THE ECOLOGY OF LAKE NAIVASHA, KENYA: INTRODUCTION AND HISTORICAL REVIEW

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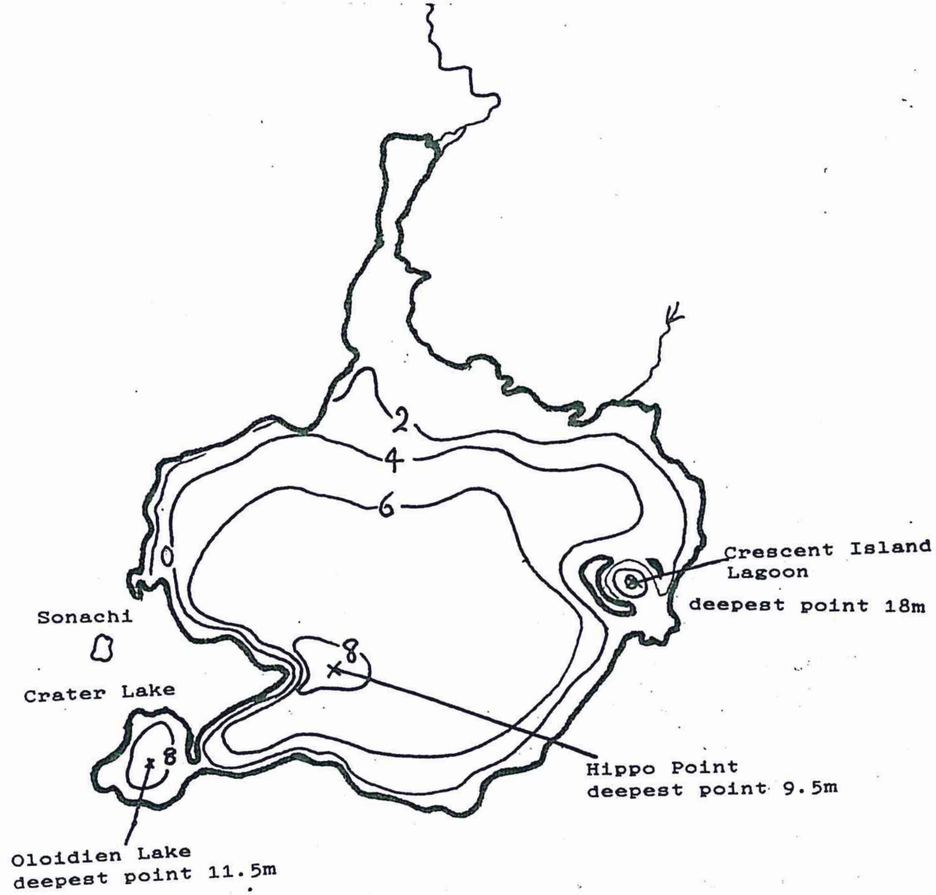
Introduction

Lake Naivasha is a closed freshwater lake basin of approximately 150 km^2 area, at an altitude of 1890 m above sea level, the highest and most fresh of the eastern Rift Valley lakes. It lies about 100km to the north of the capital, Nairobi.

It has always been of economic value to the human inhabitants of its hinterland. Cattle watering by Maasai has given way this century to settled agriculture which is heavily dependent upon lake water for irrigation. Naivasha town is an agricultural centre both for the lake shore farms and the ranches and smallholdings of the adjacent Kinangop plateau. A commercial fishery has been built up over the past 30 years on introduced species with the product exported to Nairobi and Nakuru. The lake is also a centre for tourism and recreation which has been growing ever since the first sport fishing began in the late 1920s. Tourism is now sustained by the lake's proximity to Nairobi on a good road; by its fishing; sailing and by the diversity of its flora and fauna. Most recently, the area has become industrially significant as a consequence of the development of Olkaria, just to the south of the lake, as a site for geothermal energy generation, producing about 15% of Kenya's total.

The lake receives drainage water from one large perennial stream draining the Nyandarua mountains, the river Malewa (drainage area 1730 km^2) and two ephemeral streams, the Gilgil (420 km^2) and the Karati. Lying in an area of past volcanic activity, there are four lakes, three of which are at least partially connected. The main lake is fairly shallow, with the deepest area at its south-western end at about 8 m at 1983 water level (Fig 1). Within the lake, at its eastern side, is a submerged crater whose highest rim section forms Crescent Island and whose basin forms the deepest part of the lake, 18m at the 1983 water level. At low water levels this is separated from the main lake and becomes chemically distinct. A small more alkaline lake, Oloidien (5.5 km^2 in area) is adjacent to Naivasha at its

FIGURE 1 Depth map of Naivasha based upon the 1983 level of 1889 m a.s.l. from Ase (1986) but with deepest points from 1982 and 1984 grab surveys of Clark et al (1987).



southern end, separated by papyrus swamp but is connected to it at times of high water levels. Within 3 km of the western shore lies an isolated, highly alkaline, crater lake - Sonachi - with an area about 0.2 km^2.

