5.4 MALAWI

Introduction

Malawi is a long, narrow country, located at the southern end of the Western Rift Valley. It stretches approximately 870 km from north to south between latitudes 9°30' and 17°00'S, and 350 km from east to west between longitudes 32°44' and 35°55'E. It has a total area of 94 080 km^2 and supports an estimated population of 6 429 000 (1982), giving a mean density of 68 persons/km^2. The highest population density occurs close to the Mozambique border, from Blantyre (15°46'S/35°00'E) down the Shire Valley, with other concentrations around Zomba (15°22'S/35°22'E) and Lilongwe (13°58'S/33°49'E).

Malawi is bordered by Zambia in the west, Tanzania in the north and northeast, and Mozambique in the east, south and southwest. It is a country of dramatic relief, with high mountains and deep lakes. The major physiographic feature is Lake Malawi (Nyasa) which extends from north to south for 557 km along the eastern border. In the central region, to the west of Lake Malawi, a number of plateaux reach elevations of 760 - 1579 m asl, and together cover about three quarters of the total land surface. Mountain ranges, such as the Nyika, Vipya and Dowa Highlands in the northwest, the Dedza-Kirk Range in the west, and the Shire Highlands in the southwest, attain altitudes of the order of 2400 m. In southern Malawi the floor of the Shire Valley lies at an altitude of less than 70 m asl at the Mozambique border, but the adjacent mountain massifs of Mulanje and Zomba reach 2998 and 1976 m respectively.

Climate

Over much of the country there are two seasons, with a hot wet period from November-April, and a cooler drier one from May-October. Although the whole country lies within the tropics the topography is so varied and the range of altitude so great, that climatic conditions are complex with gradations from wet to dry, and hot to cold. During winter the prevailing winds, unless deflected by mountains, are from the southeast, or less often, from the east. These air flows are characterised by a shallow layer of moist air overlain by much drier air. This produces fair-weather cloud which varies in amount according to the depth of the moist layer. After the September equinox the winds tend to become more northerly and the air becomes warmer and more humid. Showers and occasional thunderstorms occur, but heavy rain only becomes general with the arrival of the

Intertropical Convergence Zone (ITCZ) in October. This, together with strengthening winds, causes an increase in cloudiness and rainfall until the end of March when the convergence zone is driven farther north by southerly air flows, a process which leads to the cessation of rain throughout the Zambezi Basin. However, in Malawi, the escarpment bordering the lake directly exposed to the southeasterly winds continues to receive rain, partly from off the lake itself, so that in northern parts of the country April may be the wettest month. Weather becomes fair in all parts of Malawi by May.

Much rain is convective, falling in local showers or thunderstorms. It usually occurs in spells of several rainy days followed by several dry days. Periodically, rising pressure to the south results in incursions of cool moist air bringing drizzle known as chiperoni. This can occur at any time of the year, but the effect is striking when it occurs during the dry season. When a tropical cyclone moves down the Mozambique channel it tends to distort the ITCZ, so that much moister air from the Zaire Basin is drawn across Zambia into Malawi. Although the winds generated by cyclones moderate rapidly inland, winds speeds can still become high over Lake Malawi, and extremely heavy rain may persist over the country for several days in the wake of a cyclone. Such an event produced a fall of 570 mm in 24 hours at Nkhotakota in 1957.

The southern highlands, and particularly their southeasterly windward slopes, receive 2-3 times as much rain as adjacent low-lying areas, such as the Lower Shire Valley. Here mean annual rainfall varies from 635-762 mm depending upon site. Rainfall is highest on the northern plateaux of Vipya and Nyika, where the mean annual receipt is in excess of 2200 mm. Falls of more than 1500 mm are received along Lake Malawi where the shore is perpendicular to the direction of the prevailing wind. Rainfall along sections of the lake parallel to the wind is much lower. Most valleys, notably those of the Shire and Kasitu Rivers, and the southern end of Lake Malawi, are in rainshadows.

Temperatures in Malawi are greatly influenced by topography, being, for example, much warmer in the lowlands of the Shire Valley than in the highlands. In addition, Lake Malawi has a profound effect upon the weather since it acts as a heat reservoir of sufficient magnitude to set up land and 'sea' breezes. Thus cool air from the lake tends to move over the heated land during the day, but at night cold air from the land tends to drain towards the lake. The onset of lake breezes halts the normal diurnal rise in temperature, and the maximum temperature is several degrees lower than otherwise would be the case. Over most of the country the annual range in temperature is about 12°C, except in the south where it is 15°C. The lowest temperatures occur in June and July (mean monthly minimum at Lilongwe is 5°C), and the highest occur in October and November (mean monthly maximum at Lilongwe 30°C,

absolute maximum 40°C). When the rains come there is a fall of about 3°C in maximum temperatures, although the minimum temperatures go on rising until December or January. Thereafter temperatures remain steady until the end of the rains in March or April before decreasing to the winter minima.

Because of the large diurnal variations in temperature, relative humidity varies widely during the day, being highest when the temperature is lowest, and *vice versa.* At dawn, relative humidities of over 90% are common at most weather stations in the country, but by afternoon the figure has fallen to 40-60% depending upon the season. The lowest humidities occur in October, immediately preceding the rains.

Substantial amounts of sunshine are recorded even during the rainy season. The southern and southwestern parts of Lake Malawi are the sunniest parts of the country, while the northern sector is much more often overcast. Lilongwe receives 2665 hours of sunshine/yr, giving a mean daily figure of 7.3 hours, with minimum receipts of 4.6 hr/day in January and maximum ones of 9.9 hr/day in October.

Wetlands

The principal drainage system, covering 158 000 km^2, culminates in Lake Malawi, and extends outside the borders of the country. The lake is fed by the North and South Rukuru, Dwangwa, Lilongwe and Bua Rivers, but the only outlet is the Shire River via Lake Malombe. The river emerges from Lake Malombe as the Middle Shire, which loses very little altitude over a distance of 100 km before descending almost 300 m in a series of rapids and waterfalls. Below the last cataract, Kapachira Falls, the river is known as the Lower Shire. Thereafter it flows south, having a broad floodplain and in a number of places expands into extensive marshes and swamps before joining the Zambezi River in Mozambique. The Chilwa Basin is an endorheic system fed by a number of highly seasonal streams flowing into Lake Chilwa which occupies the lowest part of the basin. It is surrounded by permanent swamps and a seasonal floodplain. Other swamps and marshes are found in the Western Highlands near the border with Zambia, e.g. a large marsh surrounds the headwaters of the Bua and Dwangwa Rivers.

Wetland Flora

Riverine and Lacustrine Floodplains: These are dominated by grasses among which *Oryza barthii* and *0. longistaminata* occupy the most deeply inundated sites with *Echinochloa pyramidalis, E. scabra* and *Pennisetum* sp. in sites flooded to intermediate depths. *Acrocerus inacruni, Setaria sphacelata* and *Vetiveria nigritana* are common on the margins. In the

lowlands these are joined by *Echinochloa haploclada, Eriochloa borumensis* and *Sporobolus robustus. Hyparrhenia* and *Heteropogon* spp. are also locally common on the margins, but where grazing is intense *Cynodon dactylon* is important. On wet grazed margins this latter species is associated with, or gives way to, *Eleusine indica* and *Eragrostis aspera.*

Dambos: Grasses in permanently waterlogged but not deeply flooded, or very temporarily flooded sites, such as dambos, include *Heteropogon contortus, Loudetia simplex* and *Themeda triandra.* In addition species of *Xyris* and various dicotyledonous herbs are also usually present.

