Cape Province through to the Eastern Transvaal. Well over 1.5 million ha of mountainous land is protected in these reserves, but this does not automatically imply that all sponges and swamps are well protected. In a few cases both sponges and high valley swamps have been replaced by plantation forests, losing the storage capacity of the wetlands, and deregulating the headwater flow of local streams. Without the bogs and valley swamps, flash flooding becomes a common phenomenon on mountain streams, with greatly increased rates of erosion. However, this is not now a usual practice, and from a water conservation point of view it is essential that all these areas continue to be maintained in pristine condition. A number of sponges and valley swamps are fully protected in nature reserves and national parks. These are too numerous to discuss in detail, but e.g., no less than 38 large sponges are preserved in the comparatively small Verloren Valley Nature Reserve, which covers 6055 ha in the Eastern Transvaal (25°18'S/30°07'E) at altitudes of 2200-2300 m. There are other alpine sponges and numerous valley swamps in the Giants Castle Nature Reserve (34 638 ha, maximum elevation 3451 m asl) and in the Royal Natal National Park (8856 ha, maximum elevation 3282 m asl). Brief mention is made of wetland vegetation in some reserves in South Africa by Greyling & Huntley (1984).

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6. Artificial Impoundments

General: There are literally thousands of artificial impoundments in South Africa, ranging in size from small farm dams to the Hendrik Verwoerd Dam, which is currently the 14th largest in Africa in terms of surface area (36 433 ha). These dams store a volume of water equivalent to 40% of the total mean annual run-off of all rivers in the country and their total surface area at capacity amounts to some 210 000 ha. Most impoundments are comparatively shallow, and are subject to high incident solar energy and sediment inputs. Many are subject to pollution from agricultural, urban and industrial wastes and some are eutrophic. Toxic algal blooms, which develop periodically, have created problems on some of the smaller dams, and others have become infested with floating macrophytes. Evaporation rates are high and riverine influxes are subject to dramatic annual variations. Five impoundments have storage capacities in excess of one billion m^3, one can store over 400 million m^3 and two exceed 300 million m^3 in capacity. The remainder are much smaller. Some, including the Hendrik Verwoerd Dam, occur in or adjacent to nature reserves. Many are utilised for angling and recreational purposes, but significant commercial fisheries have not yet developed on them. Brief details of the 104 most important impoundments are given by Noble & Hemens (1978).

(A) HENDRIK VERWOERD DAM

Location: 30°40'S/25°28'E
Area: 36 433 ha (at capacity)
Altitude: 1259 m asl (upper storage level)
Nearest Towns: Port Elizabeth (335 km S); Durban (480 km ENE)

General: The Orange River rises in Lesotho with sources high on the eastern rim of the southern African Plateau, immediately west of the Drakensberg Escarpment. This first major dam on the river, which is the largest in South Africa, was closed in 1970. It has a storage capacity of 5952 million m^3 and subtends a lake within the co-ordinates 30°29'-30°52'S/25°28'-26°18'E. This has a maximum width of 10 km and extends upstream for almost 100 km, with a tributary arm near the head of the lake extending into the valley of the Caledon River.

(B) VAAL DAM

Location: 26°52'S/28°07'E
Area: 29 269 ha
Altitude: 1484 m asl
Nearest Towns: Johannesburg (64 km NNW); Durban (381 km SE)

General: The Vaal River, a tributary of the Orange, rises near the town of Ermelo on the eastern rim of the interior plateau not far from the Swaziland border. It flows westwards to its first impoundment near Vereeniging. The dam here has brought about the inundation of a narrow valley system and created a long lake with many arms between co-ordinates 26°49'-27°06'S/28°05'-28°30'E. It is the second largest artificial lake in the country in terms of surface area, but the fourth largest in terms of capacity, which is 2330 million m^3.

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(C) BLOEMHOF DAM

Location: 27°38'S/25°36'E
Area: 22 821 ha
Altitude: 1229 m asl
Nearest Towns: Johannesburg (240 km NE); Cape Town (975 km SW)

General: This, the second dam on the Vaal River, is situated some 350 km below the Vaal Dam. It has created a broad shallow lake, the third largest in the country in terms of surface area. It extends back upstream for some 90 km with a major arm extending 30 km up the valley of the tributary Sand/Vet River system. Co-ordinates for the lake are 27°27'-27°49'S/25°36'-26°15'E.

(D) THE P.K. LE ROUX DAM

Location: 30°00'S/24°42'E
Area: 13 867 ha (at capacity)
Altitude: 1170.5 m asl (at upper storage level)
Nearest Towns: Durban (600 km E); Cape Town (740 km SW)

General: This second impoundment of the Orange River is situated some 120 km below the Hendrik Verwoerd Dam and was closed in 1976. It has a storage capacity of 3237 million m^3, the second largest in the country. It subtends a shallow lake with a maximum width of about 20 km which extends upstream for some 55 km. Co-ordinates for the lake are 29°59'-30°23'S/24°42'-25°02'E.

(E) PONGOLAPOORT DAM

Location: 27°29'S/32°03'E
Area: 13 247 ha (at capacity)
Altitude: 137 m asl (upper storage level)
Nearest Towns: Durban (300 km SSW); Johannesburg (490 km NW)

General: The Pongolo River rises near Wakkerstroom at an altitude of 2200 m asl. It has a catchment of 7081 km^2 and descends steeply to the lowveld west of the Lebombo Mountains. It then traverses a gorge between the Lebombo and Ubombo Mountains to reach the Maputaland Coastal Plain. It is now dammed at the lower end of the gorge and the lake behind the dam extends upstream into Swaziland. Unlike the other major impoundments this is at low altitude. Maximum storage capacity is estimated as 2500 million m^3, making it the third largest reservoir in the country in this respect. The water is intended for irrigation projects on the Makatini Flats, but the effect of the dam on the people and biology of the floodplain of the river (section 5.7.3b) is almost certain to be adverse. The potential impact of the dam is discussed in a report by Heeg & Breen (1982).

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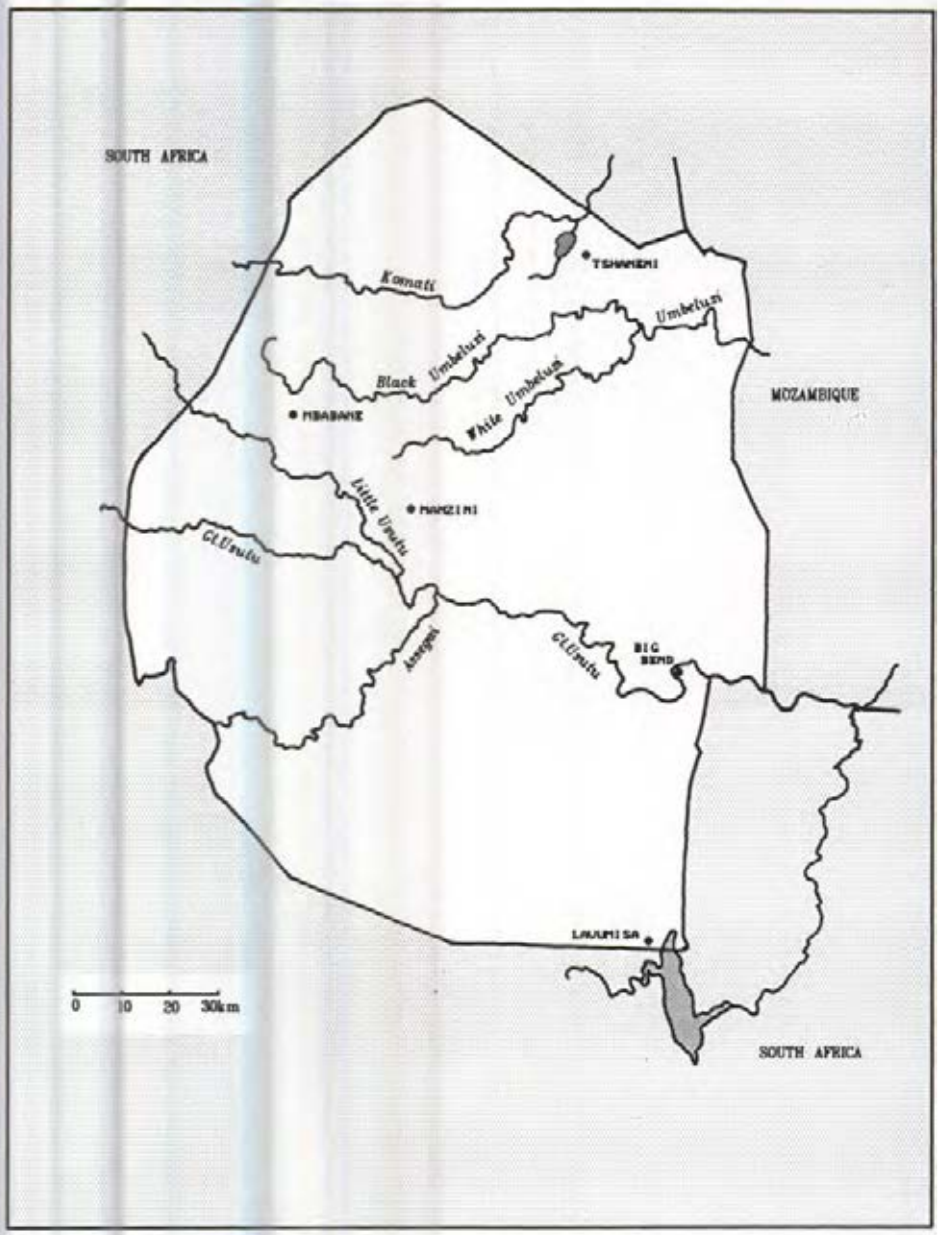

Map of Swaziland

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5.8 SWAZILAND

Introduction

Swaziland lies between latitudes 25°42'-27°23'S and longitudes 30°51'-32°12'E with an area of just 17 365 km^2. It has a population (1982) of 634 678, which represents a mean density of 21 persons/km^2, showing an increase of over 40% during the decade 1972-1982. The bulk of the population is found on the high veld, with centres on the middle and low veld regions. In general the low veld is very sparsely populated. The country is landlocked, being almost enclosed by South Africa, but having a short border with Mozambique in the east. The Lebombo Mountains, rising to some 600 m asl, lie along this border and fall steeply to the low veld of Swaziland. This is gently undulating country, 150-300 m asl, which supports a thorn savanna. The low veld comprises about 33% of the total national area, and rises towards the west, to the middle veld, and then steeply to the high veld on the rim of the central plateau of southern Africa. Much of the highveld, which comprises 45% of the total national area, is situated 1100-1400 m asl, but numerous peaks rise above this. The highest are Ngwenya (1829 m asl) and Embelembe (1862 m asl) in the northwest.

Drainage is predominantly from west to east across the country. Two major rivers, the Umbeluzi and Ingwavuma, rise on the high veld, while two others, the Komati and Usutu, have their sources in South Africa. These latter streams have cut dramatic valleys through the high veld where they enter the country, and all four rivers flow through narrow gorges in crossing the Lebombo Mountains to Mozambique.

Climate

The low veld is hot and arid, being in the rain shadow of the Lebombo Mountains. Mean annual rainfalls at stations in this region are in the range 550-770 mm. The middle veld is cooler, with higher rainfalls, c. 1250 mm, while on the peaks of the high veld, where it is substantially cooler, annual precipitation often exceeds 2000 mm.

Wetlands

There are no major wetlands in Swaziland, and of those that occur there the most important are sponges found at elevations of 1400-1800 m on the summits of the mountainous western parts of the country. These have formed above springs, or below seepages from clefts and discontinuities in the bedrock. They provide perennial reservoirs for the headwaters of countless streams, upon which much of the local population depends directly, and which feed the principal rivers. Small swamp and peat bog areas, and numerous pools, occur along these streams wherever they traverse flat areas. The upland terrain is smooth and rounded, with occasional rugged outcrops, but it is deeply dissected by river valleys. Grassland predominates over the high veld, except for small areas protected from burning (which happens every year) and grazing (which is intense). These areas include the many deeply incised valley heads, clefts in rock faces and large granite boulder clumps which are scattered all over the mountain sides. In such places the remnants of a once extensive forest persist. Many streams flow underground, even

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on steep slopes, where boulders and soil have collapsed into their channels, forming a grassy roof. The courses of these streams are visible as shallow depressions lined by tree ferns, and they are interrupted by sink holes, around which some arborescent vegetation is usually clustered. Small reed swamps occur on the margins of numerous farm ponds and dams, and along the courses of rivers over a wide altitudinal range. Some isolated saline pans occur in the low veld.

A number of larger dams (that on the Sand River near Tshaneni is 27 m deep) are used for irrigation. The reed-fringed storage ponds at Edalweni and Magaduza, between the Little Usutu and Great Usutu Rivers near their confluence, are used principally for hydroelectric generation. Another artificial water body is produced by the Mnkomo Weir in the town of Manzini, and the Pongolo River, which is dammed at Pongolopoort in South Africa, has created an upstream lake which extends back into the southeastern corner of Swaziland.

Wetland flora

The flora of the upland swamps is particularly rich and includes, in addition to many grasses and sedges, a large number of other monocotyledons. Among these are *Anoiganthus breviflorus, Brunsvigia natalensis* (Amaryllidaceae); *Hypoxis acuminata, H. filiformis, H. gerrardii, H. angustifolia* (Hypoxidaceae); *Aristea woodii, Dierama medium, Gladiolus papilio, Hesperantha lactea, Moraea marionae, M. pubiflora* (Iridaceae); *Albuca fastigiata, Aloe boylei, Anthericum haygarthii, Bulbine stenophylla, Drimia neriniformis, Drimiopsis maculata, Eriospermum cooperi, Eucomis poleevansii, Kniphofia multiflora, K. porphyrantha, K. praecox, K. umbrina* (Liliaceae); and *Disa versicolor, Disperis tysonii, Eulophia parvilabris, Habenaria cornuta, H. dives, Neobolusia tysonii, Satyrium atherstonii, S. cristatum, S. macrophyllum, S. ocellatum* and *Schizochilus strictus* (Orchidaceae).

The drainage of swamps in the catchment of the Black Mbeluzi River has virtually eradicated *Brunsvigia natalensis* from an area where it was once abundant.

Permanently swampy areas on valley floors support medium to tall grassland, with *Agrostis barbuligera, Andropogon appendiculatus, Helictotrichon turgidulum, Hyparrhenia dregeana, Pennisetum macrourum, P. sphacelotum, P. thunbergii, Setaria rigida* and *Stiburus alopecuroides*, either dominant or co-dominant.

Wetland fauna

The freshwater crab, *Potamon sidneyi*, is common in streams and pools throughout the country and *Oreochromis mossambicus* occurs in many of the larger impoundments. *Alestes* sp., *Anguilla bicolor, Barbus paludinosus, B. toppini, B. trimaculatus, Chiloglanis swierstrae, Clarias gariepinus, Eutropius depressirostris, Marcusenius macrolepidotus, Petrocephalus catostema* and *Synodontis zambezensis* are among species found in the Usutu River on the low veld. Many of these also occur in Pongolapoort Dam. There are several amphibians associated with the wetlands, including *Breviceps adspersus, Bufo gutturalis, Cacosternum boettgeri, Heleophryne natalensis, Phrynobatrachus natalensis, Pyxicephalus adspersus, P. natalensis, Rana angolensis, R. fasciata, R. grayii* and *R. vertebralis*. Among reptiles *Crocodylus niloticus*

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is now endangered in the rivers and dams of the middle and low veld regions, but *Pelusios* spp. are not uncommon. Ten snakes are known to be associated with wetlands of Swaziland, namely *Amblyodipsas polylepis, Crotaphopeltis hotamboiea, Lycodonomorphulus rufulus, Philothamnus hoplogaster, P. natalensis, Psammophis crucifer, P. sibilans, Psammophylax rhombeatus, P. taeniatus* and *Python sebae*. These are more common in the lowlands than in the mountains. Waterfowl occur on dams and ponds in the middle and low veld regions, while *Ardea purpurea, Ardeola ralloides, A. rufiventris, Ardierallus sturmii, Butorides striatus, Casmerodius albus, Nycticorax nycticorax* and *Scopus umbretta* frequent the rivers and dams. *Bubulcus ibis, Chalcomitra amethystina, Cinnyris chalybeus, Hagedashia hagedash* and *Nectarinia famosa* frequent montane bogs and swamps. *Hippopotamus amphibius* has been re-introduced to the Mlilwane Game Sanctuary, but otherwise the only mammals associated with wetlands are small species. They comprise *Aonyx capensis, Atilax paludinosus, Dasymys incomtus, Lutra maculicollis* and *Otomys irroratus*.

Human Impact & Utilisation: Irrigation schemes producing citrus fruit, pineapples, rice, tobacco, cotton and sugar, have led to the disappearance of several swampy areas adjacent to rivers in the middle and low veld, while the hillsides of the high veld are heavily overgrazed by goats and domestic cattle, and are fired every winter, when even the swamps may be burnt. It has been estimated that there are some 770 000 cattle in the country, of which as many as 550 000 are owned privately by small farmers. Grazing rights on the hillsides are communal, and little if any provision is taken for rotation grazing. Overgrazing, together with burning, has brought about significant changes in the grassland flora over the past 50 years. The small bogs and sponges are heavily trampled, and tend to dry and erode in consequence. Most bog pools, which are used as water holes, have been degraded and their banks broken down, so that they drain by streams rather than by a gentle outwelling over their lips through the bog vegetation. Intensive farming is virtually confined to the irrigation regions of the middle and low veld. Fish are taken on a small scale from the rivers, ponds and reservoirs by the local people, but there is no commercial fishing.

Conservation Status: Two substantial herb swamps occur in valleys in the Malolotja Nature Reserve (26°00'S/31°03'E), while towards the high southern boundary of the park there are extensive and relatively undisturbed areas of sponge and peat bog. The reserve was first established in 1972, and proclaimed a Nature Reserve under Notice 22 of the National Trust Commission Act in 1977. It comprises some 18 000 ha of high veld in the Ngwenya Hills in the northwest of the country. Land in the reserve has an altitudinal range of 1213 m, from a low point on the floor of the Komati River valley (615 m asl) to the summit of Ngwenya (1828 m asl). The reserve has been fully protected since its inception, but a rest camp has recently been established and visitors will be encouraged. Buffer zones are to be established around the rest camp, the access roads, the administration buildings and a site of archaeological interest.

A number of small wetland areas have also received a degree of protection in the Mlilwane Wildlife Sanctuary (26°28'S/31°05'E) since its establishment under private ownership in 1960. This area, of 4545 ha, was finally declared a Public Nature Reserve in 1977. The sanctuary spans 777 m in altitude, straddling the escarpment between the middle and high veld regions. It reaches a high point of 1437 m asl, and is centred on

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the Ezulwini Valley. Abandoned open cast tin mining pits have been transformed into small swamps and lakes which support waterfowl and *Hippopotamus amphibius*, and there are small montane bogs and valley swamps in the area. Four rivers, including the Little Usutu, traverse the reserve.

Some small saline pans occur on the Usutu River in the Mkhaya Nature Reserve on the low veld near Big Bend (26°48'S/31°56'E). This reserve covers 6000 ha including limited areas of river and riverine forest. *Crocodylus niloticus* is protected in this reserve.

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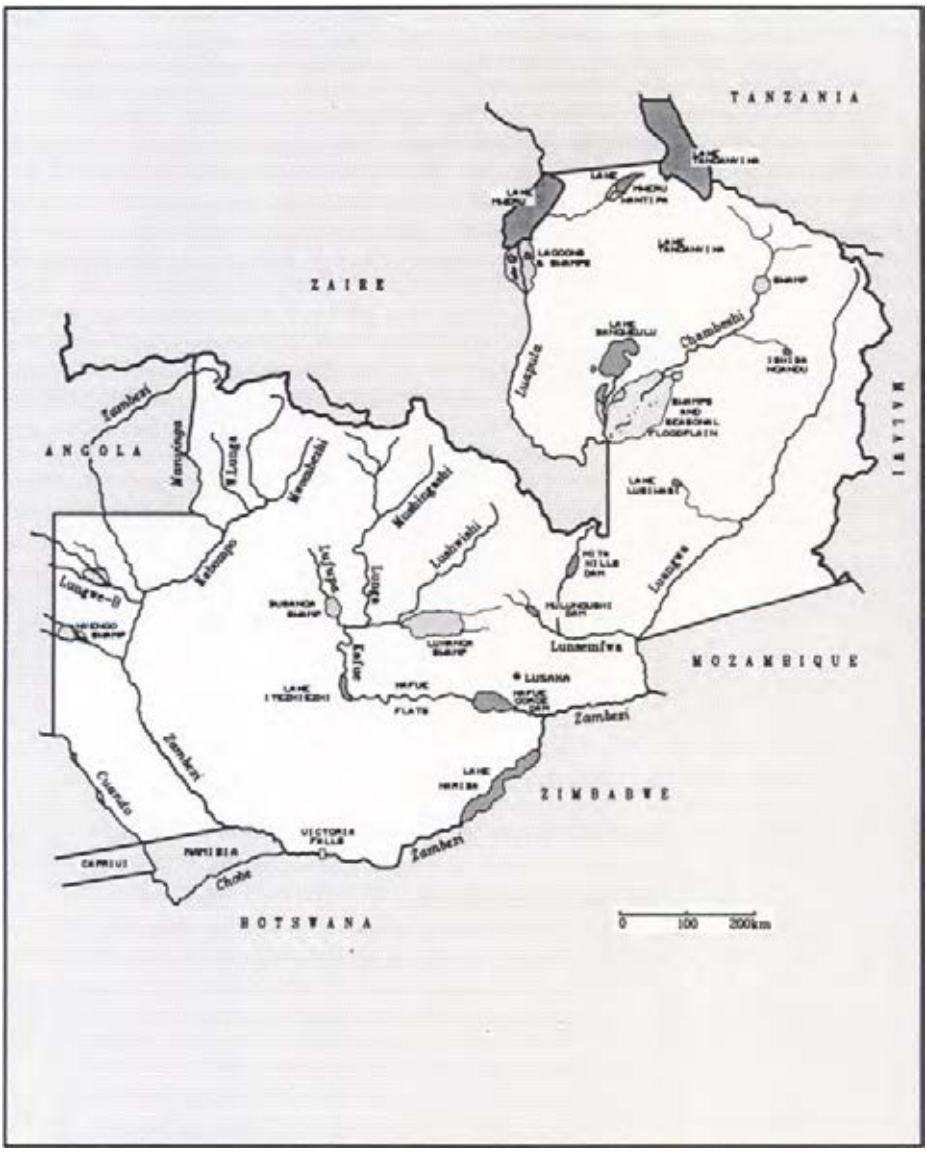

Map of Zambia

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5.9 ZAMBIA

Introduction

Zambia is a landlocked country, bounded by Angola in the west, Zaire and Tanzania in the north, Malawi and Mozambique in the east, and Zimbabwe, Botswana and Namibia in the south. It has an area of 752 615 km^2 and a population (1982) of 6 242 000, giving a mean density of 8.29 persons/km^2. It is situated on the Central African Plateau. 80% of the land surface is above the 1000 m contour, with maximum altitudes of 2067 m asl near Mbala (8°50'S/31°24'E) at the southern end of Lake Tanganyika, and 1788 m asl at Mt. Chimbwingombi (13°04'S/31°11'E) on the Muchinga Escarpment on the western side of the Luangwa River.

Drainage from the western region and most of the eastern region is either by, or to, the Zambezi, and therefore ultimately to the Indian Ocean. The Zambezi rises in the north of the country at Kalene Hill (11°10'S/24°12'E), and after flowing south, through Angola, re-enters Zambia and, together with Lake Kariba, constitutes the southern border for 995 km. The principal tributaries are the Kafue, which together with the Zambezi, drains the entire western region of the country, and the Luangwa, which drains the southern half of the eastern region. Drainage from the northern part of the eastern region is from three watersheds. The principal ones lie along the Muchinga Escarpment and the border with Tanzania, from where water flows northwards and westwards respectively, into the great basin occupied by Lake Bangweulu. From this point water flows through marshes and streams to the Luapula River, and thence eventually to Lake Mweru, the Zaire River and the Atlantic Ocean. The third watershed lies to the west of Lake Bangweulu, parallel to the border with Zaire, and from here numerous streams flow westwards into the Luapula River, which, flowing due north, forms the border with Zaire.

Climate

After the September equinox winds tend to become northerly or northwesterly and by October, warm humid air from the Zaire Basin moves south and begins to invade the country. Showers and thunderstorms occur in the north, but rain does not become general until the establishment of the Intertropical Convergence Zone (ITCZ) over the country. This arises because the flow from Zaire coincides with the humid flow of the South East Trade Winds, emanating from the Indian Ocean. The region where these air flows meet is referred to as the Intertropical Convergence Zone (ITCZ). The Zaire flow is usually the dominant one over Zambia, but both air streams bring rain to the country and the position of the ITCZ, the movements of which vary from year to year, influences precise precipitation patterns. This explains why, although these air movements are initiated in October and prevail until March, the principal rains do not usually commence until December. The rains normally begin in the north and move south across the country, as the ITCZ retreats southwards, with precipitation decreasing from north to south. The highest falls are received in the mountains near Mbala, where mean annual precipitation may reach 2000 mm. The northern and most mountainous third of the country experiences mean annual falls of 1000-1500 mm, the central third, falls of 750-1000 mm, and the southern third, falls of 500-750 mm. Tropical cyclones in the Mozambique Channel

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may cause substantial fluctuations in the position of the ITCZ. Any strengthening of winds towards the ITCZ strengthens the convergence and brings an increase in cloudiness and rainfall. After the March equinox, cool southerly winds prevail over Zambia and displace the warm humid air, the skies clear, and the rest of the year is dry. In July, the coolest month, air temperatures may fall to 10°C over much of the country during the day, and there may be night time frosts in the highest mountains. Annual rainfall is variable, but less so in the north. Vegetational cover across the country reflects both decreasing rainfall and increased unreliability of rainfall, from north to south, in parallel with decreasing altitude. The mean annual receipt of sunshine is 7.7 hr/day, rising to 9.6 hr/day in July, and falling to 5.3 hr/day in December. Mean annual temperatures are fairly constant across the southern and central regions and vary from mean monthly figures close to 24°C in October to ones near 16°C in July.