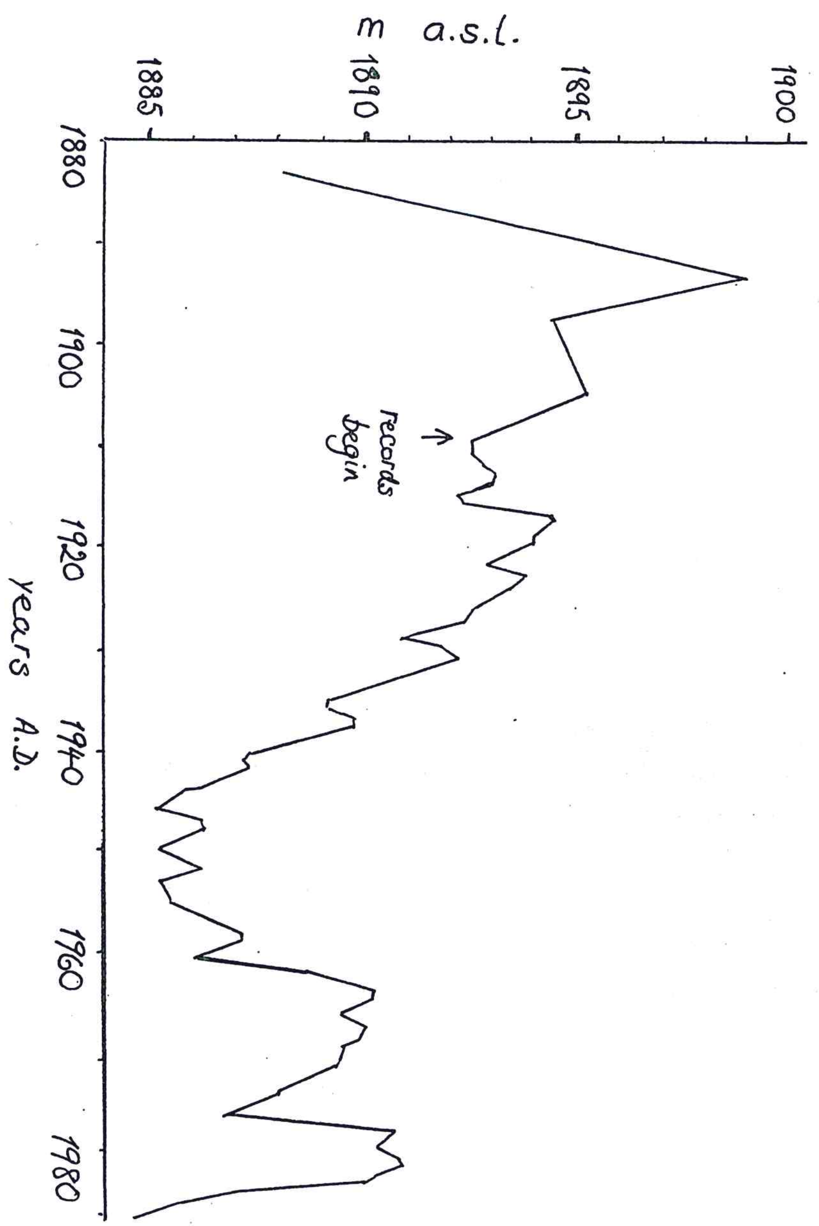
History of the Lake

The lake has only a short written history, though known to Maasai and other original inhabitants of the Rift Valley for centuries. In 1885, Thompson described it as "a papyrus-fringed lake", ..."there are no fish though Hippopotami are numerous. One remarkable characteristic is that it is the habit of enormous numbers of wild duck. These literally cover considerable areas at certain seasons of the year" (Thompson 1885). Its earliest record is that, according to Maasai oral history, there was a period immediately before the arrival of the first Europeans when the lake was completely dry (Sikes 1936, Edmondson 1977).