Permanent Swamps & Marshes: The permanent swamps are dominated by *Phragmites mauritianus* and *Typha domingensis,* or by *Cyperus papyrus* in permanent water with seasonally fluctuating levels. Papyrus is accompanied by a typical spectrum of low growing, often floating, associates. These include *Aeschynomene nilotica, Echinochloa haploclada, Ipomoea aquatica, Leersia hexandra, Ludwigia stolonifera, Nymphaea caerulea, N. capensis, N. lotus,* and most importantly, *Vossia cuspidata* at the outward waterside faces. A number of free-floating species occur on open water in these swamps, e.g. *Azolla nilotica, Eichhornia crassipes, Pistia stratiotes* and *Salvinia hastata,* while beneath the surface of open water *Ceratophyllum demersum, Ottelia exserta* and *Utricularia* spp. are common. The flora of these swamps may change with the onset of the dry season, since many aquatic plants die back as the water level falls, and other species appear.

Sudds often form in these swamps at high water, the most important sudd-forming species being *Cyperus papyrus, Echinochloa pyramidalis, Ludwigia leptocarpa, L. stolonifera* and *Pycreus mundtii.* Their roots and rhizomes interweave and are bound together by masses of *Nymphaea capensis* and *Trapa natans.* Early in the season when the water is low, new vegetation extends outwards from the *Cyperus-Typha* border of the swamp. This often becomes established in masses of old vegetation which was banked up when the floods subsided at the end of the previous cycle. In the comparatively shallow water of the dry season, the new vegetation is at first rooted, but with increases in water levels and the development of flood currents following the onset of fresh rains, it becomes detached from the substratum.

Sedge Marshes: These occur where inundation is neither very deep nor permanent, in sites where the surface dries for a short period each year. Often they are found on the landward side of permanent swamps. *Cyperus articulatus* and *C. digitatus* tend to dominate these areas, reaching 1.5 m in height, with *Echinochloa haploclada, Ipomoea aquatica, Leersia hexandra, Ludwigia stolonifera, Nyrnphaea caerulea, N. capensis, N. lotus* and

Vossia cuspidata as common associates. Many of the free-floating species mentioned above are abundant at high water. During the dry season the exposed land between sedge clumps is invaded by annual herbs, e.g. *Cyperus esculentus* and *Hibiscus cannabimis.*

Riverine & Levee Forests: Scattered trees of Acacia *albida, Diospyros mespiliformis, Ficus sycomorus, Ilex nzitis, Khaya nyasica, Kigelia pinnata, Rims longipes,* R *tenuinervis* and *Syzygium cordatum* occur on levees in the swamps and along rivers, with lower growing bushes of *Ficus verruculosa* and *Hibiscus diversifolius* at the water's edge.

Wetland Fauna

Fish: The cataracts of the Middle Shire are reputed to act as a total barrier to fish movement, with the result that the fishes above the cataracts belong to the Lake Malawi fish fauna and those below to the Zambezi fish fauna. The extraordinarily rich fish fauna of Lake Malawi is dealt with in section 5.4.6, Lake Malawi, but the Shire system contains some 61 species including *Astatotilapia calliptera, Carcharhinus leucas, Clarias* **ga***riepinus, C. ngamensis, Eutropius depressirostris, Hydrocynus vittatus, Labeo altivelis, L. congoro, Marcusenius macrolepidotus, M. livingstonei, Oreochromis mossambicus, 0. shiranus, Petrocephalus catostoma, Protopterus annectens and Tilapia rendalli*. The Malawi Plateau fish fauna, described by Tweddle (1982), is also distinct and contains such species as *Barbus kerstenii, B. lineomaculatus, B. paludinosus, B. radiatus, B. tri-maculatus, Chiloglanis neumanni, Labeo cylindricus, Leptoglanis cf. rotundiceps, Oreochromis shiranus* and *Pseudocrenilabrus philander.* The Chilwa Basin has an impoverished fish fauna dealt with in section 5.4.9, Lake Chilwa.

Reptiles: *Crocodylus niloticus* occurs throughout the country in suitable habitats, and snakes including *Atheris superciliaris, Bitis arietans, Dromophis lineatus, Lycodonomorphus mlanjensis, L. rufulus, Naja mossambica, Natriciteres olivacea, Philothamnus hoplogaster, Psammophis sibilans* and *Python sebae* are ubiquitous in the wetlands.

Birds: Highland floodplains support *Grus carunculatus, Cisticola njombe, Francolinus levaillantii* and *Neotis cafra jacksoni* among many other species. Swamps, lake margins and rivers support *Ardea cinerea, Ceryle rudis, Chlidonias leucoptera, Corythornis cristata, Dendrocygna viduata, Egretta garzetta, Haliaeetus vocifer, Larus cirrocephalus, Megaceryle maxima, Merops nubicus, Phalacrocorax africanus, P. carbo, Plectropterus gambensis, Scopus umbretta* and *Scotopelia peli.*

Mammals: *Aonyx capensis, Hippopotamus amphibius* and *Lutra maculicollis* are found in wetlands throughout the country, while *Alcelaphus lichtensteini, Equus burchelli, Hippotragus equinus, Loxodonta africana, Potamochoerus porcus, Redunca arundinum* and *Syncerus caffer* are frequent visitors to floodplains during the dry seasons. Tweddle & Mkoto (1986) provide an extensive bibliography of limnological work carried out in Malawi.

List of Wetlands Described

1. Marshes of the Ruwenya Hills
2. Marshes of Fort Hill Plain
3. Wetlands of the South Rukuru River System
    (a) Northern Tributaries
    (b) Vwaza Marsh
    (c) Southern Tributaries
4. Marshes of Kasungu Plain & the Bua River
5. Marshes of the Lilongwe Plain
6. Lake Malawi
7. Wetlands Associated with Lake Malawi
    (a) Karonga Lakeshore Plain
    (b) Limpasa Dambo
    (c) Nkhotakota Lakeshore Lowlands
    (d) Salima Lakeshore Plain
8. Lake Malombe
9. The Shire Marshes
10. Lake Chilwa
11. Lake Chiuta

1. Marshes of the Ruwenya Hills

General: In the extreme northwest of Malawi the Ruwenya Hills rise from 1220 to 1830 m asl. The mean annual temperatures are from 18-21°C depending upon site, while rainfall varies from 864-1143 mm and winds are predominantly from the east. In this remote, sparsely populated region, small grass and reed swamps occupy the heads of little valleys. One of the largest swamps (9°20'S/32°55'E) covers about 1000 ha. Stunted riparian forests containing *Ilex initis* and *Syzygiuin cordatum* are found up to 1700 m asl along stream banks. This area is unprotected.

2. Marshes of Fort Hill Plain

General: This is a gently undulating plain with widely spaced marshy rivers situated south of the Ruwenya Hills. It lies at an altitude of 1250-1400 m asl, has a mean annual temperature of 20°C and mean annual rainfall of 820 -1300 mm depending upon location. Easterly winds predominate. There are more than ten marshes of approximately 1000 ha each in an area 9°30'-10°10'S/33°15'-33°20'E, the largest one being on the Mambukiro River. Sandy ferallitic soils supporting *Brachystegia-Julbernardia* woodlands cover the plain with the marshes (dambos) in isolated depressions. The sparse local population practises shifting cultivation, but maintains small patches of permanent cultivation near the rivers. None of this area is protected. The flora and fauna of the wetlands is as indicated in the introduction.

3. Wetlands of the South Rukuru River System

General: This river drains a large basin (10°35'-12°16'S/33°12'-33°50'E) below the watershed on the western border with Zambia. Tributary streams rise on the western slopes of the Nyika Plateau in the north and on Perekezi Hill in the south, and flow to a confluence at a point 11°11'S/32°28'E. Thereafter the river flows east to Jakwa Gorge, traversing Fufu and Wangwe Waterfalls before entering Lake Malawi at Mlowe (10°46'S/34°13'E) on the west bank.

(a) Northern Tributaroes

General: A number of marshes occur on the northern tributaries in a comparatively flat area to the north of Katumbi (10°47'S/33°36'E) beneath the Nyika Massif proper. Most of this upland plain is seasonally very wet. The mean annual temperature is 20°C and the mean annual rainfall is close to 1300 mm.