Wetlands

A relatively large proportion of the land surface of Zambia is occupied by permanent or seasonal wetlands. The highlands are riddled with dambos, clay based, low lying areas, which are flooded by a combination of direct precipitation, surface run-off, and seepage from higher ground, and which are more or less permanently waterlogged and covered by hygrophilous grassland. The term dambo is however, subject to a variety of different interpretations, and may even be applied by the indigenous people of Zambia and Malawi to rivers. In the earlier literature there is a tradition of treating dambos as depressions which collect and store water, but from which there is no canalised outlet, and from which water exits only during high water periods by sheet flow over the rims. However, while many dambos conform to this pattern, many others are situated on sloping land, and are drained by sluggish central or peripheral watercourses, which may exhibit only intermittent flow. Lines of moist forest may fringe or occlude these watercourses so that this type of dambo can appear as a long broad strip of hydrophilous grassland, with low sedge associates, and central or peripheral strips of moist evergreen swamp forest. Dambos of this type tend to have a discontinuous distribution along intermittent watercourses descending hillsides, and are particularly common in the highest rainfall areas, where in places they account for as much as 10% or even 15% of the landscape.

Riparian reed swamps, dominated by *Phragmites mauritianus* and *Typha domingensis* occur along the upper courses of many rivers, with riverine forest coming in at lower altitudes, e.g. along parts of the Kafue and on the Zambezi above Victoria Falls, where dense stands of *Syzygium* spp. may characterise the river banks. Farther downstream, several rivers flow into large depressions which hold permanent swamps, each of which may cover tens of thousands of hectares, and across which water flow is diffuse, often taking place in the absence of discrete river channels. At even lower levels the major rivers spread their waters over huge seasonal grassy floodplains during the rainy season, or expand to inundate wide beds. In the dry season these latter streams are 'sand rivers', having braided courses among innumerable sand banks of various elevations, each of which supports a different type of vegetation. In the wet season however, they are brim full, the sand banks being covered. Along the banks of these latter rivers there is often a series of low terraces, each of which may also be distinctively vegetated. The Luangwa is a river of this type, while the Kafue and Zambezi spill their waters over broad grassy

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floodplains. A substantial proportion of the population depends upon these floodplain systems for protein (fish and cattle). In the north of the country, rivers flow to sudd-type swamps in the vicinities of Lakes Bangweulu and Mweru. Elsewhere there are several small natural lakes and there are 4 major impoundments, including that at Kariba which is shared with Zimbabwe.

Wetland Flora

Dambos: Among the most important dambo grasses are *Andropogon schirensis, Hyparrhenia* spp., *Loudetia simplex, Miscanthus teretifolius, Monocymbium ceresiiforme, Themeda triandra* and *Trachypogon spicatus*, while sedges, which become more important in the wettest areas, include *Ascolepis anthemiflora, A. elata, Bulbostylis cinna- momea, Cyperus esculentus, C. platycaulis, Fuirena pubescens, Kyllinga erecta, Mariscus deciduous, Pycreus aethiops* and *Scleria bulbifera*. Herbs common in dambos include *Acrocephalus sericeus, Hypoxis angustifolia, Moraea natalensis* and *Pachycarpus linoleatus*. Tree species in the associated evergreen woodland may include some swamp forest species.

Swamp Forest: Common trees include *Adina microcephala, Anthocleista schweinfurthii, Aporrhiza nitida, Dacryodes edulis, Erythrophleum suaveolens, Ficus congensis, Ilex mitis, Khaya nyasica, Mitragyna stipulosa, Parkia filicoidea, Phoenix reclinata, Pterocarpus angolensis, Raphia farinifera, Syzygium cordatum, S. owariense, Treculia africana, Uapaca guineensis, Xylopia aethiopica* and *X. rubescens*. Shrubby species include *Aeschynomene elaphraxylan, Craterispermum laurinum, Dracaena camerooniana, Ficus verruculosa, Garcinia smeathmannii, Gardenia imperialis, Hibiscus diversifolius* and *Pychotria peduncularis*. Often, in glades, there may be a ground flora of swamp grasses, e.g. *Leersia hexandra* and *Panicum repens*, together with various ferns including *Histiopteris incisa, Lygodium microphyllum, Microlepia speluncae, Thelypteris confluens* and *T. striata*.

Seasonally Inundated Woodland: This occurs on elevated river banks throughout the country as levée woodland, which is only shallowly and temporarily flooded, and in riparian strips in sites flooded more deeply and for longer periods. Almost pure stands of *Syzygium guineense* ssp. *barotense* flank stretches of the Zambezi and its tributaries upstream of Victoria Falls, but in places this gives way to mixed semi-deciduous riparian forest, containing species such as *Acacia albida, A. erubescens, A. galpinii, A. nigrescens, A. polyacantha, A. robusta, A. sieberana, Albizia versicolor, Berchemia discolor, Chlorophora excelsa, Combretum imberbe, Cordylo africana, Croton megalobotrys, Diospyros mespiliformis, Erythrophleum africanum, Ficus sur, F. sycomorus, Kigelia africana, Lecanodiscus fraxinifolius, Lonchocarpus capassa, Mimusops zeyheri, Rhus quartiniana, Scleryocarya caffra, Strychnos potatorum, Terminalia sericea, Trichelia emetica* and *Ziziphus mucronata*. *Salix subserrata* occurs on the upper Zambezi and its tributaries. *Borassus aethiopum, Ficus sycomorus, Hyphaene benguellensis* and *Raphia farinifera* occur on sandy levées, riverine sand banks and elevated sandy patches in swamps throughout the country, but are especially common in the valley of the Luangwa. *Acacia xanthophlaea* and *Adansonia digitata* occur along the boundaries of floodplains to which the flood waters just reach. *Colophospermum mopane*, however, which also fringes many floodplains, tolerates considerable inundation.

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Reed Swamps: Tall reed swamps, reaching or exceeding 4 m in height are well developed along rivers, around lakes, and in wet swampy depressions. They are dominated by *Phragmites mauritianus*, but *Typha domingensis* is a common associate. Individual plants of *Phragmites* may reach almost 8 m in height. They may be rooted 4 m below the water and their inflorescences may rise 4 m above it. Local fishermen establish semi-permanent channels through these reed beds in their dugout canoes, en route to fishing grounds in central areas of open water. *Typha* generally grows in water flooded to depths of 2 m in the rainy season. On the landward fringes, where inundation is less deep, but not necessarily less permanent, there is usually a sedge zone, often up to 2 m tall. Common species here include *Cyperus articulatus*, *Cyperus imbricatus*, *Eleocharis dulcis* and *Scirpus inclinatus*, or there may be thickets of *Kotschya africana*.

Papyrus Swamps: *Cyperus papyrus* occurs on channel and lake banks and in some valleys. The culms attain heights of 4 m or more and stands are dense and invariably almost monospecific, but are frequently flanked by stands of *Phragmites mauritianus* and *Typha domingensis*, or they may give way to patches of these species. In places *Phragmites* may form huge mono-dominant stands in or around the papyrus. A spectrum of lower growing associates is usually found in the water around the bases of the culms and the most common of these is *Vossia cuspidata*. Often rafts or 'sudds' of papyrus break away and float on open water. Generally many other species are then found in a tangle of vegetation in the base of the raft, including such species as *Crassocephalum picridifolium*, *Cyperus nudicaulis*, *Ethulia conyzoides*, *Lagarosiphon ilicifolius*, *Lymnophyton angolense*, *Ludwigia leptocarpa*, *Melanthera scandens*, *Oldenlandia* sp., *Polygonum senegalense*, *P. tomentosum*, *Pycreus mundtii*, *Scirpus cubensis*, *Thelypteris totta* and *Utricularia* spp.

Aquatic Plants: Floating, floating-leaved or floating-stemmed species occur in almost all Zambian waterbodies, permanent or seasonal. Important species include *Aeschynomene fluitans*, *Aponogeton desertorum*, *Azolla pinnata*, *Brasenia schreberi*, *Echinochloa stagnina*, *Eichhornia crassipes*, *Floscopa glomerata*, *Hydrocotyle* sp., *Ipomoea aquatica*, *Leersia hexandra*, *Lemna* spp., *Ludwigia leptocarpa*, *Marsilea* sp., *Najas pectinata*, *Nymphaea caerulea*, *N. capensis*, *N. lotus*, *Nymphoides indica*, *Pistia stratiotes*, *Trapa natans*, *Spirodela* spp. and *Vossia cuspidata*. Submerged species include *Ceratophyllum demersum*, *Najas pectinata*, *Ottelia exserta*, *O. myricata*, *O. ulvifolia*, *Potamogeton pectinatus*, *P. schweinfurthii*, *Rotala cordipetala* and *Vallisneria aethiopica*. A few species appear to be characteristic of permanent water holes on floodplains. These include *Aeschynomene fluitans*, *Burnatia ennendra*, *Floscopa glomerata*, *Ipomoea aquatica*, *Polygonum senegalense* and the grasses *Leersia hexandra* and *Sacciolepis africana*.

Floodplain Grasses: Monospecific meadows of *Oryza barthii* occupy the most deeply flooded parts of the floodplains, to water depths of 5 m, with *Acrocerus macrum*, *Echinochloa pyramidalis*, *E. scabra*, *Paspalum orbiculatum* and *Sacciolepis africana* in intermediate zones. Where inundation is 60-70 cm *Panicum parviflorum* often appears. Where flooding is regular but seldom more than 40 cms, a mixed grassland tends to develop containing *Chloris gayana*, *Cynodon dactylon*, *Heteropogon contortus*, *Nyparrhenia* spp., *Loudetia simplex*, *Panicum repens*, *Setaria sphacelata*, *Themeda triandra* and *Vetiveria nigritana*. In saline areas *Sporobolus marginatus* and *Sparobolus spicatus* are

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common. These grasses survive moderate periods of inundation and produce new growth soon after the waters recede. *Setaria sphacelata* grows particularly rapidly and flowers early. Later in the season it may be replaced by later flowering species, including *Hyparrhenia filipendula* in drier spots. *Cynodon dactylon* and *Heteropogon contortus* are especially common in places where grazing is intense. *Echinochloa stagnina* and *Leersia hexandra* are common along streams on the floodplain.

The very landward margins of the floodplains are frequently covered by *Hyparrhenia filipendula* and *Setaria ciliolata*, but these species, which extend up into the surrounding woodlands, are killed by prolonged flooding. They are replaced by tussocks of *Hyparrhenia rufa*, reaching up to 2 m in height, in wetter areas. *Hyparrhenia rufa*, together with bushes or low trees of *Acacia polyacantha*, *Maytenus senegalensis*, *Phoenix reclinata*, and *Rhus quartiniana* are found on the deltas which extend onto the Kafue Flats. A twining legume, *Terminus andongensis*, is common throughout all the landward vegetation. In swampy areas near the margins, where inundation is usually quite shallow, but where the soil is permanently waterlogged, sedges are abundant, particularly *Cyperus digitatus*. Annual herbs and grasses often appear on the floodplains in the wake of the collapsed water grasses and among the former, *Vernonia glabra* and *Vernonia kirkii* are common throughout on unchanged black clay soils.

Termitaria: A feature of the fringes of the floodplains is a zone of termitaria. Termitaria rise above flood level and carry a spectrum of woody terrestrial plants. Along levées, where inundation is often only a few centimetres, and seldom more than 2 m in depth, large termitaria are again numerous. They reach some 3 m in height with basal diameters of 6-10 m, and tend to be situated 30-50 m apart. The peripheral belt of termitaria on the Kafue Flats occupies about 200 000 ha. The characteristic vegetation throughout the country includes *Boscia albitrunca*, *Dichrostachys cinerea*, *Euphorbia candelabra*, *Friesodielsia obovata*, *Grewia bicolor*, *Lannea stuhlmannii*, *Maerua parviflora*, *Sanseviera* spp. and *Ziziphus mucronata*, with the grasses *Setaria avetiae* and *Vetiveria nigritana*. The trees also occur in riverine thickets.

Wetland Fauna

Invertebrates: There has been comparatively little investigation of the invertebrate fauna of the wetlands except for the termites and the species that cause or transmit diseases. Among the former, *Cubitermes* sp. builds small mounds less than a metre high, and *Odontotermes* sp. builds large mounds. Both occur on the fringes of the floodplain and on the levées. The most important vectors of diseases are the mosquitoes *Anopheles funestes* and *A. gambiae*, which transmit malaria, the aquatic snails *Biomphalaria pfeifferi*, *Bulinus africanus* and *B. globosus* which transmit *Schistosoma mansoni*, *S. capense* and *S. haematobium* respectively (the causative agents of urinary and intestinal bilharzia), and *Lymnaea natalensis* which transmits *Fasciola gigantica* to cattle. *Bulinus globosus* is also believed to transmit *Schistosoma margrebowiei* which causes schistosomiasis in aquatic Bovidae and domestic cattle. *Bulinus globosus* is the commoner of the three aquatic snails mentioned, being found in all sites on submerged vegetation in ponds and streams, but also in pans where, in the dry season, it can aestivate in the mud. A bivalve, *Mutela bargeri schomburgki*, is believed to be endemic in the Bangweulu system. A common leach, *Placobdella jaegerskioeldi*, parasitises crocodiles.

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Fish: The fish faunas of the Zambezi and Zaire basins differ and information concerning both is given by Lowe-McConnell (1975). Check lists for the various Zambian systems are cited in the text at appropriate places. However, *Clarias* spp., *Ctenopoma multispinis* and *Protopterus annectens* occur in riverine swamps and floodplains, while *Alestes macrophthalmus, Hepsetus odoe, Hydrocynus vittatus, Labeo altivelis, Mormyrus lacerda, Oreochromis macrochir, Schilbe mystus* and species of *Gnathonemus, Haplochromis, Mormyrus, Serranochromis, Synodontis* and *Tylochromis* are widespread.

Amphibia: Frogs and toads abound in the wetlands and include among others, *Afrixalus* spp., *Bufo gutturalis, B. maculatus, B. vertebralis* (S only), *Hemisus marmoratum, Hyperolius pusillus, H. nasutus, Kassina senegalensis, Leptopelis* sp. (S only), *Phrynobatrachus acridoides, Phrynomerus bifasciatus, Prychadena mossambica, P. oxyrhynchus, P. porosissima, Pycicephalus adspersus, Rana angolensis* and *Xenopus muelleri.*

Reptiles: There are two crocodile species in the north of the country, in the Zaire Basin, *Crocodylus cataphractus* and *Crocodylus niloticus*, but only the latter is common in the Zambezi Basin. The aquatic snake *Boulengerina annulata* is found in Lakes Mweru, Mweru Wa Ntipa and Tanganyika. Other snakes which regularly frequent the lagoons, swamps and floodplains include *Dromophis lineatus, Limnophis bicolor, Natricitieres olivacea, Naja melanoleuca, N. mossambica, Philothamnus irregularis, Psammophis sibilans* and *Python sebae.* Arboreal species in swamp and gallery forests include *Dasypeltis fasciata, D. scabra, Dendroaspis angusticeps, Dispholidus typus, Philothamnus semivariegatus* and *Thelotornis kirtlandii.* Both *Varanus exanthematicus* and *V. niloticus* are present, also *Pelamedusa subrufra, Pelosios rhodesianus* and *P. subniger.*

Birds: Well over 400 species of birds have been recorded in Zambian wetlands and check lists are cited for individual sites in the text. Noteworthy species in reeds include *Acrocephalus baeticatus, A. schoenobaenus, Amplyaspiza albifrons, Ardeola ralloides, Botaurus stellaris, Bradypterus baboecalus, Calamiocichla gracilirostris, Centropus cupreicaudus, Euplectes orix. Ixobrychus minutus, Ploceus pelzelni, Portana pulsilla* and *Quelea erythrops.* Those associated with lagoons, lakes and swamps include *Actophilornis africana, Anas undulata, Anastomus lamelligerus, Ardea goliath, Balaeniceps rex, Ceryle rudis, Chlidonias leucoptera, Circus aeruginosus, Cisticola galactotes, C. pipiens, Corythornis cristata, Dendrocygna viduata, Ephippiorhynchus senegalensis, Fulica cristata, Hagedashia hagedash, Halcyon chelicuti, Haliaeetus vocifer, Larus cirrocephalus, L. fuscus, Limnocorax flavirostris, Motacilla capensis, M. flava, Muscicapa aquatica. Netta erythrophthalma, Nycticorax nycticorax, Pelecanus onocrotalus, Phalacrocorax africana, P. carbo, Phoeniconaias minor, Phoenicopterus ruber, Plectropterus gambensis, Podiceps ruficollis, Rallus coerulescens, Riparia riparia, Sarkidiornis melanotos, Sarothrura rufa* and *Thalassornis leuconotus.* Some species from the floodplains are *Ardea purpurea, Balearica pavonina, Ciconia abdimii, C. ciconia, C. episcopus, Egretta vinaceigula, Euplectes axillaris, Grus carunculatus, Neotis cafra, Pelecanus onocrotalus, P. rufescens, Plectropterus gambensis, Plegadis falcinellus, Rostrulata benghalensis, Threskiornis aethiopicus,* and *Vanellus senegallus.* Along riversides *Alcedo semitorquata, Alopochen aegyptiacus, Anas sparsa, Apus horus, Butorides striatus, Ceryle maxima, Charadrius marginatus, Hagedashia hagedash, Merops nubicus, M. bullockoides, Nycticorax nycticorax, Podica senegalensis, Rhynchops flavirostris, Riparia paludicola, Scopus umbretta, Scotopelia peli* and *Vanellus albiceps* are common.

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Mammals: Small mammals resident in the wetlands or on the fringes include *Aonyx capensis, A. congensis, Atilax paludinosus, Dasmys incomtus, Herpestes sanguineus, Lutra maculicollis, Pelomys fallax* and *Thryonomys swinderianus*, while large species are *Hippopotamus amphibius, Kobus ellipsiprymnus, K. leche leche, K. leche smithemani, K. vardoni, Redunca arundinum* and *Tragelaphus spekei*. Those which visit the swamps and, or floodplains in the dry season are more numerous and include *Acinonyx jubatus, Aepyceros melampus, Alcelaphus lichtensteini, Canis mesomelas, Connochaetes taurinus, Damaliscus lunatus, Diceros bicornis, Equus burchelli, Hippotragus equinus, H. niger, Loxodonta africana, Lycaon pictus, Ourebia ourebi, Panthera leo, P. pardus, Papio ursinus, Raphicerus sharpei, Taurotragus oryx, Tragelaphus scriptus, Sylvicapra grimmia* and *Syncerus caffer*. Smaller species found in riparian forests include *Cercopithecus aethiops, C. mitis, Galago crassicaudatus* and *Potamochoerus porcus*.

List of Wetlands

1. Wetlands of the Upper Zambezi Valley
    (a) Swamps of the Kabompo River
    (b) Swamps of th Lungue-Bungo River
    (c) The Luena Flats
    (d) The Nyengo Swamps
    (e) The Lueti & Lui Swamps
    (f) The Barotse Floodplain
    (g) The Sesheke-Maramba Floodplain
2. Wetlands of the Kafue Basin
    (a) Swamps of the Upper Catchments
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3. Wetlands of the Luangwa Valley
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5. The Lake Mweru System
    (a) Lake Mweru & the Luapula Floodplain
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    (a) Lake Kariba
    (b) Kafue Gorge Dam
    (c) Lake Itezhitezhi
    (d) Mita Hills & Mulungushi Dams

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L Wetlands of the Upper Zambezi Valley

General: The Zambezi River rises in Zambia, near Kalene Hill (11°08'S/24°22'E), but its headwater basin lies almost exclusively in Angola, as discussed in section 5.1, Angola. It receives over 20 major tributaries, draining its shallow swampy upper basin, before re-entering Zambia at Caripande (12°59'S/22°42'E) above Chavuma Falls. Below this point swamps occur along its tributaries, and on inter-riverine plains between tributaries, and finally, along the Zambezi itself in the Barotse Floodplains. On leaving Barotseland the Zambezi enters a faulted trough in Karoo sediments overlying lavas, through which it flows swiftly between Ngonye Falls (16°42'S/23°38'E) and Mulilo Rapids (17°33'S/24°12'E). After this it again traverses a sandy plain at the northeastern extremity of the Caprivi Strip, where its flood waters sometimes mingle with those of a southern tributary, the Chobe. The confluence of these two rivers is at Kazangula (17°45'S/25°20'E). The floodplain extends along the river from Sesheke (17°33'S/24°20'E) to Maramba (17°50'S/25°53'E) just above Victoria Falls where the upper course of the river is deemed to end. The swamps associated with the tributaries are now described sequentially before the Barotse and Sesheke District Floodplains of the Zambezi itself.

(A) SWAMPS OF THE KABOMPO RIVER

General: Small swamps occur along the Kabompo River, and are best developed immediately above the confluence of this stream with the Zambezi. The swamps are essentially riparian, extending upstream in narrow strips, backed on each side by narrow seasonal floodplains. The largest block (14°10'S/23°12'-23°37'E) covers approximately 18 000 ha. This block includes a seasonal pan, Kandala Pan, with an area of 800 ha. It comprises mostly tall reed swamp along the river, with some isolated patches of papyrus. In places it reaches widths of 2-3 km on either side of the river, and is backed by floodplain grassland. Farther upstream, where the river traverses flat land for short distances, there are other smaller swamps.

(B) SWAMPS OF THE LUNGUE-BUNGO RIVER

General: A large swampy area (13°30'-14°04'S/22°05'-22°54'E) is situated on the plain upstream of the confluence of the Lungue-Bungo and two tributaries, the Litapi on the north bank and the Lutembwe on the south bank. Here at an altitude of just over 1100 m, in the triangle of land between the two rivers as they flow SE towards the Zambezi, flood waters inundate a large area of permanent swamp. This contains many pools, and is backed by a seasonal floodplain on higher ground. The major wetland, reaching 25 km in width, lies immediately upstream of the triple confluence, but riparian swamps extend back for 74 km along the Lungue-Bungo, and for 34 km along the Lutembe. The total area of wetland approaches 100 000 ha in a wet year, comprising papyrus swamps close to the confluence, with *Phragmites* swamps dominating the long riparian strips. Typical floodplain grasses occur behind these and the wetlands become narrower and discontinuous in passing upstream.

An isolated headwater swamp, roughly triangular in shape, occupies the shallow headwater valley of the Litapi (13°37'S/22°26'E). This is 20 km long, 9 km wide at maximum,

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and occupies 9000 ha. It is a reed/grass swamp, dominated by *Phragmites* with some *Typha*, and some hygrophilous grasses, but with little papyrus. After the triple confluence, the Lungue-Bungo begins to descend quite steeply to the Zambezi.

(C) THE LUENA FLATS

General: These are situated (14°30'-14°57'S/23°11'-23°56'E) on the Luena River immediately before it leaves the plateau proper and enters the Zambezi Valley, across which it flows for 35 km through the Lubitanei Canal to its east bank confluence with the Zambezi near Lealui (15°12'S/22°59'E). The canal carries water through the Zambezi Floodplain which is well developed at this point. The Luena Flats are 'frying-pan' shaped, with the 'pan' downstream, just above the 1000 m contour, and the 'handle' extending back up the valley behind. Swamps occupy the 'pan' in a block roughly 30x35 km, covering some 67 669 ha, while upstream of this the 'handle' swamps extend for 55 km in a strip up to 6 km wide comprising another 22 000 ha of wetland. *Cyperus papyrus* occurs in the 'pan' together with *Phragmites mauritianus*, while this latter species is dominant over much of the 'handle'. Narrow grass floodplains encompass the permanent swamps. These swamps are fed by several small streams, notably the Nkala, Luambua, Lukuti and Ndanda.

(D) THE NYENGO SWAMPS

General: These are situated in the basin of a west bank tributary, the Luanginga, which also joins the Zambezi near Lealui. However, the swamps are not on the Luanginga itself, but on and between some of its south bank tributaries, principally the Luale. This latter stream receives a tributary, the Ninda, on the Angolan border, immediately after which, the reinforced river bifurcates and the two branches enclose a diamond-shaped parcel of land, 35 km long and 15 km wide, before they rejoin. Meanwhile, a second tributary joins the diamond from the south. Seasonal flood waters spread over the diamond-shaped area, which is virtually covered by permanent swampland, and also over land some 10 km to both north and south of it. The maximum area flooded during the rains reaches some 70 000 ha (14°49'-15°00'S/22°01'-22°17'E).