Evidence concerning climates and lake levels prior to last century has come from cave excavations to the south of lake Elementaita, levelling of ancient shorelines (Leakey 1931, Nilsson 1939, Washbourne 1967) and most recently, examination of cores from the deepest part of the lake (Richardson & Richardson 1972). There is agreement from

these studies that the former climate of the Rift was far wetter than the present-day and that a much larger lake existed around 10,000 and 12,000 B.P. (Before Present), following a period of maximum aridity between 15,000 and 13,000 B.P. (Street & Grove (1972)). Nilsson (1939) gave the level as about 40 m higher than the present lake, whilst Bishop (1971) and Richardson & Richardson (1972) suggested it was more than 100 m higher than present, overflowing Njorowa gorge at the south of Naivasha and cutting the lip to its present height. These high lake levels were maintained for several thousand years, to about 5,700 B.P., indicated by a stable planktonic diatom assemblage in the basal 3 m of the lake core (Richardson & Richardson 1972). For the next 1,500 years the lake level fell to approximately present-day levels, then dried out for a short period of perhaps not more than 100 years at around 3000 B.P. For the last 3000 years, variations in diatoms from the core indicate that the lake has fluctuated considerably with levels generally below those of the present day. However, at the end of last century the writings of the European travellers indicate that the lake level must have been rising between the years 1880 to 1895 to a maximum height of 1899 m a.s.l. (above sea level) (Sikes 1936, Ase _et al_ 1986), which is some 10 m greater than any level since that time. Levels then declined in a drought which lasted for about 4 years at the turn of the century so that when continuous recording commenced in 1908 the level was 1894 m a.s.l (Ase <u>et al</u>. 1986). Since 1908 continuous records have been maintained at several places and these are combined in Fig 2 (taken from Ase (1982) and updated with data from the Ministry of Hydrology). This shows a general decline to a low point in the decade 1945 - 1955 of around 1885 m a.s.l., which would have given the lake a maximum depth of 15 m and an area of about 100 km^2. There was then a period of rapid increase in 1961-3 to just over 1890 m, a level retained for about 10 years and followed by a decline of 2.5 m in the early 1970s. An increase occurred again over the last four years of the decade and by late 1982 the level had exceeded 1890 m, where it remained for about a year. Since early 1984 the level has been falling steadily and in 1986 was about 5 m below its 1983 peak, similar to that reached in the 1950s.

The lake level fluctuations do not show any general relationship with local rainfall, except that periods of exceptionally high rainfall are followed by lake level rises (eg 1922, 1930, 1961-3), and annual evaporation always exceeds annual rainfall (Ase <u>et al</u> 1986). In a statistical analysis however, Vincent <u>et al</u> 1979) suggested that the lake level is an indicator of the long-term pattern of high-level climate, particularly the penetration of equatorial westerlies and their influence on land above 2500 m a.s.l. Evidence for this hypothesis comes from the correlation of monthly lake level change with high altitude



<u>GURE</u> 2 Annual fluctuations in the surface water level of ke Naivasha (compiled from Ase (1982) and most recent records the Ministry of Hydrology).

meteorological stations such as Equator at 2700 m, and correlation of lake level with the altitude of the snout of the Lewis Glacier on Mount Kenya, which is SW facing. Long term lake level fluctuations showed close similarities with Lake Turkana, which also has no visible outlet and a mountainous catchment, compared to no similarities with the fluctuations in Lake Victoria.

The freshness of the lake water, upon which its biological diversity depends is of interest, since there is no visible outlet yet a perennial inflow, at least in the Malewa river. Initially there was assumed to be some undiscovered subterranean outlet (Gregory 1922) together with very dilute inflows (Worthington 1932). This view was refined by Gaudet & Melack (1981) who showed that the lake was hydrologically a seepage lake, with input via groundwater seepage in the northern area and outflow in the southern section. They concluded that the lake remained fresh partly because of its dilute inflows and seepage losses but additionally because of biochemical and geochemical sedimentation removing certain solutes.

History of Limnological Studies on the Lake

The lake's biology was first investigated in 1929 by the

Percy Sladen Expedition to the Rift Valley Lakes. (Jenkin 1932, 1936) and again by the Cambridge Expedition to the East African Lakes in 1930-31 (Beadle 1932, Worthington 1932). Measurements on the lake by the two expeditions were not extensive over time because numerous lakes were covered, but all flora and fauna collected was identified and published in the next few years. Following these expeditions there is a gap of some thirty years when little limnology was reported. However, studies on other major Rift Valley lakes, particularly those exploited as fisheries, continued and in the 1960s Talling & Talling (1965) brought together earlier work with extensive investigations of their own on the chemical composition of African lake waters. These confirmed Naivasha as a low salinity alkaline lake dominated by Sodium and Bicarbonate ions. It was placed in their 'Class I' lakes all with electrical conductivity below 600 µS/cm . Studies of the lake's chemistry were extended in the late 1970s by Melack & Gaudet (1981) on the major ions.