Flora & Fauna: The wet parts of the plain are covered by short open grassland dominated by *Exotheca abyssinica, Loudetia simplex* and *Themeda triandra.* A comparatively high level of speciation among plants has been recognised here, with at least 15 endemics, including species of *Cardiochilos* and *Holmesia.* The widely spaced rivers are bounded in places by broad riparian marshes, and the surrounding *Brachystegia-Julbernardia* woodland is locally joined by *Cryptosepalum pseudotaxus.* Several streams in the area have been stocked with rainbow trout. Subspecies of reptiles, amphibians and butterflies are endemic to the area, while wetland birds include *Cisticola njonzbe, Francolinus levaillantii, Grus carunculatus* and *Neotis cafrajacksoni.* Many of the small mammals cited in the introduction are present.

Human Impact & Utilisation: The population is sparse. Shifting cultivation is practised.

Conservation Status: Part of the area is protected within the Nyika National Park, which was created in 1966 and extended in 1978. This park is contiguous with the Nyika National Park in Zambia and wetlands extend across the border. The greatest threat to the marshes, both inside and outside the park, is annual burning carried out by the indigenous population.

(b) Vwaza Marsh

General: South of Katumbi the Hewe River flows into a marshy area known as Vwaza Marsh, from which it emerges as the Luwewe River. This area lies between 1100 -1130 m asl and experiences mean maximum temperatures close to 17°C in July and 23.5°C in January, with a mean annual temperature of 21°C. Mean annual precipitation for 1981-83 was 1279 mm, with most rain falling between November and April, and no rain falling between June and September. Most of the wetland is situated west of the Luwewe River where it occupies a shallow depression floored by alluvium. There are patches of permanent reed/grass/sedge swamps, seasonally inundated grassy flood-plains, abandoned levees and dambos, as well as reed swamps along the active course of the river. In addition an extensive flat area is subject to waterlogging if not to flooding. In total the wetlands occupy an area of about 40 000 ha.

The Luwewe River meanders south from the principal area of permanent 'marsh' in a channel which is 5-10 m wide for most of the year, although, in some years it may be reduced to a series of pools by the end of the dry season. To the southwest of the marsh proper some 7500 ha of grassland covers a seasonally inundated clay pan. This probably represents a former swamp or lake which has been drained by the Luwewe River. Large termitaria are a feature of this pan which is regularly burned during dry seasons.

Flora & Fauna: The floras of the different types of wetland are as indicated in the introduction. The fish fauna is as described for the Malawi Plateau in the introduction. The marsh is an important wildfowl location and many large mammals visit the floodplains during the dry season. However, *Hippopotamus amphibius* is the only large resident. Most of the small mammals cited in the introduction are present.

Human Impact & Utilisation: There has been little impact upon the wetlands. The whole area is infested with tsetse fly and there is endemic sleeping sickness which affects both cattle and people. This has hindered both the development of tourism and the integration of the local people with surrounding communities.

Conservation Status: The full length of the Luwewe River and its floodplains are protected in the Vwaza Marsh Game Reserve, which has a total area of 100 000 ha centred at 11°00'S/33°28'E. However the eastern

corner of the 'marsh' is not protected and this locality is utilised intensively by villagers, many of whom were displaced when the reserve was created in 1977 and expanded in 1985.
Hunting occurs in the area, including the illegal hunting of elephants in the reserve. Fishing occurs in all watercourses and, although illegal in the reserve is widespread there. It is especially intense in the south where the river flows close to the reserve boundary. Currently there is pressure from local villagers to have some of the wetland excised from the park for rice cultivation. There is potential for tourism in the reserve and one small camp site, but access is difficult at present. Much of the wetland has been zoned for safari hunting, and game viewing is good during the dry season.

(c) Southern Tributaries

General: The southern branch of the South Rukuru River rises in the highlands in the west of Malawi (12°15'S/33°40'E) and makes a steep descent for a short distance to the southwest. It then turns northwards and follows a meandering course, receiving several tributaries, before it reaches the confluence with the Luwewe at Zaro Pool, a swamp fringed widening of the river. From here, for 20 km to Lake Kazuni, another broadening of the river with permanent marshes, the South Rukuru River forms the boundary of the Vwaza Marsh Game Reserve.
The areas of both Zaro Pool and Lake Kazuni fluctuate considerably. Lake Kazuni dried completely in the dry season of 1970, but contained over 80 ha of open water in December of the same year. In September 1979 there were 50 ha of open water (Tweddle, pers. comm.). Lake Kazuni is situated at an altitude of 1082 m asl.
Along the lower part of its upper course, and throughout its entire middle course between its confluence with the Luwewe and Jakwa Gorge (about 120 km), the South Rukuru River and its tributaries are accompanied by broad grassy marshes/floodplains up to 4 km wide on dark cracking clays or coarse sands. Along the upper course (1250-1050 m asl) the mean annual temperature is 20-21°C and the mean annual rainfall 820-1030 mm. The middle reaches of the river, below 1050 m, experience higher temperatures (mean annual 22°C) and lower rainfall (mostly less than 820 mm/yr).
The Kasitu, the last major tributary of the South Rukuru, rises to the east of the South Rukuru River and flows in a northerly direction to join its south bank. Riparian swamps and a floodplain also occur on this stream, for a distance of 45 km above the confluence, but they are less extensive than those of the South Rukuru.
Flora & Fauna: Scattered trees are found in the marshes, mostly growing on termite mounds. A spectrum of trees grows on the levees, as indicated in the introduction, behind which the river and its pools are fringed by reed swamps and grassy floodplains. Species of *Barbus* and *Clarias* which do not occur elsewhere in Malawi are found in the upper reaches of the river. Many large

mammal species visit the floodplains during the dry season, including, along the upper reaches, *Kobus vardoni.* Both Zaro Pool and Lake Kazuni are important for wildfowl, and are visited by buffaloes, elephants and hippopotamuses.

Human Impact & Utilisation: Permanent cultivation is carried out in small patches near the rivers and on interfluves. Population density is generally high.

Conservation Status: Part of this section of the river is protected within the Vwaza Marsh Game Reserve and is important for the maintenance of fish stocks in the river.

4. Marshes of Kasungu Plain & the Bua River

General: The Kasungu Plain (13°20'-13°45'S/32°50'-33°18'E) is situated at altitudes of 975-1220 m asl. The mean annual temperature is 21.7°C. Daily maxima often exceed 29°C between September and May, while daily minima may fall to 4°C between June and August. Annual rainfall over the plain varies between 765-1015 mm. In the southern part of the plain, the Bua River, and its tributary the Busa, both rise in grass swamps, at 14°09'S/33°27'E and 13°31'S/32°55'E respectively. These swamps are dominated by *Hyparrhenia* spp. and are dotted with pools. The headwaters of the Bua carry a marshy floodplain some 70 km long and up to 3 km wide, while the upper Busa carries a similar wetland 48 km long and 1-5 km in width. In addition there are more than 20 marshes and dambos, each exceeding 500 ha, on the plain between the rivers, and 20-30% of this inter-riverine area is subject to periodic inundation. As the rivers gain in size so their riparian swamps widen above their confluence at a point 13°20'S/33°27'E. The Bua is the largest river to enter Lake Malawi from the Malawi side, descending the steep slopes of the Rift Valley escarpment in a series of fault-controlled steps.

Conservation Status: Kasungu Plain has been extensively deforested, and this together with increased ground water extraction threatens to change flood and flow patterns in the rivers draining the plain. Kasungu National Park covers a drier northern part of the plain between the Busa and Dwangwa Rivers. The source of the Busa is situated in the extreme southwest corner of the park. Part of the lower Bua is protected in the Nkhotakota Game Reserve, where fishing is prohibited. This is important since the river supports huge breeding runs of the migrating cyprinid fish *Opsaridium microlepis,* which is endemic to Lake Malawi and is one of the major commercial species in its northern and central regions. Protection of the Bua River is considered necessary for the survival of the fishery.