A series of isolated swamps, pans, lakes and lakelets occurs on the plain to the south of the Nyengo Swamps, close to the Angolan border. The largest of these, Lake Sihole (15°17'S/22°34'E), has an open water area of 1500 ha. Some of these are endorheic systems and occupy depressions in the gently undulating inter-riverine plain. They are related to the Malundo and Chiume Lakes in Angola which are dealt with in section 5.1.3b.

(E) THE LUETI & LUI SWAMPS

General: Both these rivers, which join the Zambezi just below Senanga (16°09'S/23°16'E) on the Barotse Floodplain, have extensive floodplain systems in their lower reaches, and these merge with the Barotse Floodplain. The floodplain on the Lui, an east bank tributary, rises from an altitude of about 985 m asl at the confluence with the Zambezi to about 990 m, and extends back up the Lui for 70 km, with widths of up to 7 km. The principal floodplain (15°15'-15°20'S/23°27'-23°45'E) occupies an area of 23 500 ha and may be fully inundated at the height of the rains. At the upstream end of

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the Lui Floodplain there are several patches of permanent swamp dominated by *Cyperus papyrus* and *Phragmites mauritianus*. These occur in the head of its lower valley, at an altitude of close to 994 m, where the Lui receives several headwater tributaries, notably the Mulwa, Siowe, Mutondo and Namengo.

The Lueti is a west bank tributary which rises in Angola and drains the swampy southeastern interior of that country, including the Chiume Lakes. A permanent swamp, some 24 km long, and reaching a maximum width of 8 km (15°46'S/22°20'E) lies along the Lueti, above its confluence with the Ndoka, and a series of permanent, but variable, ponds occurs along this latter stream in the region 15°15'-15°40'S/22°30'E. Some ponds have as much as 800 ha of open water in the rains. All are fringed by reed swamps and surrounded by marshy land. A floodplain reaches 20 km back up the Lueti from its confluence with the Zambezi, covering some 14 000 ha.

(F) THE BAROTSE FLOODPLAIN

Location: 14°19'-16°32'S/23°15'-23°33'E
Area: 770 000 ha
Altitude: 980-990 m asl
Nearest Town: Senanga (on the central floodplain)

General: The Barotse Floodplain is situated on the upper course of the Zambezi River on the high plateau in western Zambia. The whole area is 240 km long and up to 40 km wide, with a total inundatable area approaching 770 000 ha. In traversing the plain the river meanders so much that its length exceeds 590 km. The floodplains lie on Kalahari Sands and the river bottom is predominantly composed of shifting sand. Deposition of alluvium over the floodplain each year is not heavy and the waters of the river are clear at all seasons. This region is warm to hot, with average midday temperatures reaching 32°C in August, but often being lower than this in the rainy season when there is heavy cloud cover. The mean annual rainfall on the floodplain is about 1050 mm, with 90% of this falling between November and March, and 50% in January and February.

Hydrology & Water Quality: Up to 1500 mm of rain falls over the headwater catchments of the Zambezi each year, usually beginning in late October and finishing in April. Flooding of the upper Zambezi normally commences in November, but the date varies depending upon the intensity of the early rains. The central part of the Barotse Floodplain is inundated to a depth of 1.5-3 m when the flood peaks in April. The flood recedes over a six month period from May until October, but by September most of the floodplain is dry, and water is restricted to lagoons connected to the river by backwater channels, and to numerous isolated lakes. At this time the main channel is some 25-50 m wide and 3-6 m deep.

Conductivity of water in the upper Zambezi remains below 65 µmhos/cm through the months February to August, then rises abruptly to peak at a mean value of 126 µmhos/cm in mid October, after which it declines slowly to the February figure. The lowest conductivities are recorded at the peak of the flood, in April, with a mean value of 57 µmhos/cm. pH and total dissolved solids also peak in October, with a mean average of 52 ppm total dissolved solids. The upper Zambezi drainage area is not productive; burning of the entire grassland watershed is carried out annually, and over the years has depleted the nutrient status of the sandy soils.

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Human Impact & Utilisation: A fishing industry on the Barotse Floodplain provides the bulk of the protein in the diet of about 200 000 people. Fishing is carried out using gill nets, seines, fence and weir traps, as well as baskets and spears. Gill-net fishing is the principal method and occurs throughout the year, although some 200 boats were operating seine nets in 1981. Dugout canoes are almost exclusively used. It has been estimated that about 3400 people are engaged in the fishing industry on the floodplain, either full or part-time, operating some 2175 boats. The floodplain is covered by thousands of reed, mud and stone weirs, but this method is most successful only when water is flowing on to or off the plain. Tall fence traps are successful when the flood is rising. Many species are trapped when they leave the river to spawn in the shallow rising waters over the floodplain. Basket fishing is carried out in all seasons, but is most rewarding in July and August when the receding waters trap fish in small pools. Small mud and grass walls may be used to lead fish into traps comprising grass baskets (maalelo). Spear fishing takes place from the banks of the river and lagoons during the dry season. Some 23 species of fish are caught commercially on the floodplain including four species of *Clarias*, four species of *Tilapia*, and three species each of *Serranochromis* and *Haplochromis*. *Hydrocynus vittatus* is also very important, together with *Mormyrus lacerda*, *Schilbe mystus*, *Hepsetus odoe*, *Labeo lunatus* and *Synodontis woosnami*.

Fisheries Department estimates show that the total recorded catch for 1980 was 6570 tonnes, with a five year average (1976-1980) of 5220 tonnes. Most fish are marketed locally as access to the area is poor. Much of the catch is dried, or smoke dried, especially after the rains start. Accounts of the fisheries are given in two reports by Kelley (1968) and Duerre (1969), and in the Zambia Inland Fisheries Development Project Interim Report of 1982, available from the Ministry of Lands & Natural Resources, Lusaka. Another fishery is developing on the Zambezi from Sesheke down to Maramba (Livingstone), with an annual catch up until 1982 of about 2000-2500 tonnes. Some is consumed locally and much is sold in Maramba, but towns as far afield as Kaloma and Zimba are supplied.

Some 300 000 head of cattle graze the Barotse Floodplain during the dry season and the adjacent forested area during the wet season. Overgrazing is a problem and the mortality rate due to malnutrition and internal parasites is great. Drainage schemes to increase the efficiency of cattle ranching promise to be deleterious to the fishery.

Conservation Status: All the upper Zambezi wetlands lie within the West Zambezi Game Management Park and thus receive a measure of protection. Some small swamps on the Kabompo River are fully protected in the West Lunga National Park, but the largest swamps on this river are outside the park.

(G) THE SESHEKE-MARAMBA FLOODPLAIN

General: Along the northern border of the Caprivi Strip the Zambezi has a broad sandy course, and in places, e.g. between Sesheke (17°28'S/24°20'E) and Mwandi (17°30'S/24°51'E), it flows in several channels across a bed 5 km wide. In this sector its waters spread over an extensive floodplain, much of which lies within Namibia. Towards the confluence with the Chobe at Kazungula the floodwaters of both streams mingle. Downstream of this place the floodplain is less well developed but the river expands into a broad open water body above Victoria Falls. In total the floodplain and lakes may encompass 150 000 ha.

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2. Wetlands of the Kafue Basin

General: The Kafue Basin lies on the Southern African Plateau and is confluent with the Zambezi Valley, providing a subcatchment to that river system of approximately 155 000 km^2. It is entirely tropical being situated between latitudes 11°30' and 16°50'S, but because of its elevation it has a comparatively temperate climate. The Kafue River, which rises in the western province of Zambia, at an elevation of 1370 m asl, ultimately drains the entire basin and discharges into the Zambezi. The river first flows in a southeasterly direction through the Copperbelt, then after traversing the Mpatamatu and Itezhitezhi Gorges, it crosses the Kafue Flats in a broadly meandering course from west to east. Near the town of Kafue, at the eastern end of the flats, the river leaves the basin and flows through the Kafue Gorge. Here its annual discharge has on occasion exceeded 28.3 billion m^3, representing a sustained outflow rate over the year of 897.38 m^3/sec. Over the final 24 km of its course it falls 610 m, plunging over a series of rapids to meet the Zambezi River. A dam came into operation for hydroelectric power at the head of the Kafue Gorge in 1972, and another, at Itezhitezhi, designed to control the flood regime of the Kafue Flats, came into operation in 1978.

In its middle course, between the Mpatamatu Gorge and the Kafue Flats, the Kafue River picks up its main tributaries, the Kafalufuta, Lufwanyama, Lushwishi, Lunga, Lukanga and Lufupa Rivers. Most of these rivers have narrow floodplains or strip swamps along parts of their upper courses, and both the Lufupa and Lukanga flow through areas of permanent swampland. The Lufupa flows into the basin of the Busanga Swamp, from which it sometimes fails to emerge in dry seasons. Prior to its confluence with the Kafue, the Lukanga River flows through a shallow depression containing the Lukanga Swamp. This is the largest permanent swamp in the basin having an area in excess of 210 000 ha. At the height of the rains, flow may be reversed in the lower Lukanga as water from the Kafue River spills into the Lukanga Swamp. East of Itezhitezhi, seasonal flood waters spread over the broad floodplain of the Kafue Flats, where the greatly re-enforced river crosses the floor of the basin. The entire basin is riddled with dambos, the total water rententive capacity of which is great, so that their influence on the surface hydrology of the basin is profound.

(A) SWAMPS OF THE UPPER CATCHMENTS

General: Many permanent swamps occur on the Kafue River and its tributaries in the upper catchment areas. Most of these are narrow strip swamps occupying one or both banks of the river, and many are but a few hundred metres in width. However, there are several large permanent swamps. Lushwishi Swamp (13°15'S/27°24'E), measuring some 13x13 km and with an area of 9959 ha is situated on the Lushwishi River above its confluence with the Mininga River. To the east, Lufwanyama Swamp (13°15'S/27°42'E) covers 7400 ha, with maximum dimensions of 13x9.5 km. Mininga Swamp (13°30'S/27°12'E) extends for 24 km along the Mininga River, with a maximum width of 8 km and an approximate area of 14 400 ha. At this same latitude on the Kafue River, an apparently un-named swamp extends for 24 km along the river. It reaches widths of up to 19 km in places, and has an approximate area of 31 000 ha.

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(B) BUSANGA SWAMP

Location: 14°05'-14°21'S/25°46'-25°57'E
Area: c. 60 000 ha
Altitude: c. 1070 m asl
Nearest Town: Mumbwa (140 km SE)

General: This very isolated swamp comprises about 60 000 ha of permanent shallow swampland, situated within the tsetse fly zone on the edge of Busanga Plains. It is not exploited by man in any substantial way. There is no commercial fishery, and domestic cattle are excluded from the area. The swamp is not well known ecologically. In terms of physiography it is similar to Lukanga Swamp, lying in a shallow depression, but it differs in that there are discrete natural drainage channels across it. It supports a large and varied wildlife community and is utilised by substantial numbers of *Kobus ellipsiprymnus crayshawi, K. leche leche, K. vardoni, Loxodonta africana, Redunca arundinum* and *Syncerus caffer*. Crocodiles and monitor lizards are abundant. The flora and fauna are imperfectly known.

Conservation Status: The swamp is situated entirely within the Kafue National Park and is fully protected and undisturbed. Occasional safaris to the north of the park tend to avoid the swamp.

(C) LUKANGA SWAMP

Location: 14°00'-14°40'S/27°19'-28°00'E
Area: 210 000 ha
Altitude: c. 1090 m asl
Nearest Town: Kabwe (50 km E)

General: The swamp occupies a shallow depression of about 259 000 ha in extent, but permanent swampland and open water occupies only about 210 000 ha of this. However, nowhere is water known to exceed 6 m in depth, even at the height of the rainy season. The area of permanent inundation has an extreme E-W dimension of 97 km and an extreme N-S dimension of 77 km. The swamp includes two substantial islands, Chiposha and Chilwa Islands, the latter measuring some 14.5x6 km, and several semi-permanent lagoons and channels. The largest lagoon, adjacent to Chilwa Island, has maximum dimensions of 17x11 km. The capacity of the swamp, between average high and low water marks, has been estimated as 7381 million m^3. It receives water from several seasonal streams as well as the Lukanga River and has a sub-catchment within the Kafue Basin of some 14 245 km^2. At the height of the rainy season it receives overspill water from the Kafue River, and a broad corridor, 17 km wide, occupying 22 200 ha between the river and the permanent swamp, is inundated seasonally.

Flora & Fauna: Details are given in the introduction. Lukanga Swamp is essentially a reed/papyrus swamp.

Human Impact & Utilisation: There is a local fishery, but this is not as large as that on the Kafue Flats. The mean annual catch over the 5 years to 1980 was 792 tonnes, however, annual catches in excess of 2500 tonnes have been made and the lake is probably still underfished. The fishery is not seasonal and continues year round. During the dry season cattle are grazed on the small peripheral floodplain, especially in the area

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between the swamp and the Kafue River. Permanent canals have been dredged, linking chains of lagoons, to provide open waterways between Chilwa Island and the villages of Waya on the eastern edge of the swamp and Chitanda on the southern margin. These canals facilitate the transport of catches from the island, which is a fishing centre, to two road terminals.

Conservation Status: Unprotected.

(D) THE KAFUE FLATS

Location: 15°11'-16°11'S/26°00'-28°16'E
Area: 566 600 ha (maximum flooded area)
Altitude: 975 m asl
Nearest Towns: Lusaka (50 km NE); Kafue (at eastern end of floodplain)

General: The flats are some 256 km long and in places over 40 km wide. The area subject to flooding in the wettest years is difficult to ascertain with accuracy; estimates vary from report to report. For example, a maximum area of 438 000 ha is given by Coopconsult (1982) while an FAO (1968) report states that floods may cover 1.4 million acres, i.e. 566 580 ha (5666 km^2).

The flats are covered by deep sediments of Recent age, while older Pleistocene sediments, broken by remnants of hard plinthite crust or outcrops of bedrock, characterise much of the surrounding higher ground to north and south. There is a relatively sharp soil boundary between the flats and the adjacent uplands. The topography of the peripheral land is gently undulating and the surface soils vary from loamy sands to sandy clays. They tend to be highly porous with little capacity to retain moisture, except where a shallow depression develops over basal clay and then holds water forming a dambo. The parent soils of the Kafue Flats are heavy, black, cracking montmorillonitic clays, with lime concretions in the lower layers. Ferrolysis occurs because of the alternation of oxidising and reducing conditions imposed by the yearly cycle of flooding and drying. In this process, ferric ions are reduced by soil bacteria when the soils are inundated, and the ferrous ions so produced are exchanged for calcium ions from the clay. The soluble calcium is lost, but upon aeration the ferrous ions are oxidised. This process leads to the breakdown of the clay, with the release of aluminium and silica, and this in turn promotes the relative accumulation of sand particles over the flats. Eventually ferrolysis produces light textured and very acid topsoils.

Five months of the year are virtually rainless, but these are the coolest months, from May-September. Precipitation over the catchment varies considerably from year to year, and also quite markedly from site to site in any one year. Regardless of total rainfall, a progressive decrease in precipitation generally manifests itself from north to south across the catchment, the mean annual totals being 1375 mm in the north and 625 mm in the south. The lowest annual rainfall, averaged over the whole basin, was 750 mm in 1921-22, and the highest was 1250 mm, recorded in 1947-48 and 1951-52. Maximum and minimum temperatures in the lower Kafue Basin are in the region of 36 and 19°C in October, and 21 and 0°C in July. Mean annual class A pan evaporation ranges from 1800 mm in the lower Kafue Basin to 2000 mm along the shores of Lake Kariba.

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Hydrology & Water Quality: The natural hydrological cycle on the Kafue Flats is quite dramatic. Fully three quarters of the floodplain can change from an aquatic to a terrestrial environment within a season, and areas inundated to a depth of almost 6 m in April may be bone dry by September. At the western end of the flats, behind the Itezhitezhi Dam, a new lake, on previously unflooded ground, covering about 85 000 ha extends in a N-S direction for 85 km with a maximum width of 15 km. At the eastern end of the floodplain, behind the Kafue Gorge Dam, another area 80 km long and up to 20 km wide is also permanently flooded. This lake covers some 121 000 ha. At the peak of the rains this latter area is extended westwards so that, in a wet year, over 565 000 ha may be inundated.

The hydrological cycle of the flats is characterised by almost continuous change. Water levels are seldom stable for periods of more than 2-3 weeks at a time, and than only at peak high and low water periods. The principal inputs of water to the system are from the Kafue River, from the headwater areas above Itezhitezhi (controlled since 1978), direct rainfall over the flats, and seasonal run-off from the surrounding higher ground. Water is lost by discharge from the Kafue Gorge Dam and by evapo-transpiration. Marked annual variations in any one of the three inputs can occur independently of the others, and severe reduction of any one, causes quite dramatic changes in the total area inundated and the annual discharge to the Zambezi.

The Kafue River falls only 13 m in elevation in its 254 km transit of the flats between Itezhitezhi and Kafue. The mean gradient of the floodplain from east to west is 1:19 538, or 5.1 cm/km. But the river slope is more gradual (mean = 1:32 600). There are meanders, oxbows and abandoned channels everywhere, and the length of the river across the flats is 425 km. Levées occur on both sides of the main channel as it winds across the plain, although they are not continuous. Around the margin of the flats numerous small sandy deltas have built up where streams from the surrounding lands discharge on to the plain. Thus there is a general depression between the levées and the deltaic periphery of the flats. In this middle region numerous deeper depressions, some connected to the river and some not, are scattered all over the flats and may hold water from one year to the next. Drainage from the lowest lying areas is very slow, with innumerable pools finally drying out by evaporation and seepage. Birds swarm around these places waiting to eat stranded fish.

Drainage of the peripheral land is swift, with rapid surface drying after rain, except where water is trapped in dambos. The small streams which flow from the uplands directly onto the flats show extremely quick responses to precipitation; they may become torrents within an hour of the onset of a rainstorm, but be virtually dry again within a period of 36 hours. The subcatchment draining directly to the Kafue Flats by these seasonal streams has an area exceeding 45 300 km^2.

With the onset of the rains in December a flood crest forms at the western end of the basin and proceeds slowly eastwards, taking 80-90 days to traverse the plain due to impediments provided by vegetation and the low gradient. Peak flood levels are usually reached at the head of the Kafue Gorge in April/May, and in a wet year, high flood waters from the upper catchments may still be coming down at this time. Prior to control by the dams, the area inundated could vary greatly from year to year. In 1962-63, a wet year, water reached a depth of 12.1 m at the Kafue Rail Bridge, at the eastern end of the flats, and extended into *Colophospermum* woodland areas on the periphery of the flats. Large

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areas of water were still left on the flats at the beginning of the next rainy season in October 1963, but by contrast, this following season was extremely dry, and by April 1964 most of the flats were dry. Grass fires were observed as early as January 1964. However, with the operation of the Itezhitezhi Dam in 1978, the prospect of a more constant flood regime emerges. A two volume report (DHV, 1980) contains a computer model designed to maximise water availability and to assist in the regulation of water flow over the flats, but little if any use has yet been made of this. To date the effects of regulation have been erratic and unpredictable.

Measurements at the Kafue Rail Bridge since 1905 have revealed a pattern in annual run-off for the catchment, in which 3-4 successive dry seasons are followed by 3-4 successive wet ones. Moreover, during the past 70 years the annual run-off measured at this site has almost doubled, the most substantial increase having occurred since 1930. This seems to be due in major part to an increase in annual precipitation, but possibly also to changes in land use and development. It has been postulated that the discharge of aerial pollutants from chimneys along the Copperbelt, which began to discharge in the 1930s, led to cloud seeding, but the phenomenon is too widespread, increased rainfall also having been detected in Angola, Zimbabwe and Malawi. Today the mean annual run-off for the entire catchment is estimated at about 12.16 billion m^3, of which some 73%, or 8.876 billion m^3, reaches the Kafue Rail Bridge (FAO, 1968). The remaining 27%, or 3.284 billion m^3, is thought to be lost by evapo-transpiration jointly from the Kafue Floodplain (56% or 1839 million m^3) and the Lukanga and Busanga Swamps (44% or 1444 million m^3).

Seasonal changes are dramatic. In lagoons with abundant submerged vegetation, dissolved oxygen remains near saturation level throughout the year. By contrast in the river channels, dissolved oxygen falls as the season progresses. Most of the floodplain dries during the dry season and chemical nutrients are released by the decomposition of biota, by burning, and from the faeces of animals which invade the area to graze, principally domestic cattle and antelopes. With the advance of the season the nutrients dissolve and are taken back into plants as the floodplains are moistened by the rains. The speed and magnitude of this process increases with progressive inundation. The fact that floodplains are characterised by alternate periods of fallowing and flooding leads to higher productivity than in most other types of aquatic systems. The dissolved oxygen cycle on the flats determines the spatial distribution of fishes. In new and shallow flood waters the dissolved oxygen content is high. However, all but shallow waters quickly become oxygen deficient as the flood progresses and waters deepen, and they may remain this way until the peak of flooding, due to a prolonged biochemical demand for oxygen for decomposition. De-oxygenated water is chiefly populated by *Clarias* spp. which can utilise atmospheric oxygen.

The pH of the water on the flats rises as the flood recedes, from about 6.8 when the flood peaks in March to maxima of around 8.2 in September. Conductivity rises from about 95 µmhos/cm in March to over 350 µmhos/cm in November, while the concentration of total dissolved solids rises from about 60 ppm in March to about 210 ppm in November. However, in comparing the chemistry of water from Itezhitezhi with that from the Kafue Rail Bridge it is apparent that pH, total dissolved solids and suspended matter decrease as water traverses the flats from west to east, due to precipitation and deposition over

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the flats. For example, while incoming water at Itezhitezhi had a pH of 7.9 in May 1964, outgoing water at the gorge had a pH of only 7.1, and while incoming water contained 124 ppm total dissolved solids, outgoing water contained only 105 ppm.

Flora & Fauna: There is little reliable information regarding the phytoplankton of the Kafue Flats. The periphyton on plants in the permanently inundated regions at the east of the floodplain is dense. The flats are essentially grasslands, having in places, clear vegetational zones determined by the depth and duration of the inundation that they receive. However, within these zones, changes of dominant vegetation may occur in association with the alternation of aquatic and terrestrial environments, and also with annual variations in the extent of flooding. Over 40 herbaceous floodplain communities have been recognised on the flats and the vegetation has been described in some detail by van Rensburg (1968). Further information is given in the introduction.

Human Impact & Utilisation: Just over one million people, about a third of all Zambians, live in the Kafue Basin, which is nevertheless still very sparsely populated. A large part of the basin is infested by tsetse fly and is presently unsuitable for human habitation because of the threat of sleeping sickness, and two agents, *Trypanosoma gambiense* and *T. rhodesiense*, have been identified. In other parts, health conditions are primarily influenced by the occurrence of dambos and other marshy areas which harbour the carriers of malaria and bilharzia. River blindness (onchocerciasis) is rare in the basin, but its vector, *Simulium damnosum*, occurs both there and in neighbouring countries where the disease is prevalent. Irrigation projects in the basin could promote the spread of these diseases, so prevention and control measures must be a part of any development project. Fishing and cattle grazing are the two traditional occupations on the Kafue Flats, but in recent years various agricultural schemes have been inaugurated. Land use possibilities on the Kafue Flats are discussed in a report by Marchand *et al.* (1983).

Fishing: Fishing takes place continuously throughout the annual water cycle on the Kafue Flats. Gill nets, with a stretched mesh size of not less than 7.6 cm, are used during periods of high water from camps around the margins of the floodplain. Villages along the river banks are mostly inundated during high water and are vacated. Most fishing is accomplished from canoes. With the recession of the water, fishermen continue to use gill nets; seining cannot begin until late in the season when suitable beaches are exposed on the river and lagoon sides. A population of about 100 000 (18 000 households) gravitates around the fishing industry, but the number of active fishing families is about 2000. It has been estimated that some 1200 dugout canoes, largely made from *Acacia albida* trees, are still operated on the flats, mainly at the western end. Other fishermen operate glass fibre boats with outboard motors. Estimates of the total number of boats operated by fishermen in 1981 varied between 1620-2200. The use of weirs, lines and spears on the flats is insignificant. Extensive areas of the flats have been underfished because fishing takes place mainly from dugout canoes and is limited to areas within daily paddling range of dry ground, but this is changing as outboard motors are used. The annual catch averaged 5808 tonnes during the 13 years 1957-69, according to 'Fisheries Statistics (Natural Waters)', Central Statistics Office, Lusaka, 1970, but this figure had increased to 9273 tonnes/yr by 1980. The annual catch is however, still very variable, depending upon the wetness or dryness of the year. The catch in bad years has been as low as 2500 tonnes and as large as 12 500 tonnes in good years. However, of the

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67 fish species known from the flats, only 21 are utilised commercially, and the great bulk of the catch comprises three species of *Tilapia* and two of *Clarias*. The economic status of fishermen varies from poor, at subsistence level, to comparatively wealthy. Fish is presently sent to market in a rather haphazard way from the western and central regions. Traders come in lorries to collect the catch, which they preserve in ice, but since the lorries can drive only over the dried flats, they are often unable to reach the villages when catches are best. In this case the catch is dried, and sent to market in bundles when transport is available, but much valuable fishing time is then wasted in slitting and preparing the fish. Roads to the eastern end of the flats are much better and fishing is much more competitive here. A new fishery on Lake Itezhitezhi is becoming established and yielded 400 tonnes in 1982.