In 1961 the first unintentional immigrant species to have a marked effect on the lake's ecology, the floating water fern <u>Salvinia molesta</u> Mitch. was reported (van Someren 1972). The ecology and distribution of all the aquatic plants was subsequently investigated by Gaudet (1976a, 1976b, 1977, 1980,) with particular reference to the papyrus swamps and the ecology of the drawdown zone. This led to studies of the nutrient relationships of the swamp communities (Gaudet 1979, 1980, Gaudet & Muthuri (1981)).

The plankton of the lake was little studied other than qualitatively by Lind (1965, 1967) and briefly by Millbrink (1977) until Melack (1979) made comparative measurements of the primary productivity of the Naivasha basins together with Winam Gulf (Lake Victoria) between 1973 & 74. A sucession of workers followed up until 1981 so that for seven years aspects of the phytoplankton biomass and productivity were more or less continuously studied (Kallquist 1978, 1979, Njuguna 1983, Kalff & Watson 1986). The work of Njuguna, in particular, related phytoplankton to nutrient supply. Concurrent with Njuguna's work the first study of the zooplankton since the 1930s expeditions was carried out, by Mavuti between 1978 and 1980 (Mavuti & Litterick 1981).

The ecology of the littoral and benthic macroinvertebrates has hardly been studied at all through this period. Some observations from 1971 and 1973 were reported by Millbrink (1977) but with minimal species identification. Work on the introduced crayfish (see below) was carried out through the 1970s (Lowery & Mendes 1977a, 1977b, 1977c) and is being extended by Oluoch (unpublished). Benthic invertebrates were considered by Siddiqui (1977) in his examination of fish diets and Watson et al (1970) in their examination of the diet of duck and coot, but neither study related stomach

contents to availability in the lake.

The lake was opened to commercial fishing in 1959 and this provided the initial stimulus to further investigations of the ecology of the fish and their food web. Major reports on the progress of the fishery were produced by Garrod & Elder (1960), Mann & Ssentongo (1969), Okorie (1972), Malvestuto (1974), and Siddiqui (1977, 1979). Additional research was carried out on hybridisation of tilapia (Elder & Garrod 1961, Elder et al. 1971); on the breeding biology of Tilapia by Hyder (1969, 1970) and aspects of the the parasitology of Tilapia by Malvestuto & Ogambo-Ogoma (1978).

Larger vertebrates other than fish have also been little studied with the exception of duck by Watson et al (1970), Watson & Parker (1970), Van Someren (1982), Fish Eagles by Brown (1971), and the general collection of species records (Williams 1970). The introduced coypu have been studied by Gosling (1976) and Gibson (1973) and a range of vertebrates examined for pesticide residues (Lincer et al (1981). This is surprising since the vertebrate species are the main basis of tourism. There are numerous naturalists' reports of a decline in the diversity of birds seen in the period following water-lily loss compared with the more stable period of the lagoons in the 1970s, but there are no precise measurements or clear explanations. There have certainly been dramatic changes in numbers of birds. For example there were thousands of duck and coot in the 1970s up to

1981 when 35,000 were censussed in the first 3 months of that year (Van Someren 1982). Two years later, at a higher water level and in the absence of any submerged, macrophytes (Harper 1984) ducks and coot could only be counted in a few tens over the whole lake (C. Taylor pers comm). Other recent changes have included an increase in the number of resident flamingos to several hundred in the Crescent island area, together with about a thousand terns for most of 1985-6 feeding on small amphibians and crayfish in the lake shallows (C. Taylor pers comm.).

Other vertebrates about which there is little current information are amphibia, coypu, otters and the other major aquatic mammal, hippopotamus. This latter species has a high but unknown density of perhaps several hundred individuals at the lake. Some of these are in conflict with agricultural activities.

The physical limnology of the lake was investigated to a certain extent in many of the above studies, particularly those on the plankton, so that scattered measurements of for example, temperature and Secchi disc transparency exist over the past two decades. However little detailed work has been done, except recently on the water balance, lake depth and bottom topography by Ase et al (1986).

No single study had attempted to treat the lake as an ecosystem and examine all its major components concurrently

until the short studies described in preliminary form by Harper (1984), although all work up to the late 1970s was synthesised in a report (Litterick et al (1979) prepared for the International Conference on African Limnology held in Nairobi (Symoens et al 1981).