5. Marshes of the Lilongwe Plain

General: More than 70 marshy areas, each greater than 500 ha, lie in a

crescent orientated north-west-south on the Lilongwe Plain, at altitudes of 1100-1340 m. Here mean annual temperature is 20.5°C and the mean annual rainfall 890 mm. The surrounding woodlands comprise *Acacia, Combretum* and *Piliostigma* spp., and cultivation is largely restricted to the marshy areas.

6. Lake Malawi
Country: Malawi
Coordinates: 9°30'-14°27'S/33°58'-35°19'E
Area: 2 450 400 ha (1 750 400 ha in Malawi)
Altitude: 475 m asl
Nearest Towns: Lilongwe (90 km W); Blantyre (165 km S)

General: Lake Malawi is situated in the southern part of the Western Rift Valley. It is 557 km long in a north-south direction, has a maximum recorded depth of 706 m, and is the second deepest lake in Africa. In the north, the Livingstone Mountains of Tanzania plunge almost vertically into it and continue into the depths of the northern basin. To the east and west, other escarpments form sheer cliffs at the water's edge. Much of the shoreline is rocky, giving rise in places to sheltered bays, but where the escarpments do not descend directly into the lake, there are coastal plains of varying widths, which are subject to flooding when water levels are high. In the south of the lake the topography is less rugged. The lake is of sufficient size to modify the climate locally, as discussed in the introduction. Annual rainfall varies from 650 mm at Mangachi in the south to 2500 mm at the northern extremity. The lake surface rises 0.7-1.8 m and falls an average of 1.1 m each year. 80-90% of the annual loss is through evaporation with the remaining 10-20% leaving via the Shire River. Below 250 m depth the lake is homothermal at 22.5°C, and is anoxic. Above 250 m there is a seasonal cycle, with the development of a marked thermocline during the warmer months. Reputedly the lake contains the greatest number of endemic fish species of any lake in the world, and fish from it are very important as a source of protein for the people of Malawi.

Hydrology & Water Quality: The principal rivers entering the lake from Malawi are, from north to south, the Lufilya, North Rukuru, South Rukuru, Dwangwa, Bua and Lilongwe, all of which rise in the western highlands of Malawi. The watersheds of these highlands form the boundary between Malawi and Zambia. These rivers have small catchments so that their volumetric flow at any time depends upon the vagaries of local rainfall; they are all subject to sudden flooding and changes of water level over short time periods. Lake Malawi drains to the Indian Ocean via the Shire and Zambezi Rivers.

Its hydrology is delicately balanced and the level of the lake and the volume of the outflow also react rapidly to short term changes in precipitation over the catchments. However, there have also been long term changes in the patterns of precipitation which have caused the coastal plains to be alternately flooded and exposed for long periods. This has led to demographic changes, and has possibly promoted the great speciation of the fish fauna which characterises the lake. During the past century the level of the lake changed by some 6 m, from 469 m asl in 1915 to its present level of 475 m asl. When Livingstone first saw Elephant Marsh on the Shire River in 1859, it was large, but for the 20 years from 1915 to 1935, Lake Malawi did not overflow into the Shire River, and most of the Shire Swamps became dry land and were cultivated. The re-flooding of the area when the lake level rose again caused serious social disruption to the people of the plains.

The salinity of the lake water is quite low, having a mean conductivity of 200230 pmhos/cm. Salinity is close to 1.90700, pH varies between 8.2-8.8, and the following ionic concentrations, in meq/l, are typical: Na 0.16, Ca 0.99, Mg 0.39, carbonate + bicarbonate 2.36, chloride 0.12 and sulphate 0.11.

Flora & Fauna: Throughout the lake there are substantial growths of filamentous algae on the submerged rocks, extending to depths of 5-6 m. This is often dominated by cyanophytes, e.g. *Calothrix* spp. Sheltered sandy shores support *Ceratophyllum denier-sum, Myriophyllum* sp., *Potamogeton* spp. and *Vallisneria* sp., while swampy banks are covered by hygrophilous grasses including *Panicunt repens, Sacciolepis africana* and *Vossia cuspidata.* Some bays are fringed by reed swamps with carpets of the free-floating *Pistia stratiotes* on quiet shallow water.

The lake supports a very large number of endemic Cichlidae. Almost 300 species of fish have been described from the lake, but the total number is quite possibly in excess of 500 (Tweddle pers. comm.). Many species have limited distributions within the lake, e.g. almost all islands support unique populations of rock-dwelling cichlids. It has been suggested (Beadle, 1981) that the Murchison Rapids on the Middle Shire River prevent the exchange of species between Lake Malawi and the Middle Zambezi system.

Rocky shores harbour a wealth of invertebrates (e.g harpacticoid copepods, chironomid fly larvae, hydrachnid water mites, ostracod crustaceans and larvae and nymphs of various insects). Molluscs are generally only poorly represented, but among those present are the endemic species *Neothauma ecclesi* and *Bulinus nyassanus.* Crevices in rocks hide the crab *Potamonautes lirrangensis* and provide refuges for many fish. Cichlids

characteristic of rocky shores are known collectively as mbuna. They tend to be very colourful and are important to the aquarium export trade.

Sandy shores support an almost entirely different fauna. Invertebrates utilising this habitat include copepod and ostracod Crustacea, the prawn *Caridina nilotica,* chironomid larvae, the larvae and nymphs of Odonata and Trichoptera, and a number of gastropod and bivalve Mollusca. A different spectrum of cichlid fishes occupies this niche, e.g. *Haplochromis viola, H. sintilis, Lethrinops* spp., *Oreochromis saka* and *Tilapia rendalli.*
In the open waters the zooplankton comprises primarily copepods and cladocerans (e.g. *Diaptomus* spp. and *Mesocyclops* spp.), together with the larvae of chaoborid flies.

Consumers of the zooplankton include the cyprinid *Engraulicypris sardella,* which is possibly the only pelagic fish to breed in the deep open water, although shoals sometimes swim into shallow waters when they tend to be caught by hand and seine nets. A group of about 16 species of *Haplochromis,* having protusible mouths, are also zooplankton feeders and are known collectively as utaka. The zooplankton feeders are preyed upon by other fish, including *Bagrus rneridionalis* and some species of *Ramphochromis* which are fast swimming, thin bodied cichlids with jaws and teeth suitable for predation. These predators are of considerable economic importance.

Species of fish which regularly inhabit depths of 200-300 m include *Bagrus meridionalis* (Bagridae); *Dinotopterus* (= Bathyclarias) *foveolatus, D. felicibarbis, D. rotundifrons, Haplochromis heterotaenia* (Cichlidae); *Synodontis nyassae* (Mochokidae); and *Mortnyrus longirostris* (Mormyridae).

Crocodylus niloticus is widespread but uncommon around the lakeshore, except in certain localities. Crocodile hunting is regulated by licence and a strict quota system is in operation. *Cycloderma frenatum* and *Varanus niloticus* are common all round the lake.

Birdlife is abundant and includes *Ceryle rudis, Chlidonias leucoptera, Corythornis cristata, Dendrocygna viduata, Haliaeetus vocifer, Larus cirrocephalus, Megaceryle maxinza, Phalacrocorax africanus, P. carbo, Plectropterus gambensis, Scopus umbretta* and *Scotopelia peli.*
Among mammals, *Hippopotamus amphibius* is fairly common, particularly in peripheral swamps and lagoons, where some may be shot each year for reasons of crop protection. *Aonyx capensis, Atilax paludinosus* and *Lutra maculicollis* are common.

Human Impact & Utilisation: By far the most important activity is

fishing. A number of distribution centres have been set up, many of which are close to the shore. There is a continuing improvement in the numbers of these centres and their facilities, and also in the roads which are used to transport the fish to the rest of the country. Most fish are sent to the Blantyre area, but substantial quantities also go to Lilongwe. Over 33 000 tonnes of fish may be landed at Malawian ports in a good year.