Cattle Grazing: Cattlemen drive their herds on to the flats as the waters recede, at the time when forage on the surrounding uplands is becoming scarce. The uncovered plain provides an abundant source of food; vast quantities of stranded rice-grass, *Oryza barthii*, and other aquatic vegetation is burned, and new terrestrial grasses grow rapidly. Cattle do not readily eat the collapsed rice-grass because it is coarse and frequently covered with mud, but they relish the new growth which appears almost immediately after burning. However, *Vossia cuspidata* and other lagoon grasses remain palatable and where the water recedes sufficiently, cattle eat them throughout the dry season. The cattlemen move further into the swamps as the season progresses, eventually coming to camp beside the lagoons and main river channel in September. By this time almost the entire floodplain has been burned by grass fires and grazed down by cattle and wild animals. The cattle are then driven back towards the uplands. Estimates of the number of cattle which visit the flats annually are unreliable but there can be little doubt that at least 200 000 and possibly as many as 350 000 domestic animals graze there each year. It is regretable that only a fraction of the enormous primary production of the grasses over the flats during the wet season is ultilised directly. The flats are infested with snails (*Limnaea* sp.) which are the secondary hosts of a liverfluke, and most cattle are infected. Others develop schistosomiasis, transmitted by another snail (*Bulinus globosus*), and in consequence a great many leave the flats in poor condition at the end of the dry season, despite the good grazing. Conjoint operation of the dams has decreased the area available for cattle in normal and wet years by increasing the area permanently flooded.

Agricultural Development: Various schemes for the development of agriculture on the flats have been undertaken, but with limited success. The most successful enterprises have been established on the unflooded fringes using water from the flats for irrigation. Empoldering the flats frequently meets with the problem that woody weeds like *Dichrostachys cinerea* invade and form immense tangled thickets on the dry land.

Conservation Status: Parts of the floodplain are protected in two national parks, situated roughly halfway along the flats. These are Lochinvar National Park (15°43'-16°01'S/27°11'-27°19'E), established in 1974 on the south side, and Blue Lagoon National Park (15°21'-15°43'S/27°15'-27°32'E), established in 1973 on the north side. The two national parks were formerly private ranches and had been managed as game reserves for many years prior to obtaining full protection. Approximately 60% of the Blue Lagoon Park and 50% of the Lochinvar Park are on the floodplain proper and are inundated in most years. A further large area, 517 000 ha, connecting the two national parks and straddling

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the Kafue River, comprises the Kafue Flats Game Management Area. A comprehensive range of vegetational types is conserved in the two parks, and they are both important refuges for local wildlife. Herds of *Kobus leche*, numbering 35 000, out of a total population of 50 000 on the Kafue Flats, enter the two parks seasonally. Most of the fishes, amphibians, reptiles and mammals which frequent the flats occur in the parks.

3. Wetlands of the Luangwa Valley

General: The Luangwa River rises at a point (9°53'S/33°20'E) on the northwestern tip of the Nyika Plateau which extends from Malawi into Zambia at an altitude of 1600 m asl, and receives 31 major tributaries before it discharges into Lake Cahora Bassa between the towns of Luangwa and Zumbo astride the Mozambican border. The upper reaches, above the 1300 m contour, are comparatively swift flowing and occasionally boulder strewn, but below this the river carries strips of fringing reed-swamp and riparian forest. At first it flows S, descending 600 m, to the 1000 m contour over a distance of 265 km with a mean gradient of 1:446. Thereafter it flows SW, more slowly, and begins to meander over a broader alluvial valley floor, between the high N-S watershed on the Malawian border and the Muchinga Escarpment to the west. Both of these highlands reach altitudes of 1800 m in places and many short tributaries descend from them. The Luangwa itself has a mean gradient of 1:555 as far as Lusangazi (13°28'S/31°32'E), after which it descends below 500 m, and meanders even more, as also do the lower reaches of its tributaries. It continues to flow SW to the town of Luangwa (15°37'S/30°27'E), but then swings S to Lake Cahora Bassa which it reaches at an altitude of 330 m. In this final section of its course its broad bed contains many oxbows, and sections of abandoned channel with levées, and in places the river has a braided course in a wide shallow terraced trench, graven in the sandy floor of the upper broader valley. Here the mean slope is only 1:2071, the river descending just 169 m in 350 km. In the dry season the river is confined to small channels winding their way between shallow sand banks, many covered with rheophytic vegetation, and with different vegetational types on higher banks and terraces towards the sides of the valley. In the rainy season, the entire river bed, several kilometres wide in places, is completely inundated, sand banks and all.

Flora & Fauna: In the upper reaches, and especially in the headwaters of the west bank tributaries, where rainfall may exceed 1200 mm/yr, evergreen or semi-deciduous forest fringes the river and its headwater tributaries, being especially well developed on patches of deep alluvium. Patches of swampy forest occur around springs in the headwaters. Lower down, some of the swamp forest species may fringe the streams, but where rainfall decreases below 850 mm/yr, as it does over most of the main Luangwa Valley, the riparian woodland becomes more open, and comprises many heliophilous species. These occur in a complex of riverine vegetation throughout the meander belt. Here species of *Acacia*, *Terminalia* and *Ziziphus* are present among many others. Occasional palms of *Borassus aethiopum*, *Hyphaene benguellensis* and *Raphia farinifera* may be seen among these trees on sandy riversides and *Acacia xanthophloea* and *Adansonia digitata* occur along the boundaries to which the flood waters just reach. The valley becomes drier towards the south, and the riverine vegetation lower and more open in this direction. More detailed information is given in the introduction.

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Crocodylus niloticus and *Hippopotamus amphibius* occur in the river, the latter species being abundant locally, and most of the small mammals listed in the introduction are present in the gallery forest. The Luangwa valley contains herds of an endemic subspecies of wildebeest, *Connochaetes taurinus cooksoni*, and these animals may often be encountered along the river together with many of the larger mammals found on the savannas.

Various tree snakes are common in the riverine forest, including *Dispholidus typus*. Birds closely associated with the rivers of the Luangwa valley include *Alcedo semitorquata*, *Alopochen aegyptiacus*, *Anas sparsa*, *Apus horus*, *Butorides striatus*, *Ceryle maxima*, *Charadrius marginatus*, *Hagedashia hagedash*, *Merops nubicus*, *M. bullockoides*, *Nycticorax nycticorax*, *Podica senegalensis*, *Rhynchops flavirostris*, *Riparia paludicola*, *Scopus umbretta*, *Scotopelia peli* and *Vanellus albiceps*.

Human Impact & Utilisation: The lower stretch of the river, some 250 km long, between the towns of Lusangazi and Luangwa is very sparsely inhabited and there are no significant centres of population. It is in this region that the heliophilous riverine forest reaches its best development. To the north of Lusangazi, there are some small towns, and a road follows the river northeastwards up into the headwater regions. Hunting takes place in the game reserves, and wildfires often burn through large areas.

Conservation Status: The Luangwa River forms the boundaries of three national parks, the North and South Luangwa Parks, and the smaller Luambe National Park. It also flows through the Musalangu, Munyamadzi, Lumimba, Chisomo, West Petauke, and Luano Game Reserve Areas. Thus more than 500 km of the seasonally flooded course of the river is protected to a greater or lesser extent.

4. Wetlands of the Bangweulu Basin

Location: 10°35'-12°05'S/29°28'-30°41'E
Area: c. 273 300 ha (open water) + 700 000 ha (swampland)
Altitude: 1140 m asl (main lake surface)
Nearest Towns: Mansa (75 km E); Lusaka (475 WSW)

General: The Bangweulu wetland system is among the largest in southern Africa, rivalling the Okavango Delta in size and complexity, yet it is far less well known, doubtless because access is difficult. The Bangweulu Basin lies on an ancient craton, in a shallow depression which has been filled with alluvium. On this alluvium the vast wetland, with its intricate lake, lakelet and waterway system has developed. The system covers nearly 1 000 000 ha and its drainage basin constitutes a headwater catchment of the Zaire River. It is situated in NE Zambia to the NW of the Luangwa Valley and Muchinga Escarpment. Lake Bangweulu, together with its subsidiary lakes and swamps, collects most of the run-off from a catchment 450 km long and up to 275 km wide, covering about 96 000 km^2 (other authors' estimates vary between 105 000-190 000 km^2). The basin receives most water from the NW slopes of the Muchinga Escarpment and the SE slopes of the Rift Valley Highlands on the Zambia-Tanzania border, but also from lands of low relief to the north, and from low watersheds to the west and south.

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Lake Bangweulu, which has maximum dimensions of 80 and 41 km, has an open water surface of some 273 300 ha. It subtends a major bay on the west (22 500 ha), known as Lake Chifunauli, and another basin on the east (58 500 ha) known as Lake Waliilupe. This latter area is not a separate lake but a basin largely separated from the main lake by Mbalala Island (45 km long), with connecting channels at both ends of the island. The main basin has a mean depth of 4.7 m and a maximum known depth of 10.4 m, while the 'baya' have respective mean and maximum depths of 2 and 3 m (Chifunauli) and 3.3 and 5.4 m (Waliilupe). Three large islands, Chishi, Mbabala and Chilubi are inhabited. Chilubi Island on the eastern 'shore' of the lake, has open water on its western side, but is surrounded by permanent swamp on its other sides. The shoreline of Lake Bangweulu is about 500 km long; it is slightly elevated, locally sandy, but mostly marshy. To the south of Bangweulu, the largest subsidiary lake, Lake Kampolombo (11°31'-11°51'S/ 29°35'-29°45'E), has a mean depth of 2 m, a maximum depth of 3 m, and an open water surface of 15 500 ha. Adjacent to this are the smaller lakes, Chali, Chifungwe and Kangwena.

A large area of permanent swampland and seasonally inundated floodplain lies to the N, E and SE of Lake Bangweulu, covering, at a conservative estimate, some 700 000 ha. This area contains innumerable shallow water bodies, some small, some large, and an intricate network of channels. Several substantial islands of dry land rise above it, the most important being Chett, Chichile, Kasansa, Nsumbu and Panyo Islands. The swamp is dominated by *Cyperus papyrus* and dense reed beds. Lake Chaya (11°23'S/30°33'E), one of the largest lakes, is situated on the eastern margin of the swamps.

Smaller wetland systems, the Kapabi Swamps (12°25'-12°35'S/30°05'-30°23'E), are situated on the Kasanka and Mulembo Rivers, in the south of the basin. They are separate from the Bangweulu Swamps, and drain directly via the Mulembo River to the Luapula River.

There are three seasons; a cool dry season from April-August; a hot dry season from August-October; and a warm wet season from November-April. Mean annual precipitation varies with site over the system between 1100-1500 mm, and is received over about 175 days. Rain is spread fairly evenly over the months January-March, but January is generally the wettest month, sometimes having total falls in excess of 300 mm. Over 3000 hours of sunshine are experienced each year, with some 300 hours in July and a monthly minumum of about 125 hours in January. Mean annual incident radiation is estimated as 180 Kcal/cm^2 over the system. Mean annual evaporation from the lake surface is estimated as 1642 mm/yr. Mean annual temperature is 21°C. October is the warmest month with a mean temperature of 24°C, a mean daily maximum of 32°C, an absolute maximum of 36°C, and a mean daily minimum of 17°C at Samfya at the southwestern end of the lake. July is the coolest month with a mean temperature of 16.5°C, a mean daily maximum of 23°C, a mean daily minimum of 10°C, and an absolute recorded minimum of 4.4°C at Samfya.

Hydrology & Water Quality: Lake Bangweulu is thought to have a capacity close to 11 250 billion m^3 at high water, and Lake Kampolombo an estimated capacity of 310 billion m^3. Lake Bangweulu receives water directly from some minor streams entering from the north (Luena and Luposhi) and the west (Lilandashi), but most enters from the swamplands on the E and SE shores. The principal affluent river of the swamps is the Chambeshi, which rises SW of Mbala, over 1550 m asl, in the highlands on the

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western margin of the East African Rift Valley. It has a drainage basin of 32 019 km^2. Together with the Lubansenshi (Lukuta) and Lutingila Rivers, which also enter the NE part of the swamps, the Chambeshi very largely loses its identity near Lake Chaya, breaking into a number of distributary streams. Some of these persist through the swamps to the Walilupe Basin, while one reaches the Luapula, below Lake Bangweulu, in the vicinity of Lake Chali (11°45'S/29°55'E). Drainage to the Bangweulu System from the Muchinga Escarpment is effected by the Munikashi, Kanchibya, Lumbatwa and Lukulu Rivers. These all disappear in the SE margins of the swamp, but the Mulembo, which drains several small swamps (e.g. 12°46'S/30°28'E and 12°40'S/30°14'E) in the Kasanka National Park, flows directly to the Luapula River, 50 km south of Lake Kampolombo.

Lake waters are high from March-June, when large areas of peripheral marshland are inundated, with minimum levels being attained between September and January when the peripheral marshes become dry. Water levels rise and fall by 1-2 m at the centre of the basin over the course of a year, causing the peripheral floodline to advance and recede by as much as 45 km. Long term studies indicate that water levels in the basin rose about 2 m during the period 1936-1943, and there is reason to suppose that this rise was an ongoing trend related to the tectonic tilting of the craton towards the NW.

The system is exorheic and the basin drains southwards into the Luapula River which has its origin on the southern margin of Lake Bangweulu. From here it flows due S for 180 km, then towards the E for a further 120 km, before descending the double Mumbotuta Falls, and finally turning N towards Lake Mweru. From here its waters eventually find their way to the Zaire River and the Atlantic Ocean. The mean discharge rate from the swamps into the Luapula River is 441 m^3/sec averaged over several years.

Surface temperatures in the main basin of Lake Bangweulu are generally in the range 24.3-27.2°C in December and 21.3-22.1°C in June, but occasional readings as low as 18°C have been made. Transparency, as determined by Secchi disks, varies with the seasons and between basins. The clearest waters are in the main basin, where Secchi depths range from 73-92 cm. Lake Chifunauli is more turbid, with corresponding figures of 42-45 cm. pH readings in Lake Bangweulu range from 6.9-8.3, falling to 6.5-6.9 in the papyrus swamps, and to 5.9-6.5 in the peripheral marshes. The lake water is generally well oxygenated, as is river water in flood, while the swamps and marshes are poorly oxygenated. The spread of oxygenated waters into the marshes, when the flood begins in January, encourages the movement of fishes out of the rivers and lakes into the seasonally flooded spawning areas.

Flora & Fauna: The phytoplankton of the lake is dominated by Cyanophyta and there is a diverse desmid flora. The open waters support dense beds of submerged and floating-leaved macrophytes, but in shallow water close to sandy parts of the shoreline, mostly on the west bank, there is a zone of emergent vegetation. This is quite open in structure, dominated by sedges, in particular by *Eleocharis dulcis*. Behind this there is usually a belt of *Phragmites mauritianus*, with thickets of *Kotschya africana* farther to landward. This latter species is inundated only seasonally. On the sand dunes along the western shore of Chifunauli Bay, there are thickets of *Diospyros batocana* and *Haplocoelum foliosum*. Along the muddy shores, which predominate in the north, east and south of the lake, *Cyperus papyrus* occludes the shoreline, with various lower growing aquatic associates. Seasonally inundated areas at the back of the landward margins of the papyrus

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swamps are dominated by grasses. The deepwater floodplain, parts of which may carry water from one year to the next, are covered by floating mat grasses that collapse as the floods recede. A feature of the floodplain is the large number of termitaria it supports. Many of these are complex structures, several metres in diameter, which rise above the peak flood levels and support islands of woody vegetation.

Woody species, also subject to seasonal inundation, occur on elevated ridges and the levées of old streams. Among these *Aeschynomene elaphroxylon* and *Ficus verruculosa* are the most common. Galleries of swamp forest occur along active affluent streams with a ground flora of swamp grasses, like *Leersia hexandra* and *Panicum repens*, together with various ferns including *Histiopteris incisa, Lygodium microphyllum, Microlepia speluncae, Thelypteris confluens* and *T. striata*. In the N and NE, away from the lake, seasonally flooded forest occurs and is dominated by *Erythrophleum suaveolens* and *Pterocarpus angolensis*.

The Bangweulu System supports a diverse fauna. The invertebrate fauna includes at least 7 species of gastropod mollusc and 8 species of bivalve mollusc. Among the gastropods, *Lymnaea natalensis* (intermediate host of the liver fluke *Fasciola gigantica*), *Bulinus africanus* and *B. globosus* (vectors of *Schistosoma haematobium* and *S. capense*) and *Biomphalaria pfeifferi* (vector of *Schistosoma mansoni*) are common. One of the bivalves, *Mutela hargeri schomburgki*, is believed to be endemic. The leech, *Placobdella jaegerskioeldi*, which parasitises crocodiles, is also noteworthy. Oligochaetes and chironomids dominate the benthic invertebrate fauna. Rotifers are abundant in the zooplankton, together with copepods (*Tropodiaptomus symoensi* endemic) and cladocerans.

Brelsford (1946) records 110 species of fish, while Mortimer (1965) identifies 86 species. Reptiles present include two crocodiles, *Crocodylus catapiractus* and *C. niloticus*, two terrapins, *Pelomedusa subrufa* and *Pelosios subniger*, the water monitor, *Varanus exanthematicus angolensis*, some skinks and geckos, and all the common marsh and swamp snakes. Accounts of the rich avifauna are given by Brelsford (1947) and Benson & White (1957), but most of the species cited in the introduction as being associated with the several wetland habitats are present. Over the past 60 years most of the larger mammals have been heavily exploited so that the present populations are well below the carrying capacity of the area. Large mammals still comparatively common in the system, including the floodplain grasslands, are *Damaliscus lunatus, Kobus leche smithemani, K. vardoni, Ourebia ourebi, Potamochoerus porcus, Redunca arundinum* and *Tragelaphus scriptus. Cercopithecus mitis*, including the ssp. *C. mitis moloneyi*, occurs in the swamp forests and peripheral woodlands.

Utilisation: The indigenous people have invaded Bangweulu Basin from the west in successive waves. The affluent peoples, who have had no experience of domestic stock, have based their livelihood on shifting cultivation, which is carried out on the floodplain areas, where cassava is the principal crop. Successive invasions have displaced established people, who have taken refuge in the swamps. These have then adopted a life based on fishing and hunting, and bartering fish and meat for clothes, vegetables and fuel, with people on the land. This has led to intense pressure on the large mammal population of the wetlands, especially on black lechwe. This is the most numerous large mammal of the floodplains, but its numbers have been reduced from at least 250 000

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(possibly over 600 000) at the turn of the century to perhaps as few as 4000 in 1966, a matter discussed by Bell & Grimsdell (1973). Intensive hunting was responsible for an initial decline to about 150 000, but rising water levels between 1936-1945 reduced the range available to this species and led to a fall in numbers to about 50 000 animals. Subsequent hunting reduced this to an all-time low during the middle 1960s, but relaxation of hunting pressure allowed the population to recover to the current figure which is in excess of 30 000. Many other species have been hunted to the point of extinction. There may now be some few hundred elephants and buffaloes, and possibly 100 lions. *Acinonyx jubatus* and *Diceros bicornis* are now very rare. During the First World War troops from Rhodesia and South Africa constructed a canal through the swamps to transport men and materials to a combat area in Tanzania, and this was also a time when animals were slaughtered on a large scale.

Fishing: The Bangweulu System was formerly the major source of fish for the nearby Copperbelt and the line of railway towns that served it, but the importance of the fishery has declined since improved communications have opened up other areas in the south of Zambia. Numerous channels were cut through the papyrus and reed beds of the swamps, connecting various open water areas, to provide passage for boats to and from road terminals. However, these have not been kept clear, and most have deteriorated. In many places the paddled canoe is the only form of transport, although there is still a passenger boat service between Samfya and the islands of Mbalala, Chishi and Chilubi. The road from Samfya to Mansa in the west is unmetalled. A total of 45 000 people lived in 870 established settlements, mostly on the western shore, and on the Kapata Peninsula which separates Lake Kampolombo from Lake Kangwena and the swamplands to the east. 6024 fishing boats were operating in the swamps in 1980. The fishing season is from May-November, during which time fishermen and their families move from their home villages to set up fishing camps on floating islands or higher land as the flood recedes. Very little fishing is done on open water; the fishery is essentially a swamp fishery. Small mesh gill nets are chiefly used, but fences, basket traps and beach seines are also utilised. Vast areas of the swamps are unfished, while small areas near the home villages are intensely overfished. Poor access to the area, and poor access to fishing areas within the swamps, are the factors responsible for the decline of the fishery, and families are leaving to re-settle in other fishing areas in the south. The mean annual yield over 5 years to 1980 was 9170 tonnes, with a maximum yield of 10 370 tonnes in 1980. The maximum sustainable yield is estimated at 20 000 tonnes/yr. *Oreochromis macrochir* accounts for a large proportion of the total catch, as much as 50% in some years, while *Alestes microphthalmus, Clarias mossambicus, Hydrocynus vittatus* and species of *Gnathonemus* and *Serranochromis* comprise the balance. Other species of lesser importance include *Engraulicypris moeruensis*, and several species of *Haplochromis*, *Mormyrus, Synodontis* and *Tylochromis*.

Conservation Status: Parts of the area to the northeast of Lake Bangweulu are fully protected, except against mining, in the Isangano National Park (established 1972). The Chambeshi River forms the eastern boundary of the park, and the Lubansenshi River traverses the park. Areas of swamp forest, papyrus swamp and floodplain are protected. Access to Isangano National Park is by foot or boat, and the area is not popular with tourists. Other large areas are protected in the Bangweulu and Chambeshi Game Management Areas to the south and southwest of the lake. The Kapabi Swamps, together

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with several small lakes, are fully protected in the Kasanka National Park (established 1972), to which access is also difficult, being confined to a rough bush track along which only 4 wheel drive vehicles are permitted. Here, areas of papyrus and *Phragmites* swamp, dambos with evergreen swamp forest (mushitu) and areas of floodplain are protected. There is no visitor accommodation in any of the National Parks or Game Management Areas in the Bangweulu Basin.

5. The Lake Mweru System

(A) LAKE MWERU & THE LUAPULA FLOODPLAIN

Location: 8°29'-10°26'S/28°20'-29°26'E
Area: c. 300 000 ha open water (in Zambia) + 300 000 ha floodplain
Altitude: 919 m asl (lake surface)
Nearest Towns: Mbala (250 km E); Kasaba (275 km SE)

General: Lake Mweru is situated on the Lusenga Plain in the extreme N of Zambia, on the border with Zaire. It is a shallow lake, deeper in the northern half than the southern half. A mean depth of 3 m, with a maximum depth of 10 m is recorded in the southern sector, but towards the north, the mean depth increases to about 10 m, with a maximum sounding of 37 m. The lake contains several islands, the most important being Kilwa, N'Kole and Isokwe Islands. The largest of these, Kilwa, covers 4600 ha. The shoreline, including that of the islands is close to 390 km. Welcomme (1972) gives the surface area of the lake as 4580 km^2, and some official records give the total open water area in Zambia as 2500 km^2. However, a careful perusal of maps suggests that the former is an underestimate, with a correct figure in the region of 5000 km^2. As to the area in Zambia, either the border is marked incorrectly on most maps, or the area is closer to 3000 km^2, and most recent authors cite the higher figures.

The lake has several affluent streams of which the Luapula and Kalungwishi Rivers are the most important, and one effluent stream, the Luvua River which leaves the northern end of the lake at Pweto (8°28'S/28°54'E) in Zaire. For some 500 km before entering Lake Mweru, the Luapula forms the border between Zambia and Zaire. Downstream of Johnston Falls (10°32'S/28°39'E), above Kasenga (10°22'S/28°45'E), where it flows due north, the river develops an extensive swampy floodplain on which are the Pembe and Mofwe (9°38'S/28°42'E) Lagoons and several smaller open water bodies, e.g. Lakes Kuswa, Kitshomponshi, Kifukula, Kainsa and Kinseneka. The floodplain increases in width to the north, and extends to the southern extremity of Lake Mweru where it covers some 25 km of the shoreline on each side of the border. Thus the southern lakeshore is swampy. The Kalungwishi River, which drains Lake Mweru Wa Ntipa, also flows through swampy flats and enters Lake Mweru half way along its eastern shore near Kafulwe (9°01'S/29°03'E) in another area of swampland. Much of the western and eastern shores are of high relief, more pronounced on the west bank above Mobanga. Here low cliffs are broken by occasional strips of sloping bank and by stream mouths. Some of the northern shoreline slopes gently into the lake, and is in many places sandy.

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A further swamp and floodplain area (9°32'-10°02'S/29°14'-29°26'E) occurs between the Kalungwishi and Lucingo Rivers, the latter stream a tributary of the Luapula. Here, during high floods, the waters of both streams mingle.

Mean annual rainfall over the lake is 1020-1120 mm depending upon site, but higher in the catchments. December is the wettest month, with falls of up to 275 mm, and the rainy season persists for about 195 days. Mean annual temperature at the lake is 22-23°C depending upon site. October is the warmest month with mean daily maxima of 31-34°C and mean daily minima of 18-19°C. July is the coolest month with a mean temperature of 20°C and mean daily maxima and minima of 28 and 14°C. Sunshine receipts are in the region of 2600 hours/yr, with a monthly maximum of 310 hours in July and a minimum of 125 hours in December. Incident radiation approximates 170 Kcal/cm^2/yr on the lake and evaporation from the lake surface has been estimated as 1700 mm/yr.