Work which has most recently been carried out describes the ecology and distribution of the zoobenthos (Barnard & Clark 1986, Clark et al. 1987), the ecology of submerged aquatic macrophytes (Rich & Harper 1987), the phytoplankton (Brierley et al. 1987), the zooplankton (Harper 1987), the birds associated with Salvinia (Taylor 1987), the feeding ecology of fish fry (White 1982. Robotham 1987) and the ecology of catchment stream invertebrates (Biggs & Barnard 1987). Such an approach is now essential because of the complexity of the interactions in the lake which have arisen as a result of the high number of introduced species or 'accidental' arrivals. These began sixty years ago.

SPECIES INTRODUCTIONS TO THE LAKE

Prior to 1925 there had only been a single species of fish in the lake, an endemic zoo-planktivorous small-tooth carp (*Aplocheilichthyes antinorii* (Vinc.). It is assumed that this paucity of fish species, highly unusual in a tropical lake, was due to the earlier periods of drying-out. In 1925 and 1926 the mouth-brooding cichlid *Oreochromis spilurus niger* (Gunther) was introduced by the Kenya Game and Fisheries Department. This flourished in the littoral fringe of the lake (Trewavas 1983) and in 1927 the American Large-Mouthed Bass (*Micropterus salmoides* Lacepede) was introduced to feed on it and provide the basis of a sport fishery (Elder *et al* 1971). Both species were successful until the low water levels of the late 1940s - early 1950s when they appeared to have died out (Litterick *et al.* 1979). Bass were re-introduced on several occasions between 1951 and 1956; in 1956 together with a second cichlid, the herbivorous *Tilapia zillii* (Gervais). The batch of *T. zillii* unintentionally contained some individuals of *Oreochromis leucostictus* (Trewavas). These species have been the basis of a commercial fishery, which opened in 1959 and whose fortunes have fluctuated since that time (see below). To them were added the Louisiana Red Swamp Crayfish (*Procambarus clarkii* (Girard)); introduced in 1970 (Parker 1974) to broaden the range of the commercial fishery and exploited since 1975 (Lowery & Mendes 1977). The most recent introduction is the only natural one - a small riverine fish, *Barbus amphigramma* Blgr. which first migrated down to the lake from the Malewa during the high water levels of 1982 (Harper 1984) and has been present in large enough quantities since then for commercial exploitation.

Several other fish species have been introduced over the past 50 years without lasting success. Sporadic reports of the trout *Salmo gairneri* (L.) derive from introductions to the catchment streams for sport. Three cyprinodont species were introduced for mosquito control - *Gambusia* sp., *Poecilia* sp. and *Lebistes reticulata* Peters, of which only the latter was found in 1982 (Harper 1984). *Oreochromis niloticus* Linnaeus was introduced in 1965 and was assumed to have disappeared since 1969. Recently, however, trial fishing during 1986 recorded this species in Oloidien and unconfirmed reports from fishermen suggest its presence in the main lake (Muchiri, unpublished data). There are also unconfirmed reports of Nile Perch (*Lates niloticus* (L.)) illegally introduced in the 1970s turning up sporadically in fishermen's nets in the 1980s.

The first unintentional arrival at the lake, as noted, was *S. molesta* in 1961. It was known in ornamental ponds and was available from aquarists in Nairobi in the 1950s (Mitchell 1969). This was closely followed by the coypu (*Myocastor coypus* (Molina)) which had been imported to the Kinangop for fur-farming in 1950. Individuals escaped and arrived at Naivasha from 1965 onwards (R.Mennell pers comm); by the early 1970s there were large populations.

Salvinia initially was seen as more of a potential threat than a real problem because its effect on the new reservoir at Kariba was well-known (Boughey 1963). For the first few years spraying the plant with herbicide whenever it was discovered kept it under control, but it increased in area in the late 1960s, covering 2-3 km^2 (Mitchell 1969). By 1973 it had spread along the whole of the lake shoreline (Gaudet 1976). Biological control with the orthopteran Paulinia acuminata was tried, but with little more success than the herbicide treatment - without 100% control of the plant, its vegetative reproduction can quickly make up any losses (Sculthorpe 1967).

Biological methods of coypu control were also tried. Pythons were introduced, the descendents of which are still reported to exist in areas of the North Swamp of the lake. However, these were ineffective and a rapid coypu population increase occurred in the early 1970s (Gosling 1976). Individuals were widely observed feeding on water lilies (J.Haynes pers comm) and lily shoots made up a major part of their diet (Gibson 1973). Water lilies had disappeared from the eatern part of the lake by 1973-4 (R.Mennell pers. comm.), and from the rest of the lake by the end of the decade. Coypu are generally blamed for the disappearence of water lilies, although there is no conclusive proof of this and it is possible that both Salvinia and Procambarus were also involved in the lilies' disappearence.