Shore seines, long lines and gill nets are used around the lake. Trawling is important at Domira Bay and Salina, and the SE Arm is the most highly developed and productive area of the lake. The principal species taken commercially are *Bagrus meridionalis, Bathyclarias* spp., *Cyrtocara* spp., *Engraulicypris sardella, Labeo mesops, Mormyrus longirostris, Opsaridium micromlepis, 0. microcephalus, Oreochromis squanzipinnis, 0. lidole, 0. saka* and *0. karongae.* The catch is sold fresh, frozen, smoked and sun dried, depending on size and consumer preferences.

Progressive deforestation and intensifying agriculture in the hinterland may eventually influence climatic patterns over the Lake Malawi Basin, and may be expected to produce increased rainfall because of changes in the land/water temperature balance. The level of the lake is kept fairly high by a barrage on the Shire River. At times of excessive rainfall this has led to damage of installations situated on the lakeshore, because the water has not been released sufficiently quickly.

Conservation Status: Most of the islands and a few sections of the mainland in the SE and SW Arms were gazetted as a national park in 1980. The protected areas include an aquatic zone extending 100 m out from the shore, within which all fishing is prohibited. This conserves the rocky shore community, together with those species which move inshore to spawn.

7. Wetlands Associated with Lake Malawi

(a) Karonga Lakeshore Plain

General: The Karonga Lakeshore Plain extends from the head of the lake in Tanzania, along the northwest shore in a SSW direction into Malawi to a latitude of 10°35'S where it is 8-20 km wide between longitudes 33°55' and 34°15'E. The plain rises from the level of the lake to 502 m asl, and enjoys a mean annual temperature of 24.5°C. Rainfall varies from about 1000 mm/yr in the south to over 2000 mm/yr in the north (Karonga town 1080 mm). The plain is covered by swamps and dambos, with a cluster of 8 sizeable swamps occuping the northern part, and a group of 3 larger swamps occupying the southern part. Here, along the shore of Lake Malawi, long

narrow lacustrine sand bars alternate with long strip marshes, all running parallel to the lake. Except for some of the larger marshes, much of the plain is under cultivation and no part is protected.

(b) Limpasa Dambo

General: Limpasa Dambo (11°30'-11°45'S/34°15'-34°20'E) is situated in the lowlands near Nkhata Bay. It is approximately 29 km long with widths of 1.5-9 km, and an area of 13 000 ha. It rises from an altitude of 475 m asl at the lakeshore to 518 m asl. The local climate is hot and wet, with a mean annual temperature of 25°C and a rainfall of up to 2290 mm/yr. The dambo floor is clay, and vegetationally it is dominated by grasses. It is uncultivated and unprotected.

(c) Nkhotakota Lakeshore Lowlands

General: Here a strip of lowlands, extending for 125 km along the western shore of Lake Malawi, contains a number of seasonally flooded areas. These include from north to south: Unaka Lagoon, Bana Swamp (c. 15 000 ha, 19x8 km), Dzedza Swamp (c. 2800 ha), Chia Lagoon, and numerous marshy areas, especially to the west of Nkhotakota and to the north of Chia Lagoon. The mean annual temperature here is 24°C and the mean annual rainfall 1275 mm. Nkhotakota Game Reserve lies to the west of the lakeshore, and apart from the Bua and other rivers which flow through it, it contains little wetland. Extensive use is made of water from the Bua for irrigation on the lakeshore plain, and there are fears that too great a use of its waters in low rainfall years may threaten the survival of the fish *Opsaridium microlepis* which breeds in the Bua River.

(d) Salima Lakeshore Plain

General: This is a very wet plain about 90 km long, which includes at least 11 sizeable marshes and the swampy delta of the Lilongwe River. This latter is 22 km long and 15 km wide at the lakeshore, with a swamp area of approximately 16 500 ha. Mean annual temperatures over the plain range from 23-24°C while rainfalls range from 1015-270 mm.

8. Lake Malombe

Country: Malawi
Coordinates: 14°29 '44°45 ' S/35°12 '-35°20 'E
Area: 47 000 ha
Altitude: 470 m as1
Nearest Town: Mangochi (10 km N)

General: This lake lies 15 km to the south of Lake Malawi. It is filled by overflow from Lake Malawi via the Upper Shire River, and discharges

downstream to the Middle Shire River. It has a maximum depth of about 4 m, and together with its associated swamps covers an area of some 30 000 ha. The bordering marshes are dominated by *Typha domingensis,* but with considerable areas of *Cyperus papyrus.* During the dry period 1915-1935 water did not enter from Lake Malawi and the system became dry. Part of the swamp and that part of the river between Lake Malombe and Liwonde is protected in the Liwonde National Park, which lies to the southeast of the lake and borders the east bank of the Middle Shire River. The shores of Lake Malombe and the margins of the Shire carry typical riverine and floodplain vegetation, with small areas of gallery forest containing the palm *Hyphaene benguellensis.* The surrounding country is covered by savanna woodland. Here the Shire supports large populations of *Crocodylus niloticus* and *Hippopotamus anzphibius.* 207 species of birds have been recorded, including *Agapornis lilianae* and many aquatic species. It is intensively fished but the annual catch fluctuates widely. This is partly related to variations in the size of the lake, and partly to the rebound effect of periodic overfishing. In 1976 the total catch was 6000 tonnes.

9. The Shire Marshes
Country: Malawi
Coordinates: 16°11 '-17°05'S/34°59'-35°19'E
Area: 74 000 ha (maximum wet season inundated area) **Altitude:** 70-85 m asl
Nearest Towns: Ngabu (on Elephant Marsh); Blantyre (90 km N)

General: The Shire River drains Lakes Malawi and Malombe and thereafter falls 400 m before reaching the Lower Shire Valley. Barrages near Liwonde regulate the dry season flow of the river to generate hydroelectric power, and influence the passage of the flood waters which pass downstream in the wet season. In its lower course, before discharging into the Zambezi, the Shire flows through an extensive low lying area, which is deeply flooded during the wet season. A series of swamps, or 'marshes' as they are called locally, extends along the river, with two major areas in Malawi. Together these support one of the country's most important fisheries.

The Shire Swamps comprise two tracts of permanent swampland, and some lagoons in the Chikwawa and Bangula areas. After descending the Murchison Falls the river traverses the swampy lagoons at Chikwawa, and then spreads over the larger of the two swamps, Elephant Marsh, which extends some 25 km upstream and downstream of the town of Ngabu (16°47'S/35°15'E). This swamp terminates just above the confluence of the Shire and Ruo Rivers, in the vicinity of Bangula Lagoon, a 1000 ha expanse of open water. Some 40 km downstream of this is Ndinde Marsh, which begins at Nsanje (= Port Herald 16°47'S/35°15'E) and continues south to

the southern tip of Malawi. On approaching the marshes the steep sandy banks of the Shire River decline and its waters traverse the marshes through a maze of shallow channels, from the almost nonexistent banks of which a flood spills over the intervening land in the rainy season.

In contracted state, at low water between August and November, the 'marshes' occupy respective areas of approximately 30 000 and 6000 ha, but at high water, towards the end of a very wet season, they expand dramatically. Elephant Marsh may then attain a length of 90 km and a maximum width of 30 km with an inundated area of 57 000 ha, while Ndinde Marsh swells to about 20 000 ha. The numerous lakes and lagoons which comprise these marshes, some with areas of nearly 2000 ha, may have connection with the anastomosing river channels only during the wet season. Islands of elevated land are small in extent and mainly peripheral; the marshes are virtually treeless and are dominated by herbaceous vegetation. Local rains between December and April are relatively unimportant in determining the water levels attained in the swamps, by far the most important factor being the flood coming down river from the vast catchments above Lake Malawi. When in spate, the waters of the Shire are dark brown where they enter Elephant Marsh, but quite clear where they leave it, and apparently the swamp traps a great deal of sediment each year. Large areas of the swamps become dry between August and November, and the black soils then become rather saline, but water levels begin to rise again in December and usually peak in May. Some chemical description of the waters of the Shire River are given by Hastings (1973).