Hydrology & Water Quality: The drainage basin, for which Lake Mweru forms a collecting point, is vast, since it receives all overspill from the Bangweulu Basin, and has a total catchment of at least 200 000 km^2. The waters of the lower Luapula are high from March-May, and low between September and January. A maximum flood level of 8 m has been recorded at Kasenga and 5.8 m farther downstream at Kashiobwe, but the mean maximum level at Kasenga is 3.8 m. The waters of the lake itself are high from April until July, reaching their lowest between October and February. The mean annual fluctuation is 1.5 m, but a maximum variation of 4.7 m has been recorded. Water leaving the lake via the Luvua, enters the Lualaba and eventually the Zaire River en route to the Atlantic Ocean.

The lake is polymictic. Surface water temperatures reach 25-30°C during October-May, but fall to 22-25°C during June-September. Secchi depths vary from 0.6-1.46 m, and total dissolved solids amount to 41-69 mg/l depending upon the season. The pH of lakewater varies between 7.0-9.3, while in the swamps it is 6.0-6.9. An analysis made at Kilwa by Symoens (1968) gives the following concentrations in mg/l: calcium 7.4; magnesium 4.3; sodium 5.6; potassium 2.05; silicate 6.0; bicarbonate 46.2; carbonate 1.2; sulphate 2.0 and chloride 3.5. The lake is well oxygenated, the surface waters containing 5.4-8.9 mg O/l.

Flora & Fauna: There are vast expanses of free-floating hydrophytes in the lake and extensive beds of submerged vegetation. Around the shallower margins there are meadows of aquatic grasses which are backed by papyrus in suitable sites. Rocky shores are dominated by Chlorophyceae, with some hygrophilous herbs at higher levels, including species of *Alternanthera*, *Ipomoea* and *Oldenlandia*. Papyrus swamps fringe lagoons along the Luapula and dominate large areas of permanent swampland, with typical associate species. The same floodplain grasses are present as at Bangweulu. Little groves of *Aeschynomene elaphroxylon* occur on isolated and elevated sandy patches along the river, and often these are accompanied around their outer, lower, margins by *Hibiscus diversifolius*, which may be deeply inundated at high water. Patches of swamp forest typical of the interface between the Guineo-Congolan region and the Zambezian region occur in some permanently wet sites along rivers and streams, while gallery forests upstream contain *Chlorophora excelsa*, *Khaya nyasica* and *Parkia filicoides* in sites subject only to shallow and very temporary inundation. *Brachystegia-Julbernardia* woodland covers much of the surrounding, unflooded country, on sandy-loam soils, but

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within this woodland there are numerous large dambos containing patches of swampy evergreen forest.

The fish fauna of the system is diverse. 146 species have been described from the system, 94 from Lake Mweru. There are numerous representatives of Characidae, Cichlidae, Clariidae, Cyprinidae and Mormyridae. *Protopterus annectens brieni* occurs in the riverine swamps and floodplains, together with *Nothobranchius taeniopygus*. Reptiles in Lake Mweru include two crocodiles, *Crocodylus cataphractus* and *Crocodylus niloticus*, both considered to be vulnerable species. Man-eating crocodiles are a problem in the system. The aquatic snake *Boulengerina annulata* is found in Lake Mweru, while the typical spectrum of snakes occurs in the lagoons and swamps. *Varanus exanthematicus angolensis* is very common along streams, as are *Pelomedusa subrufa* and *Pelusios subniger*.

The avifauna is rich and includes typical floodplain birds and those associated with lakes and reed beds. Noteworthy species in the system include *Balaeniceps rex, Ephippiorhynchus senegalensis, Musciscapa aquatica, Pelecanus onocrotalus, Phoeniconaias minor, Phoenicopterus ruber*, and *Porzana pulsilla obscura*. *Hippopotamus amphibius* occurs in Lake Mweru and the Luvua River, *Tragelaphus spekei* is common in the swamps of the lower Luapula and Kalungwishi Rivers, *Kobus leche leche* occurs in the swamps of the lower Luapula, while *Kobus leche smithemani* is reputed to occur along the lower Kalungwishi. Most large mammals from the surrounding country visit the floodplain in the dry season.

Human Impact & Utilisation: The area is virtually undeveloped, but some 160 000 persons live in the region. There is no mining or manufacturing, and tourism has not yet developed. Outside the small and widely separated towns there are few villages. Small scale agriculture takes place on the floodplains. Fishing is concentrated on the lower Luapula and on Lake Mweru, and Zambian catches averaged 8989 tonnes over the five years preceding 1980, with a maximum figure of 10 680 tonnes. There were an estimated 7210 fishermen operating 4004 boats on Lake Mweru and the lower Luapula River from Zambian bases in 1980. A substantial proportion of the annual catch is sent south to the Copperbelt towns. The bulk of the catch comprises *Oreochromis macrochir*, with some *Serranochromis* and *Tylochromis* spp., and much smaller quantities of *Alestes, Auchenoglanis, Clarias, Gnathonemus* and *Synodontis*. *Labeo altivelis*, although important in the past, now accounts for only an insignificant part of the annual catch. A motor boat service for passengers and cargo operates on the Zairean side of the border, with a fortnightly schedule, between Kasenga and Pweto.

Conservation Status: Unprotected, apart from a small swiftly flowing section of the Kalungwishi River in the Lusenga Plain National Park. Some dambos with mushitu are also included in the park.

(B) LAKE MWERU WA NTIPA

Location: 8°24'-9°10'S/29°07'-30°13'E (entire wetland)
Area: c. 23 500 ha (open water) + 146 500 ha (swamp & floodplain)
Altitude: c. 940 m asl (lake surface)
Nearest Towns: Kasama (225 km SE); Lusaka (765 km WSW)

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General: The system lies in a trough running SW-NE between two escarpments, and comprises a large seasonal floodplain which attains an extreme length of 141 km from near the village of Munono (9°04'S/29°01'E) in the SW to Chisheka Swamp (8°23'S/30°13'E) in the NE. There are a number of permanent swamps, and many lakes and ponds on the floodplain; the largest permanent open water bodies being Lakes Mweru Wa Ntipa and Cheshi (Chishi or Chisi). The former is very variable in size, attaining an open water surface in excess of 20 000 ha at high water, but shrinking to less than a third of this during some dry seasons, and with depths seldom exceeding 3 m. There are several islands in the lake, the largest being Katima Island. In the region of this lake the floodplain reaches a maximum width of 37.5 km, and reaches the Zaire frontier near Musosa. Lake Cheshi, in the central southern floodplain, has an open water surface of up to 3150 ha. A number of small subsidiary wetlands occur on the drainage lines into the system, the principal ones on affluent lines are Tondwa Swamp-Lake Kako (8°43'S/30°13'E) at the northern end, and another at 8°51'S/30°06'E on a stream entering the central floodplain from the SE. Both these swamps have areas of approximately 8000 ha.

The area receives some 2600 hours sunshine a year, with a mean annual incident radiation receipt of 175 Kcal/cm^2. Mean annual rainfall is 910-950 mm, depending upon station, with maximum falls in December (c. 275 mm) and a dry season of about 175 days. The rainy season is November-April. Annual rainfall is variable, with wet years, in which more than 1300 mm may fall, occurring about once in every five years. Potential short grass evapo-transpiration is estimated as 1200 mm/yr and real short grass evapo-transpiration at 950 mm/yr. Mean annual temperature is 22.5°C. October is the warmest month with a mean daily maximum of 32.5°C and a mean daily minimum of 18°C, while the corresponding July figures are 28 and 13°C. Mean July temperature is 20°C.

Hydrology & Water Quality: Water enters the system from the north, through Chisheka Swamp, to the west of which a low watershed separates the floodplain from Lake Tanganyika, and from the SE where numerous streams, e.g. the Kasenga and Mwambeshi Rivers, enter the central floodplain. The bulk of the water loss is probably accounted for by evapo-transpiration, but water may flow out of the system during wet periods via the Mofwe Dambo which connects the floodplain to the Kalungwishi River. Thus, at high water, drainage may occur to Lake Mweru. The water levels of the system are extremely dependent upon local climatic conditions and Lake Mweru Wa Ntipa has dried, virtually completely, on occasions, e.g. during the years 1912-1919 and again in 1949-1950. The lake reached peak levels in 1974. Lake Cheshi receives water from the Kasenga and Mwambeshi Rivers, and its surface level does not fluctuate greatly.

Water chemistry fluctuates with the climate. The waters of Lake Mweru Wa Ntipa become highly saline during dry cycles when the total concentration of dissolved solids may exceed 20 000 mg/l. Sodium is the principal cation sometimes reaching concentrations of 8000 mg/l, while among anions bicarbonate may reach 5000, chloride 4500 and sulphate 2500 mg/l. The waters are usually clear and pale brown in colour, with Secchi depths approaching 2 m, and with pH values close to 9.5.

Flora & Fauna: The surrounding vegetation on unflooded land is *Brachystegia-Julbernardia* woodland, with thickets of *Bussea* and *Combretum* close to Lake Mweru

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Wa Ntipa. However, the vegetation of the lakes, ponds, dambos, mushitu, papyrus swamps and floodplains is essentially similar to that described in the introduction.

The fish fauna of Lake Mweru Wa Ntipa is poor with only 5 species, diversity probably being limited by the high salinity of the lake. At Lake Cheshi, where conditions are less inhospitable, there are 12 species: *Auchenoglanis occidentalis, Clarias mossambicus, Gnathonemus monteiri, Hepsetus odoe, Heterobranchus boulengeri, Labeo altivelis, Oreochromis macrochir, Sargochromis mellandi, Schilbe mystus, Serranochromis angusticeps, Synodontis nigromaculatus* and *Tilapia rendalli*. The reptilian fauna includes all the swamp snakes cited in the introduction, including *Boulengerina annulata*. In addition there are terrapins, water monitors, and two crocodiles. The crocodile carrying capacity of Lake Mweru Wa Ntipa has been estimated at 4000 and cropping was carried out in 1980 and 1981. Man-eating crocodiles have always been a problem for the local residents. The birds and mammals are similar to those of the Bangweulu Basin and the Luapula Floodplain, and include most of the species cited in the introduction.

Human Impact & Utilisation: Despite the scant permanent local population, c. 15 000 people, fishing in the Mweru Wa Ntipa system is quite intense with 3500 fishermen operating 1800 boats and a mean annual catch of 10 633 tonnes over the five years up to 1980, according to the Zambia Inland Fisheries Development Project Interim Report of 1982. Thus the fishery is more productive in terms of fishing effort than that of Bangweulu or Lake Mweru and the Luapula. Fishermen tend to move into the area from Lake Mweru when catches there are falling, and overfishing in dry cycles is a problem. The most important fishing camps are at Kampinda (9°46'S/29°46'E), Kasongo, Milose, Mukubwe and Lake Cheshi and the catch comprises mainly *Clarias mossambicus* and *Oreochromis macrochir*, which between them may account for more than 90% of the total. The great bulk of the catch is exported to the Copperbelt towns. The highest reported annual catch from the system was nearly 16 000 tonnes, but several authorities, e.g. Lowe-McConnell (1975), have cast doubt upon the validity of the figures for Lake Mweru Wa Ntipa, in view of the reputedly low fish biomass in the lake.

Small scale agriculture is carried out on the floodplain margins. Some salt is produced in villages on the NW of Lake Mweru Wa Ntipa. There are no important centres of population in the area. The short grass plains on the fringes of the seasonally inundated area were an important breeding ground for the red locust, *Nomadacris septemfasciata*, particularly in the 15 years up to 1944, and control measures have been a recurrent disturbance.

Conservation Status: Lake Mweru Wa Ntipa and much surrounding swamp and floodplain is protected in the Mweru Wa Ntipa National Park which was established in 1972, but part of the area had been protected as a Game Reserve since 1942. There are permanent settlements in the park and it has been zoned, providing a total wilderness area, to which the public are denied access, a commercial fishing zone, and a restricted residence zone. There is little tourism but camping facilities are available outside the park and there is reasonable access.

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6. Lake Tanganyika

Location: 3°21'-8°51'S/29°04'-31°12'E
Area: 32 800 km^2 (2100 km^2 in Zambia)
Altitude: 773 m asl
Nearest Town: Mbala (50 km SE)

General: Lake Tanganyika is 659 km long with a maximum width of 85 km at a latitude of 5°55'S. It is slightly brackish and the second deepest lake in the world (1470 m). It occupies the southern end of the western arm of the East African Rift Valley and over much of its length its shores are steep, with adjacent high mountain ranges. However, this is not the case in the small Zambian section at the southern extremity of the lake. Here, over the 185 km of Zambian shore, gradients are more gentle and there is a papyrus swamp at the mouth of the Lufuba River (8°43'S/30°46'E). Approximately 210 000 ha of the water surface are situated in Zambia. The flora, fauna, hydrology and water chemistry of the lake are dealt with in detail in section 2.9.4b, Lake Tanganyika.

A gill net fishery operates on the lake from the Zambian shore employing over 1800 fishermen and 1240 boats, and yielding a mean annual catch of 6443 tonnes (1976-1980). The local population of the Zambian shore is 11 700 persons (1980) and much fish is exported to the south.

7. Lakes Lusiwasi & Ishiba Ngandu

General: These two high level lakes, each of some 2500 ha surface area, are situated on opposite sides of the Muchinga Watershed. Water from Lake Lusiwasi (13°00'S/30°52'E), over 1500 m asl on the western side of the Luangwa Valley, drains eastwards through a short swampy area, before descending swiftly to the Luangwa River. Lake Ishiba Ngandu (11°14'S/31°46'E), situated about 1300 m asl, receives water from several short streams which descend steeply to the lake. Drainage is then westward to the Chambeshi River and the Bangweulu Basin.

8. Artificial Impoundments

(A) LAKE KARIBA

Location: 16°33'-18°01'S/27°00'-29°05'E
Area: 536 130 ha (241 200 ha in Zambia)
Altitude: 484 m asl
Nearest Towns: Livingstone (125 km W); Lusaka (125 km N)

General: The lake was filled in 1958 and 45% of the water surface lies within Zambia, with the remainder in Zimbabwe. The lake was successfully stocked with lacustrine species, e.g. tilapias and *Limnothrissa miodon* by Zambian agencies. Gill nets are used exclusively by artisan fishermen, and prior to the prohibition of fishing in Zambian waters in 1976, total annual catches were in the region of 2000-3000 tonnes. No fishing was carried out in Zambian waters during the years 1976-1980, but in 1982 it was estimated that 1004 fishermen were again operating from the Zambian shore. The total annual recorded catch upon the resumption of fishing in 1980 was 410 tonnes, but official

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estimates are that the correct figure was nearer 1000 tonnes. A commercial sardine fishery began on the Zambian side of the lake in 1981 using mechanised dip nets and lift nets, but there are fears that the lake is being over fished for *Limnothrissa* on the Zimbabwean side. The MSY for Zambian waters is 5500 tonnes. Thus if the gill net fishery reaches its MSY of 2500 tonnes, the lake could yield up to 8000 tonnes fish/yr for Zambia. The hydrology, flora and fauna of this impoundment is dealt with in some detail in section 5.10.5a, Lake Kariba. Marshall (1981) has reviewed the sardine fishery of the lake.

(B) KAFUE GORGE DAM

General: This subtends a lake with a mean area of 121 000 ha at the eastern extremity of the Kafue Flats and is dealt with in section 5.9.2d.

(C) LAKE ITEZHITEZHI

Location: 15°00'-15°44'S/26°00'E
Area: 85 000 ha
Altitude: 988 m asl
Nearest Towns: Mumbwa (90 km E); Lusaka (255 km E)

General: This reservoir was filled in 1978. It extends almost due N-S along the parallel of longitude 26°00'E for 85 km, with widths of up to 15 km. The dam controls the flow of water onto the Kafue Flats. It supports a fish fauna typical of the upper Kafue system, and a fishery on the lake yielded 400 tonnes in 1982. Beds of submerged aquatic species are developing, together with mats of floating leaved and free-floating macrophytes. Some bays have become fringed by reeds. It may be anticipated that the avifauna will be typical of open lakes in Zambia, and that it will share all the species of that habitat found at the eastern end of the Kafue Flats.

Conservation Status: The lake is situated within the Kafue National Park and is fully protected. However, an island in the lake supports a fishing village, and a squatter settlement created by the labour force involved in the construction of the dam has persisted.

(D) MITA HILLS & MULUNGUSHI DAMS

General: These two reservoirs are situated in the Central Province of Zambia. Mulungushi Dam (14°27'-14°40'S/28°49'E) is in the hills 110 km NE of Lusaka, while Mita Hills Dam (14°03'-14°15'S/29°04'E) is 160 km NE of Lusaka. Both operate small hydroelectric power stations, and both subtend lakes some 25 km long, with surface areas in excess of 7000 ha. Both support local fisheries, and a typical aquatic avifauna. Both drain into the Lunsemfwa River, then to the Lukusashi and Luangwa Rivers, and ultimately to the Zambezi. Neither lake is protected.

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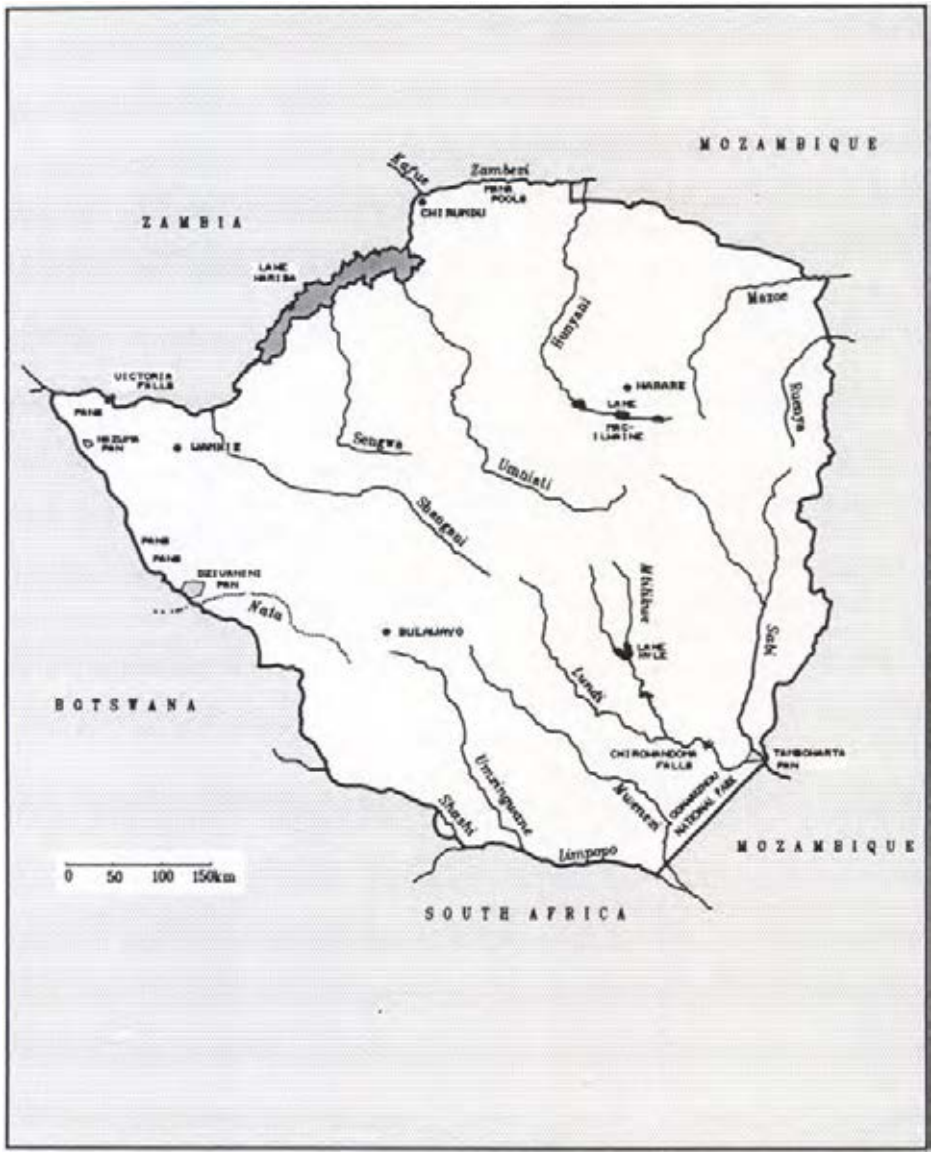

Map of Zimbabwe

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5.10 ZIMBABWE

Introduction

Zimbabwe is a land locked country bounded on the south by South Africa, on the southwest and west by Botswana, on the north by Zambia, and on the northeast and east by Mozambique. It has an area of 390 310 km^2, a population of 7 532 000 (1982), and lies on the great central plateau of southern Africa. The high rim of the plateau forms the border with Mozambique for some 450 km. To the north and south of which vast gaps have been eroded through it by the Zambezi and Limpopo Rivers, the beds of which constitute the northern and southern boundaries of Zimbabwe. Some 70% of the total land surface is above the 600 m contour, and it is virtually all (more than 99%) above 300 m. The principal physiographic feature of the interior is a broad ridge which runs 650 km from southwest to northeast across the whole country, from Plumtree (20°30'S/27°50'E) through Gweru (19°27'S/29°49'E) to Macheke (18°05'S/31°51'E). About 80 km wide, this ridge ranges in altitude from 1220-1675 m, finally rising to the summit of Inyangani (18°18'S/32°54'E) in the east, 2595 m high on the rim of the plateau. From here, both north and south, the edge of the plateau is mostly above 1500 m, with an outlier in the south, Mt. Binga, rising to 2436 m just inside Mozambique (19°47'S/33°03'E). The broad SW-NE ridge across the interior forms the major watershed of the country from where northward flowing rivers are tributary to the Zambezi and southward flowing ones tributary to the Limpopo. The lowest points in Zimbabwe are on the border with Mozambique in the Save and Limpopo valleys. Major faulting from southwest to northeast, some 100-130 million years ago, formed the middle Zambezi Trough, in the north, now partly flooded by Lake Kariba. Other faulting, in both east-west and north-south directions, affected the depressions of the Save (Sabi) and Limpopo Rivers.

Climate

Zimbabwe is entirely tropical, but enjoys a relatively cool climate because of its altitude, although solar radiation is very high, most of the country receiving more than 3200 hours of sunshine per year. Towards the end of the hot dry season from August-October, easterly monsoon winds, that have crossed the Indian Ocean and Mozambique, cause precipitation on the Eastern Highlands. The eastern districts consequently receive the heaviest rainfall, and have a more prolonged rainy season (from October into April) than the rest of the country. Here many of the high peaks receive mean annual falls of over 2000 mm, and large areas on the eastern slopes receive more than 1500 mm of rain each year. A substantial part of the country, comprising the northeastern and central districts, and an isolated pstch in the west adjoining Botswana and the Caprivi Strip, perhaps 60% of the total land surface, receives mean annual totals of 800-1000 mm. The west of the country is arid, with mean annual totals of about 600 mm, while parts of the Save and Limpopo River valleys receive less than 400 mm/yr. The altitude of the broad plateau of western Zimbabwe helps to guarantee fine weather with clear skies for most of the country during the cool, dry months of May-August. July is generally the coolest month, and October the warmest. Harare, the capital, at an altitude of 1500 m, has mean monthly minima and maxima of 6 and 21°C for July, and 15 and 29°C for October, while

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Bulawayo (1350 m) farther west has comparable figures of 7 and 21°C for July and 15 and 30°C for October. It is warmer in the west, and in the Zambezi Valley, while at low altitudes in the Limpopo Valley, temperatures often exceed 40°C in summer.

Wetlands

The principal drainage systems are those of the Zambezi in the north, the Save in the east and the Limpopo in the south. In the west the small Nata River drains into the Makgadikgadi Pans in Botswana. The mountains of the Eastern Highlands are spectacular, and many streams, rising there in sponges, flow east for short distances before plunging dramatically over escarpments in waterfalls hundreds of metres high. The highlands are deeply dissected by the many streams they spawn, especially those flowing into the Save and Limpopo Rivers. Extensive swamps and floodplains are lacking in Zimbabwe because the river valleys are steep and narrow. A small floodplain area exists in the mid-Zambezi Valley, in the Mana Pools district, where the course of the Zambezi River has slowly been moving northwards. Another floodplain occurs on the Save River upstream of its confluence with the Lundi at the Mozambican border. There are numerous pans in the west of the country, numerous impoundments in the mountains, and Lake Kariba in the north.

Wetland Flora & Fauna

The flora is described for each site individually since they are so different. However, the spectrum of reptiles and mammals utilising the various sites is fairly constant and represents the few resident wetland species and those that live in the surrounding savanna and bush, and which visit the wetland systems regularly, at least during the dry seasons.

The reptiles include the snakes *Amblyodipsas polylepis*, *Amplorhinus multimaculatus*, *Bitis arietans* (W Pans), *B. gabonica* (E Pans), *Crotaphopeltis hotamboeia*, *Dromophis lineatus*, *Limnophis bicolor*, *Lycodonomorphus inlanjensis*, *L. rufulus*, *Naja melanoleuca*, *N. mossambica*, *Natriciteres sylvatica*, *Philothamnus hoplogaster*, *P. irregularis*, *Psammophis sibilans* and *Python sebae*, together with the arboreal species *Dasypeltis medici*, *D. scabra*, *Dendroaspis angusticeps* and *Thelotornis oatesi*. *Crocodylus niloticus* and *Varanus niloticus* are widespread and the terrapins *Pelomedusa subrufa* and *Pelusios* spp. are present.