Between 1976 and 1979 there was a rapid rise in water levels coupled with a spread of Salvinia. Wind-blown floating mats

of up to about 15 km^2 together with papyrus islands became a commonplace feature of the lake from 1979 - 1983 (Gaudet & Falconer 1983, Harper 1984). These must have inhibited the growth, or re-growth of water lilies.

Over the same period, between its first introduction to the eastern part of the lake in 1970, and 1976 Procambarus spread throughout the littoral regions. Its periods of successful reproduction followed periods of lake level rise (Lowery & Mendes 1977). It is omnivorous but many closely related species are known to have severe effects upon aquatic macrophyte communities (Mugnussen et al. 1975). It is likely that the high crayfish densities (up to 4 m^{-2} reported by Lowery & Mendes (1977)) also had an impact upon the water lilies.

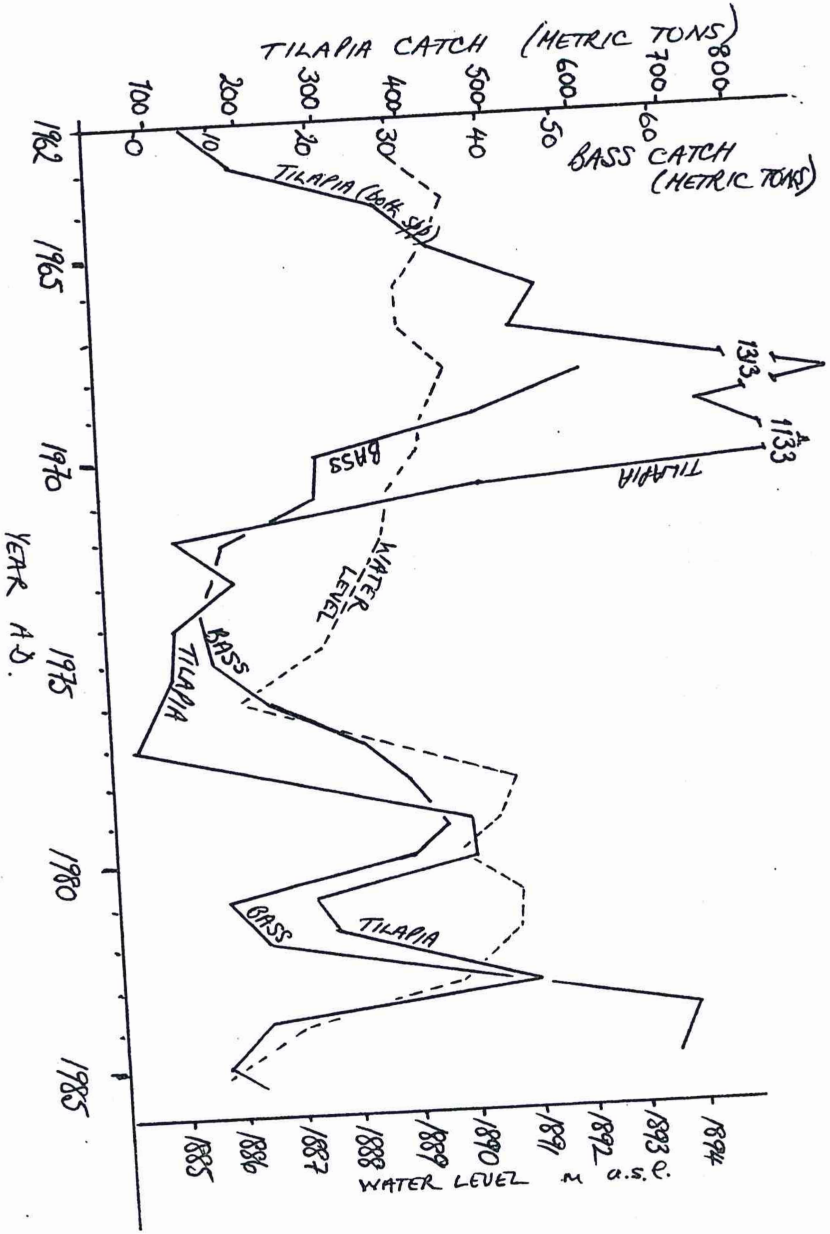
The possibility of introducing additional fish species to the lake in the future was mentioned by Malvestuto (1974) and by Siddiqui (1977), who showed in a study of the diets of the three major species that zooplankton were almost completely unexploited. Subsequent work (White 1982, Harper 1984, Robotham 1987) Muchiri unpublished) has shown that zooplankton are important food items in the littoral for O.leucostictus fry and B.amphigramma but the open water zooplankton do not appear to be exploited (White 1982), except at high water levels when local aggregations of fry around papyrus islands have access to open water zooplankton (Harper 1987). The only native fish species, A. antinorii was planktivorous, but has not been recorded since the 1960s and is believed extinct.