Flora & Fauna: The peripheral tree flora which includes *Hyphaene benguellensis, Adansonia digitata, Lonchocarpus capassa,* and several deciduous trees, is almost exclusively confined to the margins of the swamps and the few scattered islands of elevated land just in from the periphery. Hygrophilous grassland occurs in the outermost zone which is flooded only to very shallow depths in most years. Here the dominant species vary from site to site depending upon biotic and edaphic conditions. Where grazing is intense on the dry outer fringes, *Cynodon dactylon* forms an almost mono-specific sward, but in wetter areas it is joined by *Eleusine indica* and *Eragrostis aspera.* In less heavily grazed areas the dominant grass is *Sporobolus robustus,* forming clumps up to 1 m high, with *Echinochloa haploclada* and *Eriochloa borumensis* becoming progressively more important as soil wetness increases. Alkaline sites are characterised by the presence of *Sporobolus consimilis.*

Moving deeper into the swamps a sedge marsh is encountered in places where inundation is more prolonged, but exposure still occurs each year. The flora is as described in the national introduction and the width of the zone varies from 20-600 m. Free-floating species are abundant at high water in this zone including *Azolla nilotica, Eichhornia crassipes, Pistia stratiotes* and

Salvinia hastata. Beneath the surface *Ceratophyllum demersum* and *Utricularia* spp. are common. Most of these latter species are stranded and die back in the dry season, when sedge clumps are invaded by annuals.

In the broad permanent swamplands which succeed the marshy zone, towards the interior, water depths reach seasonal maxima of about 2 in. Here tall clumps of *Cyperus papyrus* are dominant, often whitened by the guano of roosting birds, and reaching 3-4 m in height. In deep water they are surrounded by more open stands of *Typha domingensis* with many floating-stemmed, floating-leaved and free-floating species about the stem bases. In less deep, but still permanent water, vast, dense, monospecific stands of *Phragmites mauritianus* occur, often isolating the papyrus clumps as islands.

The central and most deeply inundated areas of the swamps comprise expanses of open water, which are at times covered by enormous carpets of the free-floating species mentioned in the introduction. Beneath clear water, great beds of submerged macrophytes occur, including *Ceratophyllum demersum* and *Ottelia exserta, all* with a prolific algal epiphyton. At the edges of the emergent vegetation of the swamp zone, floating sudds are formed. These eventually become detached and drift away, frequently aggregating on open water, and often causing blockages which lead to the development of new channels.

The 'marshes' are infested by mosquitos, which cloud the air at night, and malaria ravages the local human population. Because of the nature and size of the swamp, effective mosquito control measures are virtually impossible. The fish fauna is typical of the lower Zambezi and distinct from that of Lake Malawi as explained previously. With the onset of the rains, fish move from the river channels into the freshly flooded areas to breed, but the diversity of fishes is always greater in river channels than it is in swamps. 61 species have been recorded in the lower Shire River so far. *Protopterus annectens,* which has been recorded throughout the lower Zambezi system is quite common on the margins of the marshes, aestivating during the dry season. The freshwater shark, *Carcharhinus leucas* also occurs here. Frogs, including a foam nesting species, abound in the swamps, and together with crickets and cicadas produce a cacophony of sound at night. *Crocodylus niloticus* is abundant, growing to 6 m in length and attaining weights of up to 2000 kg, but it is hunted commercially and stocks are slowly being depleted. High waters drown their breeding sites, and successive wet years are believed to reduce their numbers, but no counts have been made. From low flying aircraft they are frequently to be seen in circular ponds in the reed beds which they appear to have cleared for themselves. Birdlife in the marshes is prolific and includes many piscivorous species. *Haliaeetus vocifer* hunts the waterways by day while *Scotopelia peli* hunts them by night, both roosting in the peripheral trees.

Many of the species mentioned in the national introduction are present including cormorants, herons, egrets, storks and ibises, feeding on fish, frogs, snails and mussels. Piscivorous and insectivorous kingfishers are present, also lily-trotters, while the reed beds are seasonally full of flycatchers and weavers. *Merops nubicus* nests in holes in the banks of the Shire River above Elephant Marsh in tens, if not hundreds, of thousands. With the advent of the dry season and the appearance of islands in the swamp, migrant birds appear, among them ruffs, green shanks and sand pipers, all feeding along the drying margins. Apart from hippopotamuses, large mammals are now uncommon in the marshes, although when Livingstone first explored the area in 1859 they were abundant. Elephants are now absent from the area despite the fact that Elephant Marsh was named for the presence in it of large herds; one seen (and partly slaughtered) by Livingstone's party numbering over 800 beasts.

Human Impact & Utilisation: The Shire Swamps support an important fishery, producing annual catches of 3000-15 000 tonnes, suggesting that effort is as intensive as it reasonably can be. There were 1693 canoes working on the two marshes in 1985, operated by 2809 fishermen (Tweddle pers. comm.). These are mostly of the dugout type, but planked canoes equipped with outboard engines are becoming more popular; they were first introduced in the early 1970s, with government assistance, because suitable trees for dugout canoes were becoming scarce. However, planked canoes are unable to slip through the reeds like dugout canoes and are less useful in many areas.

The bulk of the annual catch is made with gill-nets, but long lines, scoop traps, seines, fence traps and spears are also used. Some areas yield much higher catches than others. The catch per canoe per year operating in the eastern part of Ndinde Marsh is for example, on average, twice as great as that taken per canoe per year in the northeastern part of Elephant Marsh. This is probably due to the behaviour patterns of the fish in relation to the vegetation and physiography of the marshes. Catches show two peaks each year, corresponding to the periods when fish are moving out over the floodplain to spawn at the beginning of the rainy season, and when they are forced to return to the river channels by falling water levels during the dry season. The second peak is the greater, reflecting the fact that the fish are concentrated in smaller and more accessible volumes of water in the dry season.

Of the 61 species of fish described from the lower Shire River, only five, *Clarias gariepinus, C. ngamensis, Eutropius depressirostris, Marusenius inacrolepidotus* and *Oreochromis mossambicus* are important to the commercial fishery. Of these, the first three, two catfish and a cichlid, comprise over 90% of the catch. Species of secondary importance include

Astatotilapia calliptera, Hydrocynus vittatus, Labeo altivelis and *L. congoro.* About 30% of the annual catch is consumed locally, while the remaining 70% is preserved for transport by smoking in kilns, or by sun drying. Access to Elephant Marsh is excellent, there being good peripheral roads and a railway. The north end of Ndinde Marsh can now also be reached by an all weather road, and traders come to the marshes to buy fish for markets in the towns. Some account of the fish fauna of the Shire Swamps is given by Hastings (1973), while information concerning the Shire fisheries is contained in Willoughby & Tweddle (1978), Willoughby & Walker (1978) and Tweddle *et al.* (1978).

Operation of the barrage at Liwonde affects the fishery in that if closure is too rapid the marsh drains quickly, with the result that anoxic and sulphurous water is flushed out so fast that there are large fish kills, and also many fish are stranded. By contrast, a carefully controlled closure, over a period of several weeks, leads to high catches as fish are encouraged to move off the floodplain slowly. A government commission now regulates closures to ensure that they have minimal environmental effect.

Cattle Grazing: The fringe lands are sometimes fired in the dry season and cattle, which are grazed on the surrounding lands, enter the marsh behind the falling waters. They graze and trample the vegetation, often paddling into shallow water in large numbers. Their dung replaces that which in the past was contributed to the marsh by wild animals. Parasitic diseases are common in the cattle, and many animals are in poor condition when they leave the marsh at the end of the season, despite the luxuriance of the grazing.