The resident mammals comprise *Aonyx capensis*, *Atilax paludinosus*, *Dasymys incomtus*, *Herpestes ichneumon*, *Felis caracal*, *F. lybica*, *Genetta tigrina*, *Hippopotamus amphibius* and *Redunca arundinum*. The regular or seasonal visitors include *Acinonyx jubatus*, *Aepyceros melampus*, *Alcelaphus lichtensteini*, *Cephalophus* spp., *Connochaetes taurinus*, *Crocuta crocuta*, *Damaliscus lunatus*, *Diceros bicornis*, *Equus burchelli*, *Giraffa camelopardalis* (W Pans), *Hippotragus equinus*, *H. niger*, *Kobus ellipsiprymnus*, *Loxodonta africana*, *Lycaon pictus*, *Mellivora capensis*, *Neotragus moschatus*, *N. moschatus livingstonianus*, *Oryx gazella* (W Pans), *Ourebia ourebi*, *Panthera leo*, *P. pardus*, *Phacochoerus aethiopicus*, *Potamochoerus porcus*, *Raphicerus campestris*, *R. melanotis*, *Sylvicapra grimmia*, *Syncerus caffer*, *Taurotragus oryx*, *Tragelaphus angasi*, *T. scriptus* and *T. strepsiceros*.

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List of Wetlands Described

1. The Mid-Zambezi Valley and Mana Pools
2. Wetlands of the Save River System
3. Gorhwe and Manjinji Pans
4. Pans of the Western Districts
5. Artificial Impoundments
   (a) Lake Kariba
   (b) Lake Kyle
   (c) Impoundments on the Hunyani River
   (d) Other Impoundments

1. The Mid-Zambezi Valley and Mana Pools

Location: 15°36'-16°24'S/29°8'-30°20'E
Area: c. 36 000 ha (total riverine expansion floodplain)
Altitude: c. 490-510 m asl
Nearest Town: Chirundu

General: Some way after leaving the Kariba Gorge the Zambezi River is joined by the Kafue River near Chirundu, where it is also crossed by the Otto Beit Bridge into Zambia. From here the river broadens and has something of a braided course for almost 130 km to the Mupata Gorge. The many fragmented streams produce between them numerous low lying sandy islands, containing pans and pools, with further pans and pools along the river banks. The lower valley floor is 12 km wide in this region and the multi-channelled river bed may account for up to 5 km of this, as for example at Nyamatusi Islands (15°40'S/29°29'E), to the northeast of Mana Pools. Much of the flat valley floor, and some shallow river terraces along its margins, used to be inundated when the river was in high flood, but now that discharges are regulated at Kariba this no longer happens; the river now does little more than spread over its broad bed to unite all its channels and inundate most of the midstream islands and the fringes along its banks. However, several small tributaries flow down through swampy land to the Zambezi in the Mana Pools region. From west to east these are the Nyamuchera, Chiruwa, Mbera and Sapi, and if floods in these coincide with major discharges from Kariba substantial areas along the south bank of the Zambezi may be inundated. The Mana Pools proper, are small permanent pools that mark depressions in former river channels which were abandoned as the main flow moved progressively northwards, towards the Zambian bank. The pools have flat, grass and reed covered banks, and are approached quite closely by surrounding forest. Some of the pools are higher than others, being situated along the southern bank on shallow river terraces; the two largest and best known depressions in the Mana region are Long Pool and Chine Pool. These are situated just above the channel bed of the river. When flow is low, much of the river bed is dry, save for several deep channels, and the area is characterised by numerous sand and pebble banks, one of which in the Mana region has an area of 6000 ha.

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Hydrology: The main pools are permanent, deriving their supplies principally from precipitation and ground water seepage, and only occasionally from flooding. The area of the Main Pools *per se* is but a fraction, say 3%, of the total area that the Zambezi once used to flood in this region, perhaps amounting to a few hundred ha of open water and equivalent areas of adjacent swamp.

Flora & Fauna: The area has a particularly rich riparian flora, all species of which show some degree of flood tolerance. A clear pattern of succession can be followed on the sandy islands of the river bed, modified on the higher ones as more terrestrial species come in. *Phragmites mauritianus* and various sedges colonise backwaters, the margins of pools and bends away from the current, producing extensive reed banks. *Phoenix reclinata* often grows behind these, and there may be small patches of *Cyperus papyrus* in backwaters. Sand binders, stoloniferous grasses, sedges and Convolvulaceae, grow on the alluvial islands and pebble spits, eventually providing conditions suitable for the germination of woody species, such as *Acacia albida* and *A. erubescens*. Thereafter seedling thickets of these trees help bind the new, sandy deposits. The floras of the islands are less diverse than those of the outer river banks over this stretch above Mupata Gorge, but the larger islands may support as many as 20 arborescent species. *Commiphora ugogensis, Kigelia africana, Terminalia sericea* and *Trichilia emetica* are common on the larger ones. Other trees sometimes found on the islands, but common in the riverine forest, include *Acacia galpinii, A. nigrescens, Balanites maughamii, Berchemia discolor, Cassine aethiopica, Combretum zeyheri, Cordyla africana, Diospyros mespiliformis, Fagara leprieurii, Garcinia livingstonei, Lannea stuhlmannii, Leeaniodiscus fraxinifolius, Lonchocarpus capassa, Olea africana, Schrebera trichoclada, Syzygium cordatum, S. guineense, Tamarindus indica, Terminalia prunioides*, and the woody climbers *Acacia schweinfurthii, Ancbotrys brachypetalus, Capparis sepiaria, Dalbergia martinii* and *Rhoicissus revoilii*. Some trees, e.g. *Berchemia discolor*, attain heights of 30 m in riverine woodland. A few species are virtually confined to the riverine woodland and are seldom found elsewhere in Zimbabwe and thus deserve special mention. These are *Cassine schlecterana, Cassipourea gossweileri, Ficus zambesiaca, Strophanthus courtmontii* and *Triplochiton zambesiacus*. This last species is endemic to the Zambezi Valley. Other trees, like *Combretum imberbe*, are most common along the dry streambeds of small tributaries.

Dense low riverine scrub occurs on the islands and river banks, beneath the frontal forest trees, and in tumbled rock and boulder clumps in the river. It contains such species as *Allophylus africanus, Bauhinia tomentosa, Bridelia cathartica, Byrsocarpus orientalis, Cadaba kirkii, Canthium frangula, Cleistochlamys kirkii, Combretum albopunctatum, C. mossambicense, C. paniculatum, Cordia goetzei, C. pilosissima, C. sinensis, Croton megalobotrys, Deinbollia zanthocarpa, Diospryos quiloensis, D. senensis, D. squarrosa, Dombeya kirkii, Ehretia amoena, Euclea divinorum, Excoecaria bussei, Feretia aeruginescens, Friesodielsia obovata, Gardenia resiniflua, Grewia bicolor, G. flavescens, G. gracillima, G. pachycalyx, Hippocratea parvifolia, Holarrhena pubescens, Holmskioldia tettensis, Hugonia orientalis, Ibota riparia, Markhamia acuminata, Maytenus senegalensis, Nuxia oppositifolia, Ochna povumensis, Oncoba spinosa, Phyllanthus reticulatus, Phoenix reclinata, Pouzolzia hypoleuca, Premna senensis, Pteleopsis myrtifolia, Rhus gueinzei, R. tenuinervis,*

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Salvadora persica, *Sesbania sesban*, *Strychnos madagascariensis*, *S. potatorum*, *S. spinosa*, *Tarenna luteola*, *Tricalysia allenii*, *Vernonia amygdalina*, *V. colorata*, *Ziziphus abyssinica* and *Z. pubescens*. All the foregoing species may be found in sites subject to seasonal flooding.

About 40 species of fish are found in the area including *Distichodus mossambicus*, *D. scheuga*, *Heterobranchus longifilis*, *Hydrocynus vittatus*, *Protopterus annectens* and *Tilapia* spp. The sand banks and spits of the middle Zambezi provide ideal habitats and breeding sites for *Crocodylus niloticus* and there are thought to be over 1000 adult crocodiles on the Zimbabwean side of the valley in the vicinity of Mana Pools. Several species of aquatic or semi-aquatic snakes present in the riverine vegetation as listed in the introduction.

Over 380 species of birds have been recorded in the area including *Agapornis lilianae*, *Circaetus cinerascens*, *Erythrocercus livingstonei*, *Glareola nuchalis* and *Nicator gularis*. *Merops nubicus* breeds in holes in the sand islands and river banks in large numbers. A wide range of mammals visits the wetland area; especially towards the end of the dry season when other watering places have dried out. An account of the seasonal patterns of large mammal distribution in the area is given by Jarman (1972), and the species concerned are listed in the introduction.

Human Impact & Utilisation: The area is not conducive to permanent human habitation on account of the wide spectrum of tropical diseases such as sleeping sickness, bilharzia, malaria and onchocerciasis. The natural flood regime of the valley has been seriously altered since the completion of the Kariba Dam in 1958. A potential threat lies in the proposed hydroelectric scheme at Mupata Gorge, where the Zambezi crosses the 500 m contour line. The lake so formed would obliterate a further 85 000 ha of the Zambezi Valley and would halve the area of the Mana Pools proper. Du Toit (1982) has published a preliminary assessment of the environmental impact of the proposed scheme.

Current problems in the area include the poaching of fish and the destruction of habitats by elephants. The Mana Pools National Park is only partially developed as a tourist centre, but it is popular and the available facilities are prone to saturation, although the number of cars allowed into the park at any one time is limited. There is a tourist camp at Chekwenya on the confluence of the Sapi and Zambezi Rivers, but there are no tarred roads and numbers of visitors are strictly limited. The Sapi and Chewore Safari Areas are subdivided into various hunting concessions which are allocated to hunters on a tender system. Many of the hunters who submit tenders each year are commercial safari operators who use the concessions for hunting by foreign clients.

Conservation Status: Almost all the riverine floodplain and riparian forest is included in the Mana Pools National Park or adjacent safari areas. The park was established in 1963. The adjacent safari areas of Chewore, Urungwe, Sapi and Doma have extensive frontages along the Zambezi River, and hunting in Chewore has been licensed since 1930. The whole area has been submitted for recognition as a World Heritage Area.

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2. Wetlands of the Save River System

General: Chipinda Pools (22°15'S/31°50'E) is the name given to a cluster of large perennial pools in the bed of the Lundi (Runde) River. The flow regime of this stream has been seriously affected by increased siltation and by impoundments on its major tributaries, and the river no longer overtops its banks in this region. Chipinda Pools are situated in the northern half of the Gonarezhou National Park and lie more than half way down the eastern escarpment, under the rainy upper slopes of the Eastern Highlands and below Chirowandoma (Chivilila) Falls, the foot of which is almost on the 500 m contour. At the foot of the falls the Lundi debouches onto gently undulating country across which it flows for 50 km, descending into a broad valley some 450-350 m asl. Chipinda Pools lie on the river bed here c. 400 m asl, and are visible only in the dry season. Numerous small depressions occur in the open woodlands far from the river, apparently being filled by direct precipitation and local surface drainage in most years. Some of these are surrounded by narrow *Cynodon dactylon* lawns.

Below Chipinda the Lundi flows quietly for a further 75 km northeast to its confluence with the Save River on the border with Mozambique near the town of Mavue (21°22'S/32°24'E). Immediately prior to the confluence, there is another wetland, as during the rainy season the flood waters of the two rivers mingle over the triangular piece of land between them, inundating between 3000-4000 ha. This land is known as Tamboharta Pan, although it is more properly a floodplain with several incorporated pans. The confluence of the Lundi and Save Rivers occurs at the lowest point in Zimbabwe. Bilharzia and malaria are rife in the area.

Flora & Fauna: Areas of dense forest occur along the Lundi River, in which trees and shrubs characteristic of hot, low altitude swamp or riparian forest are common. The species present all thrive in deep sandy alluvium, tolerate inundation, and include *Azima tetracantha, Cordyla africana, Croton megalobotrys, Diospyros mespiliformis, Ficus capreifolia, Guibourtia conjugata, Pteleopsis myrtifolia, Salvadora angustifolia, S. persica, Strychnos henningsii, S. madagascariensis, S. spinosa, Terminalia gazensis, T. sericea* and *Xanthocercis zambesiaca.*

Fishes present in the rivers and pans include *Hydrocynus vittatus, Nothobranchius* sp., *Protopterus annectens* and *Tilapia* spp. *Megalops cyprinoides* and *Pristis microdon* both penetrate the Save as far as Zimbabwe. Many snakes are associated with the pans, floodplains and riverine vegetation of the Save and Lundi Rivers. *Cyclodema frenatum* also occurs in the system and *Crocodylus niloticus* and *Varanus niloticus* are common.

The area including Chipinda Pools, the nearby courses of the Lundi and Save Rivers, and Tamboharta Pan, is rich in bird life. Notable species include *Alcedo semitorquata, Anas undulata, A. sparsa, Anhinga rufa, Ardea goliath, A. melanocephala, Casmerodius albus, Centropus grillii, Ceuthmochares aereus, Charadrius asiaticus, C. tricollaris, Circus ranivorus, Corythornis cristata, Dendrocygna viduata, Egretta intermedia, Falco biarmicus, Geronticus calvus, Hagedashia hagedash, Halcyon senegalensis, Megaceryle maxima, Melittophagus bullockoides, M. pusillus, Merops boehmi, Nettapus auritus, Porzana pusilla, Recurvirostra avosetta, Sarkidiornis melanotus, Scotopelia peli, Tringa glareola* and *Urocolius indicus.*

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Resident mammals include *Aonyx capensis*, *Atilax paludinosus*, *Cercopithecus albogularis*, *Dasymys incomtus*, *Galago senegalensis*, *Lutra maculicollis*, *Otomys irroratus*, *Paraxerus cepapi* and several bats. The red squirrel *Paraxerus palliatus* is sympatric with the yellow-footed squirrel here, but the former is more common in dense riparian forest and the latter in trees around pans. A spectrum of large mammals visits the pools and floodplain and some, including elephants, are said to migrate between Gonarezhou and the adjoining areas in Mozambique and the Kruger National Park in South Africa to the south. This means that they have to cross the Limpopo River, but when not in spate this is often reduced to broad strips of sand, with mere streamlets of water and large isolated pools.

Human Impact & Utilisation: The flow regime and water quality of the Lundi and Save Rivers have been influenced by upstream impoundment for irrigation purposes. The Gonarezhou Park is open to visitors in the dry season from May-October. There is a rest camp in the park near the Lundi River at Chinguli and camping is permitted throughout the National Park.

Conservation Status: Chipinda Pools are entirely situated in Gonarezhou National Park which was established as a nature reserve in 1968, and achieved National Park status in 1975. Tamboharta Pan is unprotected.

3. Gorhwe and Manjinji Pans

Location: 21°45'S/31°40'E (Gorhwe); 22°10'S/31°28'E (Manjinji)
Area: c. 4000 ha (total)
Altitude: c. 600 m asl
Nearest Town: Mabalauta

General: Gorhwe Pans are a series of shallow pans associated with ephemeral drainage lines on one of the subsidiary plateaux leading down from the great escarpment to the lowlands of the Gaza Province of Mozambique. They are surrounded by open savanna woodland and fringed by reeds and sedges, and tend to dry out, save for water-holes, during the dry seasons. They are situated entirely within the Gonarezhou National Park. Manjinji Pan consists of a substantial pan on a stretch of floodplain of the Mwenezi (Nuanetsi) River. It is deeper than the Gorhwe Pans and used to be perennial, but was topped up artificially by a local farmer who pumped water from the Mwenezi River. Now that this has stopped the pan is becoming occluded with reeds and grasses, and is more frequented by cattle than wild animals. The Manjinji Pan lies just outside the Gonarezhou National Park and is unprotected, but fishing is not permitted in the Mwenezi (Nuanetsi) River. All the pans attract large numbers of birds, and the Gorhwe Pans are important watering holes for a variety of large and small animals. Bilharzia is present in the Mwenezi River and all the pans, and malaria is endemic in the area.

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4. Pans of the Western Districts

Location in an area defined by: 16°58'S/25°30'E; 20°58'S/26°25'E; 20°58'S/27°10'E; 18°22'S/26°29'E
Area: Difficult to assess. 15 000 ha (conservative estimate of total)
Altitude: 935-1250 m asl
Nearest Towns: Masue; Hwange; Gwai

General: A large number of small seasonal pans are situated in the west of Zimbabwe, close to the border with Botswana. In this area mean annual precipitation is generally close to 600 mm, but may reach 700 mm in the north towards the Zambezi. Proceeding along the Botswana border from south to north, Stoffelo, Kakulwane, Namabwe, Misses, Nanyani and Kazuma Pans are the most important sites, but there are in addition many small subsidiary pans. The Kazuma Pans are situated in the Kazuma Pan National Park; the others to the north are in the Matetsi Safari Area, while Stoffelo Pan is in Zambezi National Park. Drainage in this whole area is rather diffuse but is principally from SW to NE, towards the Zambezi, and some small pans occur on the floodplains of ephemeral rivers. However, the majority are endorheic pans, and are filled by surface run-off each year.

To the south of this area, in Hwange (Wankie) National Park, there are hundreds of small seasonal saline pans. The climate here is dry and tropical with a mean annual precipitation of 550-600 mm over the pans. The mean maximum temperature in October is 32.5-35°C, depending upon location, and the mean minimum temperature in July is 3.5°C, during which time frosts are frequent. These pans are situated well into Zimbabwe, away from the border, but some moderate sized pans do occur on, and even straddle, the border. The most important of these, from north to south, are Dandari (18°50'S/26°06'E), Ngwasha (19°30'S/26°14'E) and Dzivanini (19°44'S/26°32'E) Pans. In the Hwange Park drainage is also diffuse but tends to be from NE to SW into Botswana. Immediately to the south of Dzivanini Pan the ephemeral Nata River flows across the border providing the major influx of water to the Makgadikgadi Pans.

Flora & Fauna: These pans are important habitats for waterfowl and are visited by a variety of game. The area is remote and forms part of the Victoria Falls-Matetsi-Hwange complex. The surrounding countryside is flat or very gently undulating, and in the north is covered with moist savanna forest comprising species such as *Baikiaea plurijuga*, *Pterocarpus angolensis* and *Terminalia sericea*. However, this quickly gives way, in passing southwards, to much drier country, in which grassy *Colophospermum mopane* savanna or open, dry Kalahari woodland predominates. *Acacia* species fringe the pans.

Snakes, including *Bitis arietans*, *Psammophis jallae* and various cobras are ever present, and the pans are an important waterfowl habitat with large numbers of *Alopochen aegyptiacus*, *Anas erythrorhyncha* and *Sarkidiornis melanotos*. Raptors seen on the pans include *Gyps bengalensis*, *G. coprotheres*, *Necrosyrtes monachus*, *Terathopius ecaudatus* and *Torgos tracheliotus*. During the rains other birds hawk for insects over the pans, some by day and others by night, e.g. *Apus apus*, *Camaroptera brevicaudata*, *Caprimulgus rufigena* and *Pseudhirundo griseopyga*. Most mammals of the plains utilise the pans when they contain water and many locally threatened and vulnerable species depend upon the pans. Up to 30 000 buffaloes and 15 000 elephants live within the area defined by the co-ordinates given above.

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Human Impact & Utilisation: The northern area is so remote that it is virtually undisturbed, but wildfire spreads into the area from villages and towns in the east along the Victoria Falls-Bulawayo Road, and from the south where there are many small farms. Visitors need 4 wheel drive vehicles to reach the pans and, since most are situated in National Parks or Safari Areas, they must first obtain permission.

Conservation Status: The pans are mostly within the parks and therefore fully legally protected. Fire is the major hazard and all the protected areas are criss-crossed by 100 m wide fire-breaks and watch is kept from numerous watch-towers. Animals move into Botswana which is very sparsely populated, but those in the Hwange National Park are now isolated from the Gwai River to the northeast, where animals once used to congregate in the dry season. In order to cope with increasing animal numbers, no less than 62 artificial waterholes have been established in the park to provide water in otherwise seasonally dry areas.

5. Artificial Impoundments

Lake Kariba is the major impoundment, shared with Zambia, but in addition there are about 120 large dams and well over 10 000 farm dams.

(A) LAKE KARIBA

Location: 16°33'-18°01'S/27°00'-29°05'E
Area: 536 130 ha (294 930 ha in Zimbabwe)
Altitude: 484 m asl (at capacity)
Nearest Towns: Hwange (80 km SW); Harare (250 km SE)

General: Lake Kariba was filled in 1958, and at maximum capacity its waters cover 536 130 ha of what was the Gwembe Trough. The lake is subject to considerable wave action, and the inflowing rivers still move their bed loads along their original courses beneath the surface. In addition to the Zambezi, the principal tributaries are the Sebungwe, Sengwa, Ume and Sanyati on the south bank, and the Mwenda, Zhimu, Zongwe, Nangombe, Chezya, Chibue and Lufue on the north bank. The lake has a maximum depth of 119 m and a mean depth of 29.5 m at capacity; it lies between Zambia and Zimbabwe. It is about 280 km long, in a SW-NE direction, and has a mean width of 19 km. Direct precipitation on the lake varies both seasonally and with location, with mean annual totals of 400-800 mm. Water in the lake has a mean residence time of 4 years.

Hydrology & Water Quality: Annual inflow from the Zambezi and the several rivers which discharge directly into the lake is about one quarter of the total volume of the lake. The water is well oxygenated at the surface, where temperatures vary between 17°C and 32°C. The chemistry of the lake water has changed substantially since it was first filled, and a detailed account of the physico-chemical characteristics of the lake water in its early years is given by Coche (1968), while the subject is also dealt with in a more comprehensive analysis by Balon & Coche (1974).

Flora & Fauna: During the early years the lake was highly eutrophic, but it has now apparently stabilised at a much lower level of productivity. *Lemna gibba*, *Pistia stratiotes*, *Salvinia molesta* and *Spirodela* spp. occur in sheltered bays. *Salvinia molesta*

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covers the largest areas, today about 2% of the lake surface, and it is deemed to be advantageous because it provides a substrate for fish food organisms, and cover for several fish species at times when submerged macrophytes are scarce. Sometimes *Scirpus stolonifera* grows in mats of *Salvinia* and forms small patches of floating 'sudd-type' vegetation. Since 1964 submerged macrophytes such as *Ceratophyllum demersum*, floating leaved species of *Potamogeton*, and a few emergents including *Panicum repens*, have begun to spread around the shallow margins, providing a basis for a periphyton and habitats for aquatic invertebrates. These vegetation beds provide good grazing for fishes when they are submerged, and for ungulates when exposed following draw down. In spite of seasonal fluctuations in the water level, these plants are now well established. The eutrophication of the young Lake Kariba is described by Balinsky & James (1960).

The lake is not particularly productive, but supports 42 species of fish including *Distichodus mossambicus*, *D. schenga*, *Heterobranchus longifilis*, *Labeo altivelis*, *Mormyrops deliciosus*, *Marcusenius longirostris* and *Tilapia rendalli*. *Oreochromis mortimeri*, which was present in the middle Zambezi before impoundment, was further introduced, and now dominates the commercial catches of cichlid fish. *Hydrocynus vittatus* is a popular sporting species. *Limnothrissa miodon* has also been introduced and is prospering in the vacant lacustrine habitat. Balon (1974) described the fish fauna of Lake Kariba once it had begun to stabilise, and accounts of the fish populations and fisheries potential of the lake are given by Marshall (1979). The marginal fish fauna is described by Mitchell (1976).

Crocodylus niloticus is comparatively abundant in the lake. Each year as many as 400 adults visit the Matusadona National Park, which adjoins the lake, and these animals also occur around the rest of the southern lake shore, although their distribution density varies locally. The avifauna includes *Actophilornis africana*, *Anhinga rufa*, *Egretta* spp., *Haliaeetus vocifer*, *Lybius torquatus*, *Merops pusillus*, *Phalocrocorax* spp., storks, plovers, and herons such as *Ardea goliath*. A number of large mammals visit the lake.

Human Impact & Utilisation: The initial flooding of the valley had an enormous impact on the area, and it will probably be many more years before the whole system has finally stabilised. Much forest and much animal life was lost in its creation, and the baTonga people were displaced from their homeland.

In addition to the provision of water and hydroelectric power, private and commercial fishing is encouraged on the lake, although it is restricted in certain areas. Fish are marketed fresh, deep frozen, dried or smoked. *Hydrocynus vittatus* and *Limnothrissa miodon* are canned, although the bulk of the *Limnothrissa* catch is sundried and sold throughout the country. Gill-nets (5-15 cm mesh) and beach seines are used. The sardine industry uses purse seines (encircling seines) and lift nets. Traditional methods such as basket traps, and rod and line fishing account for a great deal of the subsistence catch. In many tribal areas the local community operates a fishery administered by the tribal authority. Two inshore concession areas are granted to commercial interests, all other shore based fishing is by local residents, and it is estimated that there may be over 600 self-employed peasant fishermen on the Zimbabwean side of the lake. The major industrial fisheries operate by concession in open water areas. In 1979 the total recorded catch from the Zimbabwean sector was 5560 tonnes, of which *Limnothrissa* accounted

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for 4880 tonnes, while the estimated total catch was believed to be about 6000 tonnes. The maximum sustainable yield of *Limnothrissa* from Zimbabwean waters is estimated as 6700 tonnes, and there are fears that over-fishing may have occurred since 1981, with catches in excess of 8000 tonnes.