An East African limnetic planktivorous fish could potentially be introduced to the lake and it seems that, anticipating this possibility, a culture of <u>Daphnia pulex</u> Leydig was introduced to the eastern area of the lake in 1980. This species dominated the zooplankton in 1982 and early 1983 (White 1982, Harper 1984) but its numbers have fluctuated periodically since then (unpublished observations). However the density, biomass and production of the native zooplankton species is high (Mavuti & Litterick 1981) wo that introduction of a planktivorous fish could be sustained. Research into the effects of fish predation on zooplankton elsewhere (Brooks & Dodson 1965) at least offers the ability to predict the effects of a future fish introduction - a luxury which has not been available in the past. However, as pointed out on several occasions in the past, the unexpected effects of the several introductions to Naivasha indicate that caution has to be used in considering any further ones.

The Lake Fishery

A commercial gill-net fishery was opened in 1959, exploiting

<u>IGURE</u> 3 Annual commercial fish landings for Lake Naivasha, ith water level fluctuations.



O.s. niger and *T. zillii*. The latter was initially only present in a small proportion of the catch: the first few years of the fishery coincided with a period of rapidly rising water level which was probably not favourable for the feeding and nesting behaviour of *O. zillii*. *O. niger* was very soon replaced by a hybrid between *O.s. niger* and *O. leucostictus* (Elder *et al* 1971) which dominated the catch through the early 1960s. From 1964 to 1976 the water level remained high and was stable within a range of about 2 m, resulting in the formation of lagoons and littoral zones extensively colonised by macrophytes. Siddiqui (1979) found that lagoons were preferred habitat for the herbivorous, substrate-breeding *T. zillii* whilst the lagoons and littoral were preferred by *O. leucostictus* with the accumulations of detritus providing its major food source - chironomid larvae. Most hybrids and all *O.s. niger* had disappeared by 1971, and this was attributed by Siddiqui (1979) to the disappearence of their preferred habitat, weed-free breeding and nursery grounds. By 1975 the cichlid catch was about 74% *O. leucostictus*, 26% *T. zillii* (Siddiqui 1977). By 1985, following the high water levels and disappearence of lagoons in the early 1980s, the catch was less than 2% *T. zillii* and 98% *O. leucostictus* (Department of Fisheries unpublished data).

The gross tonnage of fish harvested from the lake has fluctuated considerably in the three decades of the fishery;

the yield of cichlids and bass is shown in Fig 3. Initially the nets used were 13 and 14 cm, reduced to 11 cm by 1961 and 10cm by 1970 with a period in the late 1960s when sizes down to 7.5 cm were used in order to sustain a frozen fillet factory (Siddiqui 1977). There was a rapid decline in catches in 1970-72 which Siddiqui (1977) attributed to overfishing. There was strict enforcement of the 10cm mesh by the Fisheries Department from 1973 onwards (Litterick *et al.* 1979), although Malvestuto (1974) showed that the 10cm mesh size caught *O. leucostictus* at about 20 cm length which was only 3cm or 6 months past maturity, giving them a very short time to breed prior to exploitation.

The fishery started to recover after 1975-6, with bass catches, albeit at a lower level, picking up first. This was probably a consequence of the crayfish introduction in 1970, since by 1975 crayfish were thriving and Siddiqui found them to make up 78% of bass diet (Siddiqui 1977). After 1977 cichlid catches began to recover, exploited initially at a lower intensity.

Malvestuto (1974) had also suggested that water level fluctuations affected the fishery as they have been shown to do elsewhere in Africa. There has been a clear correspondence between lake water level rises and fish catches 2-3 years later (Fig 4) for the last decade. This is believed to result from an increase in productivity in the lake caused by the release of nutrients from the newly-flooded littoral zone during periods of level rise, and a decline in productivity in a littoral zone of bare, formerly profundal mud during a period of water level decline.

Siddiqui (1977) also implicated the spread of *Salvinia* as a factor in the decline of fish catches. This may be true, as during the high water levels between 1978 and 1982, which resulted in the formation of large covered lagoons and mats of mobile *Salvinia* there was a rapid decline in catches in 1981-82 following only a small water level decline in 1980. However it is likely to have affected *T. zillii* more than *O. leucostictus* and cannot be considered further in the absence of clear relationships between *Salvinia* and fish.