Agriculture: Sugar and cotton are grown under irrigation in the marginal lands, and plans have been mooted for extensive drainage and flood control schemes in Elephant Marsh. However, at present the two marshes provide a livelihood for very many people, and it seems that their destruction by large scale commercial projects would be unlikely to do anything but reduce the number of people the area could support. Pesticide residues from local agriculture had not, in 1985, reached significant levels in the lower Shire fish fauna (Tweddle, pers. comm.).

Conservation Status: Unprotected.

10. Lake Chilwa
Country: Malawi
Coordinates: 15°09 '-1 5°31 ' S/35°33-35°50'E
Area: 185 000 ha (including peripheral swamp

lands)
Altitude: 622 m asl
Nearest Towns: Liwonde (45 km NW); Blantyre (85 km SW)

General: Lake Chilwa is a large shallow endorheic lake situated in a depression in southeastern Malawi. It is bordered by wide areas of *Typha* swamp and sedge marsh, which in most places are backed by a grassy floodplain. The lake supports an important fishery, having provided, in some years, one third of the country's fish protein. The open water of the lake is very turbid and saline, supporting only a few specialised plant and animal species. In the swamps and marshes the water is less turbid, and environmental changes are less extreme, so that there the biota is more diverse. The soil of the lake bed changes from sand in the north to heavy clay in the south. A thick layer of fine silt overlies the whole area of the lake, which is easily stirred up by wave action, which occurs when strong winds blow across the lake.

The Chilwa basin is approximately rectangular, covering an area of about 7500 km2, being 100 km across at its widest point and 160 km long in a north-south direction. It is bounded on the west by the Shire Highlands which rise to 1200 m asl, to the south by a flattish marshy area interrupted by the Mulanje Massif (2998 m asl), and to the east by a lower range of hills (900 m asl) in Mozambique. A sand-bar only 25 m higher than the floodplain separates Lake Chilwa from Lake Chiuta in the north. Although Lake Chilwa is much smaller now than it has been in the past, five distinct lake terraces indicate that there have been long periods of stability. There are several islands on the lake, two of which are inhabited. Nchisi Island, located near Kachulu on the western shore, is 4 km across and rises 430 m above the lake surface.

Today Lake Chilwa is roughly oval in shape, about 40 km from north to south and 30 km from west to east, with an open water surface close to 96 250 ha. In 1972, an 'average' year, the Chilwa system comprised 67 800 ha of open water, 57 800 ha of swamp and 59 400 ha of lacustrine floodplain. The maximum recorded water depth was 2.6 m in the SW corner. The level of the lake surface fluctuates by 0.8-1.0 m each year, but larger fluctuations of 2-3 m occur over periods of 6 to 12 years, and as mentioned, the lake may dry up completely.

There is a strong seasonal climatic pattern: May-September is cool with a little rain over high ground, September-November is hot and dry, and November-May hot and wet. Insolation is highest in September-October when sunshine averages 9-10 hours/day, and lowest in January-February when there is 5.5-7 hr sunshine/day. The mean annual temperature is 27°C, with mean monthly maxima of 32-34°C in the hottest months, October-December, and 24-25°C during the coolest months, May-August. Rainfall is unreliable and varies greatly from year to year.

Hydrology & Water Quality: The water level of the lake changes considerably over the course of a year, and the mean level varies from year to year. Occasionally the lake dries out completely (twice this century), the last major recession having been in 1968. Seventy percent of the total inflow comes from five perennial streams, the Domasi, Likangala, Thondwe, Namadzi and Phalombe Rivers, which rise either in the Shire

Highlands or the Zomba Mountains further north. Mean annual precipitation over the lake is 800-900 mm depending upon station, but there are great annual variations, Precipitation reaches 1600 mm in the Shire Highlands and 2000 mm in the Mulanje Mountains. Mean annual evaporation from class A pans during the decade 1961-1970 was 1763 mm.

The lake and swamp show horizontal, vertical and seasonal variations in water quality. Conductivity varies from about 12001Amhos/cm in the open waters and middle swamps, to 100 prnhos/cm at the landward edge of the swamp at times of moderate water level. Transparency is greatest at the edges where it may reach 90%, whereas by contrast the central lake is turbid and the transparency of open waters does not usually exceed 56%. In open water and the centres of the swamps, pH is frequently of the order of 8.7, but it is lower, c. 7.6, at the edges of the swamp. The lake has been extensively monitered for ionic composition, and the following figures, expressed in mg/1, are for the months of July and December respectively, averaged over a 10 year period: Na 350/780; K 10.5/23.1; Ca 13.4/13.2; Mg 6.3/8.6; Cl 277/515 and phosphate 1.2/2.0.

The conductivity of the lake water tends to remain fairly constant throughout the year, whereas in the swamp it shows an inverse relationship with the level of the water. However, during December-February, the fall in conductivity is somewhat greater than might be expected, and Howard Williams (in Kalk *et al.,* 1979) has suggested that fresh water from the rivers pushes all the water from the swamps into the lake, thereby causing a considerable water exchange. As the swamp and floodplain dry, cattle move in and graze the vegetation. When flooding occurs again many nutrients, including nitrogen, are released from the dry vegetation and animal dung.

Flora & Fauna: The very turbid waters of the lake keep it free from submerged vegetation. Occasional patches of the sedge *Scirpus littoralis* and the grass *Paspalidium geminatum* are found in the open water, and appear to be the only two species able to live in the deep water and to tolerate heavy wind and wave action. When the lake dried out in 1966-68 only three species survived on the hot mud, *Aeschynomene pfundii, Cyperus laevigatus* and *Diplachne fusca.* The mature *Aeschynomene* plant grows in water and can tolerate a wide range of salinities, but the

seeds require a dry period for germination and the seedlings cannot grow under water. As a consequence this species had disappeared by 1973, by which time the lake had been full for several years. Following the dry spell, small isolated areas temporarily supported a richer flora which included *Aeschynomene nilotica, A. pfundii, Diplachne fusca, Echinochloa pyramidalis, Ipomoea aquatica, Ludwigia stolonifera, Paspalidium geminatum* and *Vossia cupidata,* together with *Nymphaea* spp. and the submerged macrophytes *Ottelia* and *Nitella* spp.

Most of the fringing swamps are dominated by pure stands of *Typha domingensis.* At the interface between lake and swamp a few free-floating species are found, e.g. *Pistia stratiotes* and various Lemnaceae, while *Ceratophyllum demersum* and *Utricularia* spp. are submerged species. In the wet season several species grow, flower and die on the expanding margins, within a few months, e.g. *Cyperus esculentus* and *Hibiscus cannabinus.* These are replaced by *Panicum repens, Nymphaea caerulea* and *Utricularia* spp. which then decline rapidly as water levels fall.

To the north of the lake a zone of alkaline soil is usually dry, but is periodically wetted by a rise in water level caused by southeasterly winds blowing over the lake. This area is characterised by *Cyperus laevigatus, Scirpus maritimus,* the grasses *Diplachne fusca* and *Panicum repens,* and scattered clumps of *Typha domingensis.* Alkaline marsh is also found to the south of the lake where the heavy clay soils have a pH greater than 7.5. Here mixed swards of *Vossia cuspidata* and *Cyperus longus* occur, interspersed with *Aeschynomene pfundii.* Neutral to acid marsh is found on the west side of the lake where the only stands of *Cyperus papyrus* are found at the mouths of the Likangala and Domasi Rivers. Here the soils have a pH of 5.0-7.0. The papyrus associations are surrounded by a zone of typical floodplain grasses. *Cyperus procerus* and the floating grass *Leersia hexandra* dominate the area between the two rivers.