Near the end of the dry season in October/November the outflow sluices at Kariba are opened to make room for the floodwaters from the inflowing rivers during the forthcoming rainy season. The resultant fall in lake level has varied from 3-8 m in different years. In shallow areas along the edges this alternate flooding and drying helps renew the lake with valuable nutrients. This is further facilitated by the feeding, trampling and waste production of visiting herds of herbivores. Some domestic cattle are grazed on the lake shores in tribal areas. The area is utilised for tourism.

Conservation Status: The entire lake on the Zimbabwean side of the border lies in the Lake Kariba Recreational Park, excluding only the waters contained in the Matusadona National Park. It has total legal protection, although angling and commercial fishing are encouraged. Much of the shoreline is protected in National Parks and Safari Areas.

(B) LAKE KYLE

Location: 20°15'S/31°10'E
Area: 9105 ha
Altitude: 1000 m asl
Nearest Towns: Masvingo (10 km NW); (Harare 275 km N)

General: Lake Kyle provides the second largest expanse of open water in Zimbabwe. It is an impoundment to provide water for irrigation, located at the confluence of the Mshagashe and Mtilikwe Rivers. Parts of the lakeshore are steep and rocky and covered by open woodland which contains succulent *Euphorbia* trees. The lake is situated in the Lake Kyle Recreation Park, which is bounded on three sides by tributaries of the Mtilikwe River. It has a maximum depth of 56 m and a mean depth of 14.6 m at capacity. Water temperatures vary between 16-27°C. The vegetation of the park consists of grassy plains and savanna woodlands, interrupted by more densely wooded ravines. Apart from the lake itself there are no important wetlands. Despite stable water levels over the years the surface of the lake supports little vegetational cover due in large measure to the size of the herbivorous *Tilapia rendalli* population. Investigations have been aimed at the establishment of artificial cover.

Fauna: Fish in the lake include *Barbus marequensis*, *Micropterus salmoides*, *Mormyrus longirostris* and *Tilapia* spp. *Oreochromis macrochir* was introduced from Zambia in the 1950s and is now the basis of the commercial fishery on this lake. Crocodiles are present in the lake and tributary streams, and there is a crocodile pond in the park. Waterfowl are present on the lake and there are several species of piscivorous birds, including kingfishers and herons. There are resident populations of *Aonyx capensis* and *Lutra maculicollis* along the tributary streams, and several water snakes. Various large mammals have been re-introduced to the park and utilise the lake including *Ceratotherium simum* and *Connochaetes gnou*.

Human Impact & Utilisation: Given that the park is entirely artificial and designed for recreational purposes, as well as water storage, the major impact has been the drowning of 9000 ha of highland valleys. The park was established in 1963 and contains hotels,

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caravan sites and camp sites. It is heavily utilised for recreation and the lake is renowned for bass fishing. Commercial fishing concessions have in the past been awarded to 14 companies, but it has been proposed to reduce the number to two. In 1979 the total reported catch from all sources was 55 tonnes, while the estimated catch was 100 tonnes.

(C) IMPOUNDMENTS ON THE HUNYANI RIVER

Location: 18°00'S/31°06'E; 17°55'S/30°50'E; 17°45'S/30°45'E
Area: c. 19 000 ha (total of three reservoirs)
Altitude: 1350-1450 m asl
Nearest Towns: Chitungwiza; Norton; Darwendale

General: There are three major impoundments on the upper reaches of the Hunyani River in the highlands to the south of Harare. The Prince Edward Dam at Chitungwiza is small, c. 2000 ha of open water surface. This spills over into Lake MacIlwaine downstream.

Lake MacIlwaine, near Norton, provides the main water supply to Harare and is 14.5 km long and up to 4 km wide. It had an open water surface of 2630 ha when full, but the holding capacity and surface area have recently been increased. It had a maximum depth of 27 m and a mean depth of 9.5 m when constructed, but these figures will have altered. It is situated 1400 m asl. Both lake and environs were created as a recreational park. Water temperatures in the lake vary from 14 to 27°C and in the summer the lake becomes stratified. The lake became highly eutrophic in the 1960s due to the addition of treated sewage effluent. The conductivity of the water nearly doubled between 1959-1970. Sewage diversion began in the early 1970s and total dissolved solids had dropped to the 1959 level by 1976. Dense algal blooms occurred, and although fish production was high, there were large kills every year from 1969-1973 because de-oxygenated bottom water upwelled. A slight drop in fish catches has been observed since 1976. There is a recurrent problem with luxuriant growth of the water hyacinth *Eichhornia crassipes*, which began in 1971. Mechanical removal at first proved ineffective and the worst areas were sprayed with the herbicide 2-4D. By treating areas successively, the area of rotting vegetation at any one time was minimised. A permanent weed control unit now keeps the weed under control. During the early periods of eutrophication, fish downstream were killed by the release of bottom water enriched with H_2S.

At least 23 species of fish occur in the lake, including *Barbus marequensis*, *Clarias gariepinus*, *Hydrocynus vittatus*, *Labeo altivelis* and *Tilapia* spp. *Haplochromis codringtoni* has recently been introduced to the Hunyani impoundments to control mollusc populations. Crocodiles are present, and some 250 bird species have been identified in the park, many associated with the lake. These include cormorants, darters, ducks, egrets and herons. Various game animals occur in the area naturally, and visit the lake. The lake water carries bilharzia.

The third impoundment, Lake Robertson, towards Darwendale, is also encompassed by a recreational park, contiguous with that at Lake MacIlwaine. This is the largest of the three impoundments, and at capacity has an open water surface of 8100 ha. It is situated 1350 m asl, has a maximum depth of 23 m and a mean depth of 5.7 m. Water temperatures fluctuate between 16-24°C. The flora and fauna associated with this lake are similar to those of Lake MacIlwaine, as is the bilharzia problem.

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Human Impact & Utilisation: The reservoirs are utilised for water, for domestic supplies and irrigation, and for commercial fishing. Sport fishing by license is popular. The total catch from the Hunyani Lakes during 1979 was estimated at 600 tonnes, although the reported catch was less than this. An assessment of fish production in Lake MacIlwaine is given by Marshall (1978).

Conservation Status: The parks in which the reservoirs are situated are under the control of the Department of Parks and Wildlife who manage them for recreation and issue fishing licences. Some of the lakeshore areas are leased to farmers, but most of the southern shore of Lake MacIlwaine is managed as a game park. A bird sanctuary is proposed on the northern lakeshore, in an area containing a wide variety of natural and man-made habitats. The remainder of the north bank is set aside for visitor facilities.

(D) OTHER IMPOUNDMENTS

General: Other major impoundments occur on the Sebakwe River, ultimately a tributary of the Sanyati River. The impoundments here are at Dutchman's Poola Dam (18°50'S/29°55'E) and Sebakwe Dam (19°01'S/30°15'E). The latter dam is the larger and subtends an open water surface some 8 km long with a maximum width of 2 km at capacity. The smaller Ngezi Dam (18°41'S/30°20'E) in the Ngezi National Park, is situated on another river of the same name, which is also a part of the Sanyati system. All these reservoirs eventually drain to the Zambezi via Lake Kariba. Lake MacDougall (20°35'S/31°37'E) on the Chiredzi River, a tributary of the Lundi, and Siya Dam (20°15'S/31°36'E) on the Turgwe River, both eventually feed the Save River system.

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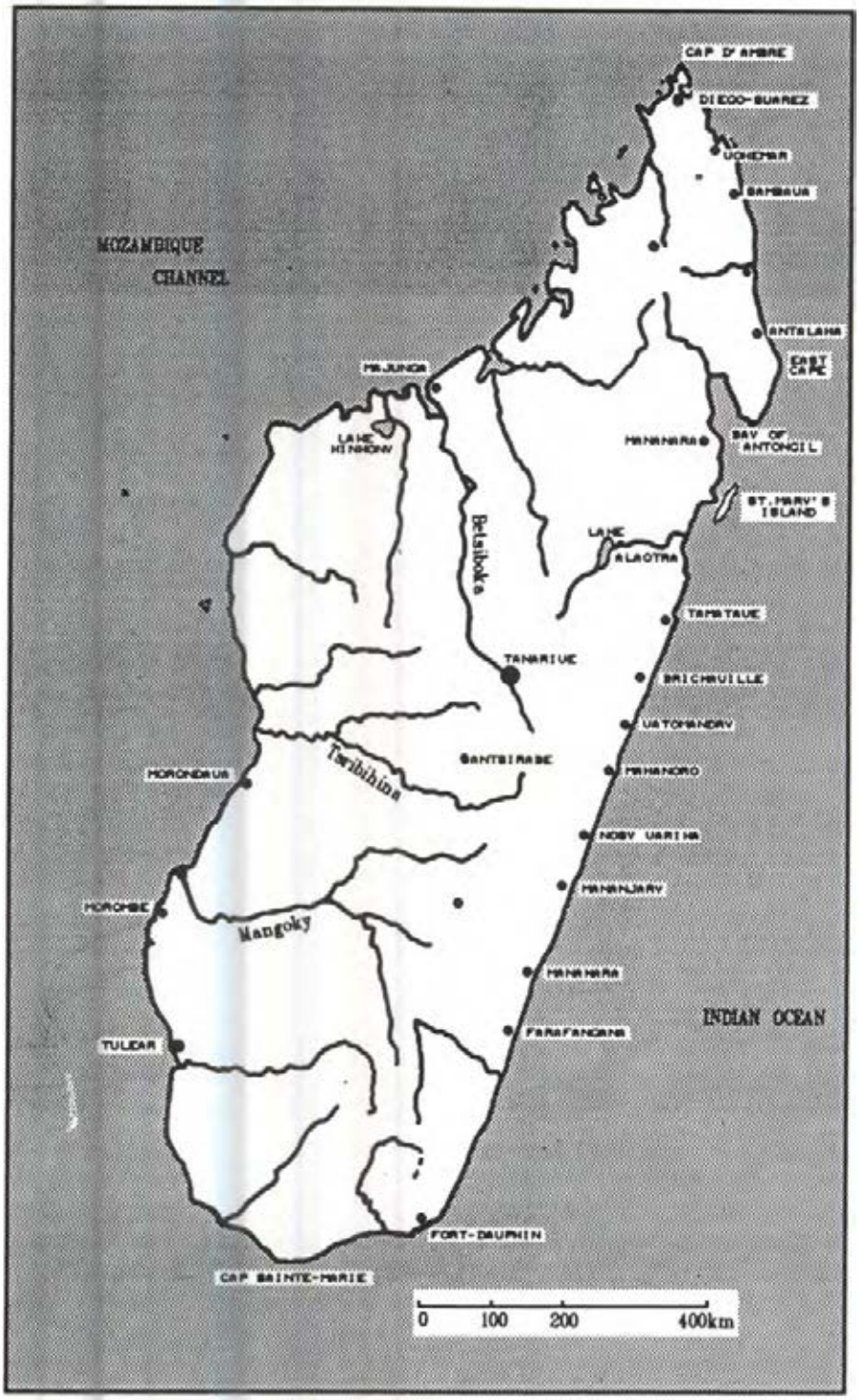

Map of Madagascar

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REGION 6

MADAGASCAR

by G. Bernacsek

Introduction

Madagascar island is located some 300 km off the southeastern part of the African continent, separated from it by the Mozambique Channel. It is the fourth largest island in the world after Greenland, New Guinea and Borneo. It has a north-south length of 1600 km between latitudes 11°57' and 25°35'S, and a maximum width of 580 km between longitudes 43°14' and 50°27'E. The surface area is 587 000 km^2. The population of 10 600 000 (in mid-1986) has a mean density of 18.1 persons/km^2. Population distribution is very uneven with most people living in the central highlands and eastern coastal plain.

The physiography of the island consists of a rugged central highland plateau (with axis running NNE-SSW) surrounded by coastal plains of varying width. The main axis of relief is assymetrically located. Highland elevations are mostly between 1000 and 2000 m asl, with occasional peaks reaching nearly 3000 m. Along the nearly straight eastern coastline, the plateau falls steeply to a narrow continuous coastal plain which develops a string of small lagoons. The western slope is much gentler, and more extensive river basins are present with complex features (floodplains, lakes, extensive coastal mangrove swamps, estuaries).

Climate

Two temperature regimes exist: a tropical lowland regime and a more temperate highland regime. Lowlands have a fairly uniform mean annual temperature which decreases from north (27°C) to south (23°C). Mean annual range in the north is around 3°C and increases to 7.5°C in the dry southwest. The warm Mozambique Channel moderates conditions in the west. On the central plateau mean annual temperatures are between 16° and 19°C. Frost may occur above 1500 m, and rarely snow. Mean annual ranges are 5-6°C in the north and 7°C in the south. Diurnal range is greater, in the order of 10°C at the capital, Antananarivo (1381 m asl, 18°56'S).

Two gradients govern rainfall: annual precipitation decreases from east to west and from north to south, and seasonality increases in the same direction. Thus, in the west and south, the dry season is longer. In the extreme southwest the climate is semi-desert or Sahelian, while the eastern coast is sub-equatorial with high rainfall and humidity throughout the year. Where seasonality exists, the dry and cool seasons coincide (June to October).

Rainfall is controlled by the interaction of the southeast trade wind with the direction of principal relief on the island. North and northwest monsoon air currents exert an

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important secondary effect. Unstable moisture-laden air carried against the eastern escarpment leads to extensive cloud formations and heavy rainfall in this region. A higher layer of drier stable air mass, markedly subject to subsidence inversion from July to September, limits cloud formation and rainfall, leading to dry clear winter weather on the western slopes. In the summer, monsoon air currents bring heavily moisture-laden air which produce a large amount of rain, with reduced effects eastwards and southwards.

The variations in rainfall and temperature produce five bio-climatic regions. On the east coast rainfall exceeds 1500 mm and sometimes 3000 mm, there is no dry month and temperatures are high throughout the year. On the eastern slopes of the plateau rainfall exceeds 1500 mm but there is a dry season of 1-4 months duration and a mean temperature of between 10-15°C during the coldest months. On the western slopes of the plateau the dry season lasts 5 or 6 months and rainfall is usually less than 1500 mm (although humidity is high during the dry season due to the trade winds). On the western plains the dry season is 7 or 8 months in southern regions and rainfall is 500 - 15000 mm while in northern regions the dry season is somewhat shorter and rainfall is around 1500 mm. In the extreme south rainfall is sparse, highly irregular in occurrence, stormy and very localized (some areas may not experience precipitation for 12-18 months).

Madagascar is prone to cyclones which hit the island during the summer only, mainly from mid-January to mid-March. Most hit the northeast coast first and travel southwest (then curve southeast). Others come via the Mozambique Channel. Winds of up to 300 km/hr and rainfall of 600-700 mm in four or five days cause large-scale flooding and massive destruction of crops and forests.

Wetlands

Water courses draining the eastern slopes (c. 25% of the island) are comparatively short with steep profiles, while those of the western slopes (over 60% of the island) are much longer with gentler slopes. All rivers show high discharges during the rainy season from November- March/April. Response to rainfall is almost instantaneous, producing sudden violent spates. In the north and east, water flow is abundant throughout the year. Flood waters are violent along the east coast. Large westward flowing rivers show more seasonal variation in discharge, but dry season rain in the highlands sustains low water flows. In the south rivers show very rapid spate and extreme variations in level. During the long dry season discharge at the mouth falls to nil in most southern watercourses.

The most extensive wetland habitat type in Madagascar is the coastal mangrove swamp. Mangroves are almost entirely confined to the west coast and cover an area of 3300 km.^{2} River floodplains are the second most extensive system, and occupy some 2000 km^2 on the lower reaches of westward flowing rivers. Natural lakes, scattered throughout the upland and lowland regions, occupy some 1400 km^2 (at high water level). Coastal lagoons are confined to the east coast and cover c. 400 km^2. Reservoirs are of only minor importance (c. 63 km^2 combined).

The largest wetland of Madagascar is Lake Alaotra, which exceeds 1000 km^2 during the rainy season. This is followed by the floodplains of the rivers, Betsiboka (850 km^2) and Tsiribihina (700 km^2) and the large mangrove swamps of Betsiboka (460 km^2) and

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Besalampy (457 km^2). The largest coastal lagoon is Loza (156 km^2), but other lagoons are much smaller. Tsiazompaniry, the largest reservoir, is only 31 km^2 at full capacity.

Agriculture is by far the most important economic activity on the island, and rice is the most important crop. 'Tavy' (slash-and-burn) cultivation is the principal source of destruction to forests. Deforestation has resulted in severe erosion, leading to heavy silt loads in many rivers. In some regions flow has been reduced in rivers and into lakes, and water tables have lowered. Marshes throughout the island have been transformed into rice-fields and fish-farms. Some 25 000 ha of rice fields are used for aquaculture, and there are in addition c. 1000 ha of fish ponds.

Vegetation

The Madagascar flora is estimated to consist of between 7370 and 12 000 species, giving Madagascar perhaps the highest area-richness index in the world (if the upper range is the true figure). Up to 86% of the species may be endemic but the level of endemism is lower for wetland floras (56% for marshes; 21% for littoral formations). The western regions are less rich floristically than the eastern regions.

Tidal Wetlands: Mangrove systems are composed of the following species: *Rhizophora mucronata, Avicennia marina, Sonneratia alba, Ceriops tagal* (= perhaps an endemic species, *C. boiviniana*), *Bruguiera gymnorrhiza, Xylocarpus granatum, X. moluccensis, Lumnitzera racemosa* and *Heritiera littoralis.*

Riverine & Lacustrine Floodplains: Aquatic macrophytes commonly found in freshwater wetlands include *Cyperus madagascariensis, C. latifolius, C. imeriniensis, Eleocharis plantaginea, Typhonodorum lindleyanum, Jussiaea* sp., *Pandanus coneretus, Crinum* sp., *Eleocharis plantaginea, Phragmites communis, Ravenala madagascariensis, Polygonum* sp., *Nymphaea stellata, N. lotus, Salvinia natans, Pistia stratiotes, Ceratophyllum* sp., *Potamogeton* sp., *Najas australis* and *Utricularia vulgaris.* The introduced water hyacinth, *Eichhornia crassipes*, has invaded many lakes and rivers and has blocked several of them.

The following salt tolerant macrophytes occur around saline lakes: *Chara zeylanica, Salicornia pachygastra, Cressa cretica, Arthrocnemum indicum, Sporobolus virginicus* and *Scleradacrylon macrostachyum.*

Wetland Fauna

Fish: The native fish fauna is relatively depauperate, but a large number of the species are endemic. *Oxylapia polli* and *Prychochromoides betsileanus* are considered highly threatened. *Paratilapia polleni, Paretroplus dami, P. kieneri, P. maculatus, P. petiti* and *Prychochromis oligacanthus* may be vulnerable. *Acentrogobius therezieni, Oryzias madagascariensis, Pachypanchax homolanotus, Rheocloides pellegrini, Typhleotris madagascariensis* and *T. pouliani* are probably rare. Other endemics whose status is sometimes not fully known are *Rheocles alaotresis, R. sikorae, Paretraplus polyactis, P. betsileanus, Pantanodon madagascariensis, Ancharius brevibarbis, A. fuscus, A. madagascariensis, Bedotia geayi, B. longianalis, B. madagascariensis, B. tricolor, Ambassis fontoynonti, Eleotris tohizonae, E. vomerodentata, Ratsirakia legendrei, Bathygobius samberanoensis, Chonophorus macrorhynchus, Gobius palyzona, Ploty-*

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gobius hypselosoma, *P. madagascariensis*, *Stenogobius vergeri* and *Gobitrichinotus arnoulti*. Endemic subspecies are *Anguilla nebulosa labiata*, *Pachypanchax playfairi sakaramy*, *Hepsetia duodecimalis waterloti*, *Kuhlia rupestris sauvagei*, *Agonostomus telfairii catalai*, *Eleotris ophiocephalus madagascarensis*, *Gobius criniger decaryi* and *Periophthalmus koelreuteri papilio*. Regional endemic species are *Kuhlia splendens*, *Agonostomus dobuloides*, *Salarias monochrous*, *Sicyopterus acutipinnis*, *S. fasciatus*, *S. lagocephalus* and *S. laticeps*.

Many euryhaline species enter inland waters seasonally. These include species of the genera *Carcharinus*, *Pristis*, *Megalops*, *Elops*, *Pellonulops*, *Chanos*, *Arius*, *Anguilla*, *Liza*, *Mugil*, *Ambassis*, *Monodactylus*, *Kuhlia*, *Chorinemus*, *Therapon*, *Lutianus*, *Leiognathus*, *Gerres*, *Sillago*, *Caranx*, *Scatophagus*, *Glossogobius*, *Gobius* and *Eleotris*.

Many species have been introduced into Madagascar to support commercial fisheries, and to control nuisance aquatic weeds and disease vectors. These include *Carassius auratus*, *Cyprinus carpio*, *Gambusia affinis*, *Heterotis niloticus*, *Hypophthalmichthys molitrix*, *Labeo rohita*, *Lepomis auritus*, *L. gulosus*, *Micropterus salmoides*, *Oreochromis macrochir*, *O. mossambicus*, *O. niloticus* and *Osphronemus gouramy*. Stocking of *Salmo gairdneri* and *S. trutta* at altitudes over 1700 m asl has seemingly not benefited river fisheries. The herbivorous cichlids *Tilapia rendalli* and *T. zillii* have been cited as being responsible for reducing vegetation cover in lakes, thus removing breeding and feeding sites for fish, invertebrates and birds. *Paretroplus kieneri*, which frequents heavily vegetated areas, has probably been so affected. Several of the introduced fish species are now of great economic importance in fisheries, but have almost certainly had considerable impact on the native species, either as competitors or predators. The importance of native species such as *Paratilapia polleni* in catches has declined drastically, but native species are not thought to be threatened with extinction as a direct result of fishing. Carp and tilapia are widely used in aquaculture.

Amphibians: All frogs associated with wetlands in Madagascar are endemic. Species include *Mantidactylus aerumnalis*, *M. aglavei*, *M. albofrenatus*, *M. alutus*, *M. ambohimitombi*, *M. betsileanus*, *M. biporus*, *M. blommersae*, *M. curtus*, *M. domerguei*, *M. femoralis*, *M. grandidieri*, *M. liber*, *M. lugubris*, *M. opiparis*, *M. pauliani*, *M. ulcerosus*, *M. wittei*, *Boophis difficilis*, *B. goudoti*, *B. granulosus*, *B. hillenii*, *B. idae*, *B. luteus*, *B. mandraka*, *B. microtympanum*, *B. opisthodon*, *B. tephraeomystax*, *B. untersteini* and *B. williamsi*.

Reptiles: Freshwater turtles include *Pelomedusa subrufa*, *Pelusios castanoides* and *P. subniger*. The endemic *Erymnochelys madagascariensis* suffers from over-exploitation for food and habitat loss, and is considered rare (and may be declining *Crocodylus niloticus* has been widely persecuted and is listed as vulnerable. The endemic lizard *Zonosaurus maximus* occurs along riverbanks. Several endemic snakes frequent wetlands, including *Acrantophis dumerilii*, *A. madagascariensis*, *Liophidium chabaudi*, *Liophalidophis seclineatus*, *L. thieli* and *Ithyciphus miniatus*. Other reptiles are *Liotheradon madagascariensis* and *Sternothaerus* sp.

Birds: Endemic species associated with wetlands are *Ardeola idae*, *Anas melleri*, *Sarothrurua watersi*, *Dryolimnas cuvieri*, *Gloreola oculoris*, *Cuculus rochii*, *Alcedo vintsioides*, *Ispidina madagascariensis*, *Leptopterus viridis*, *L. chabert*, *Tylas eduardi*, *Acrocephalus newtoni*, *Cisticola cherina*, *Dromaeocercus seebohmi* and *Foudia saka-*

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lava. *Tachybaptus rufolavatus*, *Aythya innotata* and *Halioaetus vociferoides* are considered endangered species. The latter is listed in CITES Appendix II. *Anas bernieri* is listed as vulnerable, while *Tachybaptus pelzelnii* and *Ardea humbloti* are insufficiently known to establish their status.

Non-endemic species found elsewhere in Africa are *Nycticorax nycticorax*, *Butorides striatus*, *Ardeola ralloides*, *Bubulcus ibis*, *Egretta gularis*, *E. alba*, *Ardea cinerea*, *A. melanocephala*. *A. purpurea*, *A. goliath*, *Scopus umbretta*, *Anastomus lamelligerus*, *Mycteria ibis*, *Threskiornis aethiopica*, *Phoenicopterus ruber antiquorum*, *P. minor*, *Thalassornis leuconotus*, *Porphyrio porphyrio*, *P. alleni*, *Tringa stagnatilis*, *Sarkidiornis melanotus*, *Denrocygna viduata*, *Melonophloix ardesiaca*, *Corythornis cristata*, *Milvus migrans* and *Merops superciliosus*.

Mammals: The endemic *Limnogale mergulus* is associated with wetlands and may possibly be vulnerable or endangered. *Dugong dugon* enters mangrove areas.