In the last two years a new fishery has come into being, for *B. amphigramma* which is taken in the mouth of the Malewa as the fish move into the river to spawn at the beginning of the long rains. The catch of this species, taken in locally-made scoop nets was about 20% of the total commercial catch in 1985. (Fisheries Department unpublished statistics). It is difficult to predict the future of this fishery, but it seems unlikely to be secure since a large irrigation weir on the Malewa is virtually impassable to upstream migrants. The lake populations must therefore be replenished each year by new recruits from the river populations rather than their own stock.

Debate about the management of the fishery has centred around the fishing intensity of currently-exploited species and the pros and cons of potential new species. An alternative, complementary strategy, might be to consider those species which have thrived in the lake at any time in the past together with the probable reasons for this, and to actively stock them when conditions in the lake return. Thus *O. niger*, a riverine fish which prefers weed-free conditions feeding on the mud surface, probably did well in the 1920s - 40s because the lake level was declining. It disappeared in the 1950s as the lake level stabilised and the lagoons and littoral became colonised by a stable macrophyte zone. This species and its hybrid may also have been favoured by periods of rapid water level rise - before macrophytes form a stable zone - as occurred in the first few years of the commercial fishery. *T. zillii* has been more successful in the reverse conditions, those of stable water level with a dense macrophyte zone, as it was in the early 1970s in the main lake and as it is, at least as far as the macrophyte zone is concerned, in Oloidien. Trial fishings in Oloidien show that in 1986 it made up about 25% of the population compared to only 2% in the main lake (Fisheries Department unpublished data).

It could be predicted, if this explanation is correct, that *T.zillii* will increase in importance if the late 1980s conditions are a repeat those of the late 1940s, with a low but stable water level. On the other hand, if the water level starts to rise again in a similar fashion to the early 1960s, then conditions would favour O.s.niger and a future stocking of this species might be succesful.

Management of the Lake Ecosystem

Two bodies have a direct control over some aspects of the lake. The Department of Fisheries manages the fishery by issue of licences and enforcement of the mesh size regulations. The Ministry of Water Development issues licences for the abstraction of water for irrigation. Several other bodies have interests in the lake - the Town Council of Naivasha and the Lake Naivasha Riparian Owners Association are the main ones. The Department of Wildlife Conservation and Management has an increasing local interest because two areas ajacent to the lake - Longonot volcano and Njorowa Gorge (Hell's Gate) were declared National Parks in 1983.

Many people would like to see the Naivasha lakes managed under some kind of unified authority similar to a that of a National Park (eg Njuguna 1982) although with so many people and so much money in intensive agriculture around the shoreline this may prove difficult. It would be

advantageous, however, to draw up and operate some kind of management plan. The most immediate threat of further change comes from agricultural clearance of lake-edge papyrus in the current phase of lake drawdown. Lake levels were last as low in the decade 1945 - 55 but during this period the papyrus swamps which developed on the exposed mudflats were dense and extensive, such that in the northern part of the lake, between the river inflows, that they provided safe haven for those fighting the Colonial administration (R.Mennell pers comm). By 1986, almost the entire area of the Gilgil inflow was cleared of papyrus, and 12 km^2 of papyrus swamp was reduced to 2, provoking popular concern (Anon 1986). One of the major consequences of the lack of swamps and fringing papyrus will be the loss of 'buffering' capacity for silt and nutrients brought in by the river inflows (Viner 1975, Gaudet 1980) together with any protection from inflows of fertilisers or pesticides applied to the adjacent land (Njuguna 1985). The value of swamps and the need for their conservation is well appreciated by the scientific community (eg. Mavuti 1982, Howard-Williams & Thompson 1985) and the issue is slowly becoming politically important (Anon 1986). Despite the extensive knowledge about the Naivasha swamps in particular and African swamps in general (eg Howard-Williams & Gaudet 1985) the changes in the Naivasha papyrus must be a focus of future research.

An important factor hindering the development of effective ecosystem management is the lack of continuous limnological monitoring. When the intensity of research was at its height in the 1970s, with several scientists based at Nairobi University working concurrently, detailed accounts of the ecology of the phytoplankton, zooplankton, aquatic plants and water chemistry were produced. This work was not followed by any continuous longer-term monitoring, with the result that in the 1980s information on the submerged aquatic plants and zooplankton was at least partly out of date. The possibility that such work might be set up in the future is now improved by the establishment in 1983 of a Fisheries and Wildlife training College at Naivasha, and by the increased number of trained Biology graduates in the Government Departments. In the meantime, minimum baseline limnological data is provided by co-operative groups of scientists and volunteers from several countries working on the lake for short periods of intensive study. This supplements the steady stream of individual higher degree and specialised research projects in providing information upon which future management strategies can be based.

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