Floodplains surround almost the entire lake and are inundated for 3-4 months each year, reaching a width of 35 km in the north. Grasses present here include *Acrocerus macrum, Cynodon dactylon, Echinochloa pyramidalis, Eragrostis gangetica, Hyparrhenia rufa* and *Sporobolus pyramidalis.*
The algal flora of the open waters changes with water quality. In 1977 there was a rich flora comprising species of *Cyclotella, Euglena, Nitzchia, Oscillatoria, Peridinium, Phacus, Scenedesmus* and *Tracheolomonas.*

Little benthic animal life is found under the open waters of the lake since the mud is soft and there are few aquatic macrophytes to provide suitable habitats in the turbid waters. Most invertebrates found in the swamps and marshes are associated with aquatic macrophytes. The floodplain grasslands provide one of the eight African 'outbreak areas' for swarming of the red locust *Nomadacris*

septemfasciata, but the last plague originating here occurred from 1930-45. The grasslands of the floodplain are heavily grazed by domestic cattle where dung beetles (Scarabaeidae) are important for burying dung and helping to recycle organic nutrients. The most successful and agressive species include *Euoniticellusintermedius, Liatongusmilioris, Onthophagusdepressur, O. gazella* and *Sisyphus* sp.

The open water of the lake is dominated by three omnivorous species of fish; *Barbus paludinosus, Clarias gariepinus* and *Oreochromis shiranus.* During recessions of the lake these fish migrate into the swamps where they take refuge in lagoons and streams. *Clarias gariepinus* is adapted to withstand desiccation and to tolerate saline water. It is able to traverse dry mud using its spiny fins since it has accessory breathing organs. The swamps harbour other fish, and those commonly caught for human consumption include *Alestes imbiri, Barbus trimaculatus, Haplochromis callipterus, Hemigramnopetersius barnardi, Labeo cylindricus, Marcusensius macrolepidotus, Petrocephalus catastoma, Pseudocrenilabrus philander* and *Tilapia rendalli.*

Among amphibians, *Xenopus muelleri* is found in larger pools on the floodplain, *Phrynobatrachus acridoides* lives in shallow, almost fresh water, but survives the dry season by moving to perennial streams. *Hyperolius parallelus* is found along the swamp edges, spending much of its time resting on stems of *Typha. Chiromantis xeramphelina* is also found on the swamp fringes, while the most highly specialised amphibian is Power's rainfrog, *Breviceps poweri,* which lives permanently on land.

Some nineteen species of reptiles are listed for the area, including some of special interest. *Crocodylus niloticus* is now rare in Lake Chilwa and in times of drought will bury itself in mud, migrate up rivers or traverse the sand-bar to Lake Chiuta. Many snakes are found in the wetlands including *Atheris superciliaris, Bitis arietans* and *Python sebae.* The soft shelled turtle *Cyclodernza frenatum* is also present.

Lake Chilwa has over 150 species of resident birds and up to 37 species of palearctic visitors. The open water of the lake attracts piscivores such as *Larus cirrocephalus, Pelecanus rufescens* and *Phalacrocorax africanus.* Ducks and geese frequent the lagoons and river mouths, and the swamps harbour a variety of other species including *Actophilornis africanus, Anas* spp., *Casmerodius albus, Ciconia* spp., *Egretta ardesiaca, Euplectes axillaris, Gallinula chloropus* and *Philomachus pugnax.* Birds of the open shores include *Phoeniconaias minor, Phoenicopterus ruber* and *Tringa nebularia. Circus ranivorus* and *Haliaeetus vocifer* are resident birds of prey.

Until the end of the last century the Lake Chilwa area supported a wide

variety of game including kudu, bushbuck, rhinoceros, elephant, eland, impala, duiker, klipspringer, gnu, zebra, oribi, buffalo, hippopotamus, warthog, bushpig, leopard, lion and hyaena, but many of these are now absent from the area. Mammals still found there in relative abundance include *Aonyx capensis, Atilax paludinosus, Cercopithicus aethiops, Crocuta crocuta, Hippopotamus ainphibius, Mastomys natalensis, Papio cynocephalus, Redunca arundinuin, Tatera leucogaster* and *Viverra civetta*. In addition large numbers of domestic cattle graze the floodplains.

Human Impact & Utilisation: Lake Chilwa was at a crossroads of Central Africa until the turn of the century. Caravans of people, including slave traders, passed north-south and east-west through the area. The lake provided food, supplies and a place of rest for the travellers, some of whom remained and diversified the population. Others migrated to the area to hunt and fish. In the past the resident people have accommodated to the continually changing situation, migrating away from the lake during times of drought and returning to it to fish when the lake refilled. However, the places where they were once able to subsist on berries, roots and meat from wild animals are now extensively cultivated. The former flora and fauna has been destroyed and are no longer available in times of severe drought. It has been suggested that in the past the effects of drought have been far more devastating than overfishing and that commercial fish production could be increased markedly without causing a deleterious effect on the fish population. To this end a successful experimental trawling programme was carried out in 1970-71 in the deeper waters of the southwestern part of the lake, which previously had not been fished. In 1976 an estimated 19 746 tonnes were harvested. The catch for that year represents 159 kg/ha/yr for Lake Chilwa, and was close to one third of the total national fish landing for Malawi in 1976, indicating the importance of Lake Chilwa to the nation's food supply. However, the catch varies greatly from year to year, being high in wet years and low in dry years. In 1968 it fell to only 97 tonnes.

Today fishing forms a major part of the local economy supplemented by subsistence farming. The floodplain is also important for rice production and stock keeping. Major problems facing the area now include rapid accumulation of silt as a consequence of increased agriculture on the floodplains and in the catchment. Since the lake is endorheic the silt is not carried away, causing the lake to become more shallow and turbid, leading to greater oxygen deprivation. Another problem, also associated with agricultural practices in the catchment, is the build-up of insecticides and herbicides, again exacerbated by the fact that the lake has no outflow.

Conservation Status: Unprotected.

11. Lake Chiuta
Country: Malawi

General: Lake Chiuta is situated (14°42'-14°53'S/35°47'-35°55'E) on the border between Malawi and Mozambique. It is a permanent lake having an area of 2500-13 000 ha according to season and rainfall, and is surrounded by extensive marshy areas, especially to the south. A sand-bar 15-25 m above present lake levels separates the marshes from those at the north end of Lake Chilwa. Lake Chiuta is intermittently connected to Lake Amaramba to the north in Mozambique, which is the perennial headwater of the Lugenda River, a major tributary of the Ruvuma River. The lake is shallow, having a maximum depth of 4 m, with mean conductivities of 120 limhos/cm in the open water and 220 pmhos/cm in the swamp.

Flora & Fauna: The phytoplankton comprises species of Chlorophyceae, Conjugatophyceae, Cyanophyta and Chrysophyta. In the open lake the only emergent macrophytes are found around Chiuta Island, but the substratum is covered by a dense mat of *Utricularia* spp. On the western shore a zone of *Typha domingensis* reaches 10-30 m in width, although the stands are less dense than those on neighbouring Lake Chilwa. *Nymphaea* spp. are found floating on the open water in this area. To landward of the *Typha* zone, a belt of emergent vegetation, 20-40 m wide, comprises *Cyperus alopecuroides* and *Vossia cuspidata,* with the occasional occurrence of *Aeschynornene pfundii* and *Cyperus papyrus. Ceratophyllum demersum, Nymphaea* spp. and *Ottelia ulvifolia* are common in canoe channels. The southern area of the lake supports a diverse community of emergent vegetation.

Common zooplankters include species of Copepoda, Cladocera and Rotifera. So far 37 species of fish have been recorded in the lake and affluent streams, of which 33 have been recorded in the lake proper.

Human Impact & Utilisation: Fishing is near optimal level. According to a 1985 survey there are 240 canoes and 10 boats, operated by 203 fishermen with 102 assistants. The principal species caught in the open lake is *Oreochronzis shiranus,* while *Clarias gariepinus* is important in the southern marshes. Smaller species commonly caught in traps and small meshed gill-nets include *Alestes imberi, Astatotilapia calliptera, Glossogobius giuris, Marcusenius livingstonei, Petrocephalus catostoma* and *Tilapia rendalli.* Lake Chiuta produces an average of 1400 tonnes of fish per year. Pollution is negligible. Bilharzia is present (Tweddle, pers. comm.).