List of Wetlands Described

1. Tidal Swamps
2. Wetlands of the Coastal Plain
    (a) Pangalanes-East Lagoon Complex
    (b) Loza Lagoon
    (c) Taolanaro Lagoon Complex
    (d) Other Coastal Lagoons
3. Floodplains and Inland Swamps
    (a) The Betsiboka River System
    (b) The Sofia River System
    (c) The Tsiribihina River System
    (d) Anketraka Swamp
4. Natural Lakes
    (a) Lake Alaotra
    (b) Lake Kinkony
    (c) Lake Ihotry
    (d) Lake Itasy
    (e) Lake Tsimanampesotsa
    (f) Other Natural Lakes
5. Artificial Impoundments
    (a) Tsiazompaniry Reservoir
    (b) Mantasoa Reservoir
    (c) Other Artificial Impoundments

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1. Tidal Swamps

General: Extensive mangrove swamps (with a total area of 3020 km^2) are located on the west coast of Madagascar in association with river mouths. Surface areas of swamps are as follows: Mahavavy-Nord (332 km^2), Loza and Marinda (180 km^2), Mahajamba (394 km^2), Betsiboka (460 km^2), Mahavavy-Sud and Soalala (340 km^2), Bessalampy (457 km^2), Maintirano (255 km^2), Tsiribihina (370 km^2) and Mangoky (232 km^2). Altogether there are 29 separate mangrove areas on the west coast. East coast mangrove sites number 11, but are all small (i.e. the largest at Rodo Bay is 22.2 km^2).

Flora & Fauna: Mangrove assemblages consist of *Rhizophora mucronata, Avicennia marina, Sonneratia alba, Ceriops tagal, Bruguiera gymnorrhiza, Xylocarpus granatum, X. moluccensis, Lumnitzera racemosa* and *Heritiera littoralis*. The endangered Madagascar fish eagle *Haliaeetus vociferoides* occurs in mangrove areas.

Human Impact & Utilization: Mangroves are important nursery areas for inshore fisheries stocks. Shrimp (*Paenaeus monodon, P. indicus*), crab (*Scylla serata*), and finfish (carangids, carcharinids, mugilids, serranids, sparids) are important. Salted-dried shark and sawfish meat is an important market commodity. Crab fisheries in mangroves have declined in commercial importance since the early 1970s. Little data is available on other forms of utilization of mangroves.

Conservation Status: The mangrove swamps of Madagascar are the largest in the western Indian Ocean. To date no special provisions have been made to protect mangrove habitats or species.

2. Wetlands of the Coastal Plain

(A) PANGALANES-EAST LAGOON COMPLEX

Location: 18°10'-22°49'S/47°49'-49°24'E
Area: 180 km^2 combined
Altitude: sea level
Nearest Towns: Toamasina; Mahanoro; Farafangana

General: Pangalanes-East consists of a chain of over 18 lagoons interconnected by the Pangalanes Canal. The largest lagoons are Nosive (35.7 km^2), Rasoabe (20 km^2) and Ampitambe-Irangy (11.5 km^2). Others are: Rasoamasay, Ihosy, Alanampolsy, Rangazavaka, Morongary and Tampolo. Maximum water depths are generally in the range of 3-7 m. The deepest lagoon is Rasoabe at 12 m.

Hydrology & Water Quality: The main rivers flowing into the lagoon complex are the Ivondro, Rianila, Sakanila, Mangoro, Masora, Mananjary, Faraony, Matitanana and Manampatrana. Rainfall peaks in January/February. Annual fluctuation in water level is 1-2 m. The lagoons are essentially freshwater. Conductivity (k_{20}) ranges from 1325 µS/cm during the dry season down to 437 µS/cm during the rainy season, and the incursion of seawater is minimal. Water clarity is generally excellent. Water surface temperature ranges from 23°C in July up to 32°C in November. pH is slightly acid, from 6.5 - 7.0.

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Flora & Fauna: Aquatic vegetation consists mainly of *Cyperus madagascariensis*, *C. latifolius*, *Eleocharis planiaginea*, *Typhonodorum lindlyanum* and *Pandanus* sp. Less common are *Nymphaea* sp., *Jussiaea* sp. and *Eichhornia crassipes*. Macro-invertebrates are *Macrobrachium* spp., *Metapenaeus* spp., *Pyrasus palustris* and *Melanoides tuberculata*. Some 61 species of fish are found in the lagoon, and many are euryhaline species (i.e. *Liza macrolepis*, *Mugil robustus*, *Arius africanus*, *Gerres* spp., *Leiognathus equulus*, *Paretroplus polyactis*, *Ptychochromis oligacanthus*). Fish species successfuly introduced are *Osphronemus goramy*, *Tilapia rendalli*, *Oreochromis massambicus* and *Heterotis niloticus*. Reptiles include *Acrutophis madagascariensis*, *Ithyciphus miniatus*, *Liotherodon madagascariensis* and very rarely *Crocodylus nilaticus*. The main birds recorded on the lagoons are *Sarkidiornis melanotus*, *Denrocygna viduata*, *Bulbucus ibis*, *Melanophloix ardesiaca*, *Scopus umbretta*, *Corythornis cristata*, *Milvus migrans* and *Merops superciliosus*.

Human Impact & Utilization: The lagoons are intensively fished. Catches ranged between 300 and 400 tonnes/yr in the period 1960-1975, but currently have declined to only 45 tonnes, seemingly due to excessive fishing effort. The yield of 8 kg/ha/yr is very low in comparison to lagoon fisheries elsewhere. Some 600 fishermen once earned their livelihood from the lagoons. *Paretroplus polyactis* and *Ptychochromis oligacanthus* are important components of the catch. Aside from subsistence agriculture a small production of sugar cane takes place. Tourism and industries are small local economic sectors.

Conservation Status: The lagoons are not under any special form of protection. Depletion of the fisheries resources is cause for concern.

(B) LOZA LAGOON

Location: 14°37'S/47°54'E
Area: 156 km^2
Altitude: sea level
Nearest Town: Befotaka

General: Loza is the only lagoon situated on the western coastline. The principal inflowing rivers are the Doroa and Maevarano. Salinity near the outflow to the sea is very high. An extensive mangrove system (180 km^2) is developed around the lagoon. The fish fauna is euryhaline and includes a large stock of shrimp.

(C) TAOLANARO LAGOON COMPLEX

Location: 24°47'-25°09'S/46°42'-47°11'E
Area: 45 km^2 combined
Altitude: sea level
Nearest Town: Taolanaro

General: This lagoon complex consists of a number of small lagoons not all of which are interconnected. The main lagoons are Anony (22.6 km^2), Mananivo (4.43 km^2), Ambavarano (3.3 km^2), Lanirano, Andriambe (7 km^2), Andranasy (2.5 km^2), Andratoloharano and Ranofotsy (4.6 km^2). Maximum depth is 5 m, but most are between 1-3 m.

Hydrology & Water Quality: Maximum rainfall is in January/February. Salinities vary from freshwater (in the absence of a connection to the sea) to highly saline (where a

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permanent connection exists with the sea). Water clarity is very high. pH is alkaline, from 7.9 - 8.3.

Flora & Fauna: Abundant macrophytes are *Typhonodorum lindleyanum*, *Pandanus coneretus* and *Crinum* sp. Other species present are *Eleocharis plantaginea*, *Cyperus latifolius*, *Phragmites communis*, *Pandanus* sp. and *Ravenala madagascariensis*. Important macro-invertebrates are prawns, lobsters and other crustaceans. Fish species (at Anony) include *Ptychochromis oligocanthus*, *Caranx melampygus*, *Mugil* spp., *Ambassis commersoni*, *Epinephelus fario* and *Cerognathus aequula*. Birds visiting Andranasy and Andratoloharano Lagoons are *Phoeniconaias ruber antiquorum* and *P. ruber*.

Human Impact & Utilization: Fishing in the lagoons around Taolanaro is intense and stocks are thought to be over-exploited. Shrimp are fished in large quantities mainly in December/January at the beginning of the hot season. Mainly females and juveniles are caught. Landings are about 60 tonnes/yr. Ambinanikely is 'fady' and all fishing is prohibited by local communities.

Conservation Status: Action is required to rehabilitate and rationally manage the fisheries resources of some of the lagoons.

(D) OTHER COASTAL LAGOONS

General: Several other small to medium size lagoons are scattered along the coast. These include: Ampahana (21.8 km^2) in the northeast near Antalaha (14°46'S/50°13'E), Tampolo-Fenerive-Est (1.37 km^2) near Fenerive (17°20'S/49°30'E) and Masianaka (13.3 km^2) in the south-east near Vangaindrano (23°35'S/47°36'E). The latter is adjacent to a large marsh (30 km^2). The fish fauna is diverse and typically euryhaline.

3. Floodplains and Inland Swamps

(A) THE BETSIBOKA RIVER SYSTEM

Co-ordinates of Rivermouth & Floodplain: 15°55'S/46°25'E
Area: 850 km^2 (floodplain)
Nearest Town: Ambato Boeni

General: The Betsiboka River originates near Falaise de l'Angavo at 1755 m asl. Its total length is 525 km, and it discharges to the Indian Ocean at Bombetoka Bay. The drainage basin area is 11 800 km^2. Major tributaries are the Mahajamba, Isandrano and Ikopa. A floodplain is developed in the lower course containing some 150 small lakes. These include Amparihibe-South (12.5 km^2), Ambania (9.1 km^2), Amboromalandy (6.6 km^2) and Bondrony and Matsiabe (5.0 km^2 combined). Total area of the lakes is 80 km^2. The Ikopa tributary basin has large dams at Mantasoa and Tsiazompaniry.

Hydrology & Water Quality: Flooding reaches a peak between January and March with maximum discharge of 12 000 m^3/sec at the mouth. Monthly mean discharge ranges between 74.3 and 678 m^3/sec. Deforestation has resulted in severe erosion in the upper catchment area of the river and the river is heavily silted.

Flora & Fauna: Aquatic macrophytes include *Phragmites* spp., *Cyperus* spp., *Jussiaea* sp., *Polygonum* sp., *Eichhornia crassipes*, *Nymphaea stellata*, *Salvinia natans* and *Pistia*

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stratiotes. Macro-invertebrates include *Caradina* spp., *Macrobrachium* spp., *Potamon* spp., *Hydrotelphusa* spp., *Biomphalaria madagascariensis*, *Bulinus marlei*, *B. ltranus*, *Anisus crassilabrum* and *Lymnaea hovarum*. The native ichthyofauna consists of 20 species including *Pachypanchax homalonotus*, *Paretrolus dami*, *P. kieneri*, *P. petiti* and *Paratilapia polleni*. Introduced species are *Carassius auratus*, *Cyprinus carpio*, *Tilapia rendalli*, *Oreochromis macrochir* and *O. mossambicus*. Reptiles represented include *Liopholidophis* sp., *Sternothaerus* sp., *Erymnochilus* sp. and *Crocodylus niloticus*. The heron *Ardea humbloti* may be at risk.

Human Impact & Utilization: The region is used for rice production. The floodplain lakes are subject to substantial fishing pressure and over-exploitation is thought to be a serious problem. Catches from 1960 - 1971 ranged between 1800 and 2600 tonnes/yr. The main species caught are *Oreochromis* spp., *Cyprinus carpio* and *Arius madagascariensis*. The fishery for *Anguilla* spp. is almost depleted. The watershed is subject to deforestation and erosion leading to a decline in water quality due to siltation and wetland habitat loss.

Conservation Status: No special measures are presently in effect.

(B) THE SOFIA RIVER SYSTEM

Co-ordinates of Rivermouth & Floodplain: 15°26'S/47°13'E
Area: 500 km^2 (floodplain)
Nearest Town: Port-Berge

General: The Sofia River originates in the Massid du Tsaratanana at an altitude of 1784 m asl. Its total length is 350 km, and it discharges into the Indian Ocean at Mahajamba Bay. Major tributaries are the Bemarivo and Anjobony. The large floodplain in the lower course contains over 30 small lakes, including Amparihibe-North (8.2 km^2), Tserry (6.4 km^2) and Marovario (3.2 km^2). The total area of the lakes is 37.0 km^2. The predominant fish are introduced species: *Tilapia* spp., *Oreochromis* spp. and *Cyprinus carpio*.

(C) THE TSIRIBIHINA RIVER SYSTEM

Co-ordinates of Rivermouth & Floodplain: 19°40'S/44°26'E
Area: 700 km^2 (floodplain)
Altitude: sea level
Nearest Town: Belo-Tsiribihina

General: The Tsiribihina River originates near Fandriana (Mania tributary) at 1676 m asl. Its total length is 465 km. Major tributaries are the Mahajilo, Sakay, Kitsamby, Mania and Sakeny. A large floodplain is developed along the lower course with an area of 700 km^2. It contains over 70 small lakes: Komanaomby (18.1 km^2), Hima (15.5 km^2), Andranomena-South (7.7 km^2), Andranomena-North (5.4 km^2) and Sarlaka (4.3 km^2). The larger Lake Itasy is situated upstream on the Sakay tributary. This river basin is thought to have the largest fish stocks of any in Madagascar but is little exploited due to its isolation. Noteworthy are numerous large *Cyprinus carpio*. The heron *Ardea humbloti* is present and may be at risk.

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(D) ANKETRAKA SWAMP

General: This isolated swamp, situated at an altitude of 1097 m asl has a surface area of 124.4 km^2 and is covered by a mosaic of small ponds.

4. Natural Lakes

(A) LAKE ALAOTRA

Location: 17°19'-17°39'S/48°27'-48°38'E
Area: over 1 000 km^2 during rainy season; 200 km^2 during the dry season
Altitude: 752.50 m asl (mean)
Nearest Town: Andreba

General: This is the largest natural lake in Madagascar. It has a maximum length of 38 km and maximum width of 9.5 km. Inflowing rivers are the Sahamaloto and Sahabe, and the outflow is the Maningory. Adjacent to it is a large marsh (350 km^2) which is flooded during the rainy season. The lake is very shallow with a mean depth of 1 m during the dry season and 2.5 m during the rains. Maximum depth is around 4 m.

Hydrology & Water Quality: Annual variation in water level is 2 m. Maximum rainfall occurs in December/January. Surface water temperatures vary from a maximum of 28°C in January to a minimum of 20.5°C in July. The water is turbid and red-brown in colour. Mineralization is low.

Flora & Fauna: Aquatic macrophytes are *Cyperus madagascariensis, C. imeriniensis, Phragmites* spp. and *Eichhornia crassipes*. Native fish species present are *Anguilla mossambica, A. marmorata, Rheocles alaotrensis, Paratilapia polleni* and *Eleotris legendrei*. Introduced species include *Micropterus salmoides, Tilapia rendalli, Oreochromis macrochir, O. niloticus, O. mossambicus, Carassius auratus, Cyprinus carpio* and *Gambusia holbrooki*. Threatened waterfowl include *Tachybaptus pelzelnii, T. rufolavatus, Anas bernieri* and *Aythya innotata*.

Human Impact & Utilization: Rice culture is highly developed along the shore. Fishing is a widespread occupation. Over-exploitation of fish stocks is thought to be serious. Some 1200 fishermen land around 2200 tonnes/yr. Species exploited (in order of landed weight) are *Oreochromis macrochir, Cyprinus carpio, Tilapia rendalli, Oreochromis niloticus, Micropterus salmoides*, and *Oreochromis mossambicus*. *Paratilapia polleni* has declined from a once dominant and prized position due to competition from introduced species. The introduction of tilapia is thought to have reduced the amount of aquatic vegetation and negatively affected the popluation of *Tachybaptus pelzelnii* directly, and *T. rufolavatus* indirectly. Extermination of the latter in the wild due to hybridization with *T. ruficollis* appears inevitable.

Conservation Status: No special measures are known to have been taken.

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(B) LAKE KINKONY

Location: 16°09'S/45°50'E
Area: 149 km^2 during the rainy season; 100 km^2 during the dry season
Altitude: 8 m asl
Nearest Town: Mitsinia

General: This large lake has a maximum length of 15 km and width of 10.5 km. It is fed by lateral spillage from the Mahavavy River. Annual variation in water level is 4 m. During the dry season the maximum depth is 3.5 - 4 m.

Hydrology & Water Quality: Maximum rainfall is in January/February and the dry season lasts on average 210 days. Water temperatures vary between 24 and 33°C. Conductivity is 300-420 µS/cm. pH varies between 6.7 and 8.3.

Flora & Fauna: Aquatic macrophytes present in the lake are *Phragmites communis*, *Nymphaea lotus*, *N. stellata*, *Ceratophyllum* sp., *Eichhornia crassipes* (very abundant), *Potamogeton* sp., *Jussiaea* sp., *Polygonum* sp., *Najas australis*, *Pistia stratiotes*, *Salvinia natans* and *Utricularia vulgaris*. Macro-invertebrates present include *Caridina* spp., *Macrobrachium* spp., *Hydrotelphusa*, *Bulinus* sp. and *Lymnaea hovarum*. A diverse ichthyofauna includes euryhaline invaders from the sea as well as such endemic species as *Pachypanchax homalonotus*, *Paretroplus petitit* and *P. kieneiri*. Introduced fishes are *Carassius auratus*, *Tilapia rendalli* and *Oreochromis macrochir*. The fish eagle *Haliaeetus vociferoides* occurs amongst some 39 bird species recorded.

Human Impact & Utilization: The lake area is sparsely inhabited. Agricultural activity centers on rice and cotton production. Fishing employs about 160 fishermen, and production ranges between 620 and 826 tonnes/yr (1960 - 1975 period). The main species caught are *Megalopsi cyprinoides*, *Arius madagascariensis* and *Oreochromis macrochir*. *Paretroplus kieneri* has declined in catches. Threatened waterfowl include *Anas bernieri* and *Haliaeetus vociferoides*.

Conservation Status: Hunting for waterfowl is banned on parts of the lake. No other conservation measures are in effect.

(C) LAKE IHOTRY

Location: 21°56'S/43°41'E
Area: 94.15 km^2 during rainy season; 8.65 km^2 during dry season
Altitude: 46.5 m asl (mean)
Nearest Town: Atsimo

General: The lake has a maximum length of 13 km and width of 10 km. Inflowing rivers are the Andranakanga and Iambinda. The lake is an internal basin and has no outflow. Maximum depth during the wet season is 2.5 m in the main basin.

Hydrology & Water Quality: Maximum rainfall is in January/February. The water is very saline (non-marine origin) and conductivity can reach 2000 µS/cm. Turbidity is high.

Flora & Fauna: Salt tolerant macrophytes inhabit the littoral including *Chara zeylanica*, *Salicornia pachygastra*, *Cressa cretica*, *Arthrocnemum indicum*, *Sporobolus virginicus* and *Sclerodactylon macrostachyum*. A single introduced fish species inhabits the lake, *Tilapia rendalli*. The freshwater turtle *Erymnochelys madagascariensis* is present. A

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large aquatic avifauna is recorded from the lake, including an abundant colony of *Phoeniconaias minor*. Two threatened species, *Tachybaptus pelzelnii* and *Ardea humbloti*, are associated with the lake.

Conservation Status: Fishing on the lake is prohibited by 'fady' (local customary law). Hunting for waterfowl is prohibited on parts of the lake.

(D) LAKE ITASY

Location: 19°04'S/46°47'E
Area: 35 km^2
Altitude: 1221 m asl
Nearest Town: Soavinandriana

General: Lake Itasy has a maximum length of 10 km. The inflowing/outflowing river is the Sakay. The lake is relatively shallow with a maximum depth of 6.5 m.

Hydrology & Water Quality: Maximum rainfall is in January/February. Water level fluctuates about 1.5 m annually. Surface temperatures can vary between 18 and 27.5°C. Turbidity is high and water color is brown-green. pH varies from 6.8-7.45. Mineralization is moderate, with conductivity 65-105 µS/cm.

Flora & Fauna: Aquatic macrophytes include *Cyperus madagascariensis*, *Phragmites* spp., *Nymphaea stellata*, *Najas australis*, *Jussiaea* spp., *Polygonum* spp. and *Eichhornia crassipes*. Native fish species are *Anguilla mossambica*, *A. nebulosa labiata*, *Paratilapia polleni*, *Eleotris legendrei* and *Gobius macrorhynchus*. Introduced species are *Micropterus salmoides*, *Tilapia rendalli*, *Oreochromis niloticus* x *macrochir*, *Carassius auratus* and *Cyprinus carpio*.

Human Impact & Utilization: Agriculture is practised around the lake from April to November. During the rest of the year the lake is heavily fished and stocks are now over-exploited (due to the strong market demand from the nearby capital city, Antananarivo). Catch during the early 1960s ranged between 1240 and 1400 tonnes/yr, but by 1975 had declined to only 300 tonnes. Some 700 fishermen using 184 boats exploit the lake. *Oreochromis niloticus* x *macrochir*, *Cyprinus carpio* and *Micropterus salmoides* make up most of the catch. It is thought that the stock of *Prychochromoides betsileanus* has declined due to the introduction of *Eichhornia crassipes*. Threatened waterfowl are *Ardea humbloti* and *Aythya innotata* (the latter has been severely hunted).

Conservation Status: No special measures are in effect.

(E) LAKE TSIMANAMPETSOTSA

Location: 24°05'S/43°44'E
Area: 29.88 km^2 during the rainy season; 16 km^2 during the dry season
Altitude: 34 m asl
Nearest Town: Betioky

General: This saline lake is situated in an isolated arid area. Maximum depth during the dry season is 2 m. The lake is landlocked and has no outlet.

Hydrology & Water Quality: The dry season can last 9-11 months. Rainfall volume and time is very variable. The salinity is due to a high calcium sulphate concentration. Colour of water is white.

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Flora & Fauna: The lake is too saline to support fish. However, a blind cave fish, *Typhleotris madagascariensis*, is found in nearby limestone potholes. Molluscs are abundant and serve as food for a large colony of *Phoeniconaias minor*. Many other bird species are recorded from the reserve.

Conservation Status: Tsimanampetsotsa is the only wetland in Madagascar with a protected status. The lake is situated within the Reserve Naturelle Integrale de Tsimanampetsotsa (a strict nature reserve) which was established in 1927. The few existing local communities refrain from entering the reserve as it is considered 'fady' (customary law prohibition). The reserve is little disturbed and in good condition.

(F) OTHER NATURAL LAKES

General: Aside from the larger, natural lakes and the floodplain lakes, several small isolated natural lakes are scattered across the island: Lake Anosy (18°55'S/47°31'E) has an area of 0.1 km^2; Lake Antsohaly-Fenoarivo (19°06'S/44°36'E) is 15 m asl and has an area of 9.3 km^2; Lake Bemamba (18°51'S/44°21'E), at 2 m asl is 15.9 km^2 and receives lateral spillage from the Soahanina River; Lake Mahazoarivo (18°56'S/47°32'E) is only 0.2 km^2; Lake Mandrozo (17°33'S/44°06'E) is 6 m asl with an area of 14.4 km^2; Lake Ankitrobaka (14°30'S/48°30'E), with 7.42 km^2 situated at 1102 m asl, is associated with swamp and numerous small ponds; and Lake Namonty (22°04'S/43°25'E) is 6.53 km^2.

The Montagne d'Ambre Lakes Complex consists of a group of nine small mountain lakes (12°35'S/49°10'E): Mahery (0.35 km^2, 350 m asl), Texier, Grand, Petit, Maudit, Amparihy, Tsivahiny, Fantany (0.34 km^2, 600 m asl) and Tanavo (1.49 km^2, 380 m asl).

The Nossi Be Crater Lakes Complex consists of 10 small crater lakes situated on Nossi Be Island (13°20'S/48°13'E), including Amparihibe (1.38 km^2, 60 m asl), Andjavibe (0.31 km^2, 7 m asl), Antsahamanavaka (0.39 km^2, 180 m asl), Amparihimirahavavy, Antsidihy (0.27 km^2, 70 m asl), Maintimasoa, Bempaza, Djabala and Ampombilova.

5. Artificial Impoundments

(A) TSIAZOMPANIRY RESERVOIR

Location: 19°16'S/47°53'E
Area: 31 km^2 at upper storage level; 18 km^2 at minimum level
Altitude: 1490 m asl at upper storage level
Nearest Towns: Manjakandriana; Antananarivo

General: The Tsiazompaniry Dam was closed in 1956 to form Madagascar's largest reservoir. It has a maximum length of 20 km and width of 5 km. The inflowing/outflowing river is the Varahina-South. Annual fluctuation in water level is 9 m. Some 68 fishermen are active on the reservoir, and landed 60 tonnes of fish in 1975, using 42 boats.

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(B) MANTASOA RESERVOIR

Location: 19°01'S/47°52'E
Area: 18 km^2 at upper storage level; 11.50 km^2 at minimum level; 13.75 km^2 mean
Altitude: 1385.5 m asl at upper storage level
Nearest Towns: Andramasina; Antananarivo

General: The Mantasoa Dam was closed in 1935 across the Varahina River. The reservoir formed has a volume of 0.12 km^3. Maximum depth is 17 m, and mean depth is 6.7 m (at upper storage level). Annual water level fluctuation is 7.0 m. Surface temperature can vary between 0-30°C. *Tilapia rendalli* is the main fish species caught. Fishing effort is moderate. Twenty fishermen land 55-60 tonnes/yr.

(C) OTHER ARTIFICIAL IMPOUNDMENTS

General: Several small reservoirs are scattered across Madagascar: Ambilivily (2.35 km^2), Antanifotsy (0.99 km^2), Ivakoana (2.88 km^2), Maroala (1.44 km^2), Maromandia (1.99 km^2) and Sahamaloto (2.80 km^2).

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