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 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 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 cinnamonzea, 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 Aes*chynomene elaphroxylon, Craterispermum laurinum, Dracaena camerooniana, Ficus verruculosa, Garcinia smeathmannii, Gardenia imperialis, Hibiscus diversifolius* and *Pyschotria 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 levee 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.* nigres*cens, A. polyacantha, A. robusta, A. sieberana, Albizia versicolor, Berchenzia discolor, Chlorophora excelsa, Combretum inzberbe, Cordyla africana, Croton rnegalobotrys, 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 levees, riverine sand banks and elevated sandy patches in swamps throughout the country, but are especially common in the valley of the Luangwa. *Acacia xanthophloea* 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.

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. tonzentosum, Pycreus nzundtii, 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 *Aeschy*nomene fluitans, Aponogeton desertorunz, Azolla pinnata, Brasenia schreberi, Echinochloa stagnina, Eichhornia crassipes, Floscopa glomerata, Hydrocotyle sp., *Ipomoea aquatica, Leersia hexandra, Lemna spp., Ludwigia leptocarpa, Marsilea* sp., Naja*s 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 *Aeschynonzene 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, Hyparrhenia* spp., *Loudetia simplex, Panicum repens, Setaria sphacelata, Themeda triandra* and *Vetiveria nigritana*. In saline areas *Sporobolus marginatus* and *Sporobolus spicatus* are 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, *Terainnus 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 levees, 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 avettae* 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 levees. 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 nzargrebowiei* 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 hargeri schomburgki*, is believed to be endemic in the Bangweulu system. A common leach, *Placobdella jaegerskioeldi*, parasitises crocodiles.

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 *Gnathognemus*, *Haplochromis*, *Mormyrus*, *Serranochromis*, *Synodontis* and *Tylochromis* are widespread.
Amphibia: Frogs and toads abound in the wetlands and include among others, *Afrixalus* spp., B*ufo gutturalis, B. maculatus, B. vertebralis* (5 only), *Hemisus marmoratum, Hyperolius pusillus, H. nasutus, Kassina senegalensis, Leptopelis* sp. (5 only), *Phrynobatrachus acridoides, Phrynomerus bifasciatus, Ptychadena 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*, *Natriciteres olivacea*, *Naja melanoleuca*, *N. mossambica*, *Philothaninus irregularis*, *Psammophis sibilans* and *Python sebae*. Arboreal species in swamp and gallery forests include *Dasypeltis fasciata*, *D. scabra*, *Dendroaspis angusticeps*, *Dispholidus typus*, *Philothainnus semivariegatus* and *Thelotornis kirtlandii*. Both *Varanus exanthematicus* and *V. niloticus* are present, also *Pelomedusa 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, Amplyospiza albifrons, Ardeola ralloides, Botaurus stellaris, Bradypterus baboecalus, Calamocichla gracilirostris, Centropus cupreicaudus, Euplectes orix, Ixobrychus minutus, Ploceus pelzelni, Porzana pulsilla and Quelea erythrops. Those associated with lagoons, lakes and swamps include*

Actophilornis africana, Arias undulata, Anastomus lainelligerus, 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, Lams cirrocephalus, L fuscus, Limnocorax flavirostris, Motacilla capensis, M. ilava, Musciscapa aquatica, Netta erythropthalma, 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 fakinellus, Rostrulata benghalensis, Threskiornis aethiopicus,* and *Vanellus senegallus*. Along riversides *Alcedo semitorquata, Alopochen aegyptiacus, Arias sparsa, Apus horns, Butorides striates, 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.

Mammals: Small mammals resident in the wetlands or on the fringes include *Aonyx capensis, A. congensis, Atilax paludinosus, Dasmys incomtus, Herpestes sanguineus, Lutra maculicollis, Pellomys 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
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2. Wetlands of the Kafue Basin
    - (a) Swamps of the Upper Catchments

(b) Busanga Swamp
(c) Lukanga Swamp
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3. Wetlands of the Luangwa Valley
4. Wetlands of the Bangweulu Basin
5. The Lake Mweru System
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8. Artificial Impoundments
   (a) Lake Kariba
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1. Wetlands of the Upper Zambezi Valley
Country: Zambia

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 floodplain. 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 Phragnzites 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, 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 in 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 ntauritianus*, 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 Nye

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 Luate. 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 Siliole (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 n1 as1 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 the Lui Floodplain there are several patches of permanent swamp dominated by *Cyperus papyrus* and *Phragrnites 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

Coordinates: 14°19'-16°32'S/23°15'-23°33'E
Area: 770 000 ha
Altitude: 980-990 m as1
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 pmhos/cm through the months February to August, then rises abruptly to peak at a mean value of 126 .tinhos/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 lAmhos/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.

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 *Synodotis 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.

2. Wetlands of the Kafue Basin

Country: Zambia

General: The Katue 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.

(b) Busanga Swamp

Coordinates: 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
Coordinates: 14°00'-14°40'S/27°19'-28°00'E Area: 210 000 ha
Altitude: c. 1090 m as1
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 kin, 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 km2. 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 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

Coordinates: 15°1 1 '-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.

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 then 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 Darn 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. Levees 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 levees 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 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 flood-plains 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 pmhos/cm in March to over 350iimhos/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 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, *Simuliuni 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 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, Orzya 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 (*Lininaea* 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 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

Country: Zambia
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 levees, 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 in 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.

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

Country: Zambia
Coordinates: 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 000190 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.

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 Walilupe. 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 'bays' have respective mean and maximum depths of 2 and 3 m (Chifunauli) and 3.3 and 5.4 m (Walilupe). 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 (Litandashi), 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 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 *Phragrnites 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 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 levees 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 leach, *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 cataphractus* and *C. niloticus*, two terrapins, *Pelomedusa subrufra* 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, Potanzochoerus porcus, Redunca arundinum* and *Tragelaphus scriptus*. *Cercopithecus initis*, 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 (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 presssure 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 *Haplochromi Monnyrus*, *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 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

Country: Zambia

(a) Lake Mweru & the Luapula Floodplain

Coordinates: 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.

A further swamp and floodplain area (9°32'-10°02'S/29°14'-29°26'E) occurs between the Kalungwishi and Luongo 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 km2. 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 In 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/I 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/1: 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 0/1.

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 Chloro*phora 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 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 subrufra* and *Pelosios 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, Gnathognenzus* 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 Wantipa
Coordinates: 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)
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/1, 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 *Combretunt* close to Lake Mweru 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.

6. Lake Tanganyika

Country: Zambia
Coordinates: 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

Country: Zambia
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

Country: Zambia

(a) Lake Kariba

Coordinates: 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 *Linnothrissa 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 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

Coordinates: 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°27'44°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.