2nd World Fisheries Congress

Fluctuations in the Fisheries of Kenya's Rift Valley Lakes: Causes and Prospects for the Future

S. Mucai Muchiri

Department of Fisheries, Moi University, PO Box 3900, Eldoret, Kenya.

Summary

Lakes Turkana, Baringo and Naivasha are lakes in the eastern arm of the Great Rift Valley that provide important commercial fisheries, and to a small extent provide recreation. The fishery of Lake Turkana is based on 12 main species of fish out of a total of 48 species. Tilapias, *Lates* spp., *Citharinus*, *Distichodus*, *Labeo* and *Hydrocynus* are the most important. In Lake Baringo three species (*Oreochromis niloticus*, *Clarias gariepinus* and *Protopterus aethiopicus*) are the most important of the seven species present in the lake. Lake Naivasha hosts a total of five species of which *Oreochromis leucostictus*, *Tilapia zillii* and *Micropterus salmoides* are of commercial importance. The three fisheries support an estimated 10 000 fishers plus people engaged in fish industry related services. Yet these fisheries depict wide fluctuations in fish landings.

Habitat variability has been identified as one of the most important factors influencing the fisheries of the three lakes. Lake level fluctuations are shown to be closely followed by similar fluctuations in fish catches. The observed fluctuations in lake levels are as a result of climatic factors combined with human activities which include damming of rivers and abstraction of water for irrigation. Variability in submerged vegetation cover has also been important in the three lakes.

Other anthropogenic influences on the fishery of Lake Naivasha take the form of fishing pressure and species introductions while in Lake Baringo, catchment degradation leading to excessive silt loading in the lake has played a more important role.

The persistence of these fisheries in the face of besetting environmental and anthropogenic factors is attributable, for the greater part, to the resilience of the tilapias that constitute the most important catch in each of the three Rift Valley lakes. It is suggested that an integrated approach to catchment management is necessary for the achievement of maximum sustainable fisheries in the rift valley lakes.

Introduction

Fish populations in nature are continually subject to changes in size structure and distribution, being influenced by both intrinsic and extrinsic environmental variables. These natural variables may be physical or biotic. Human involvement in certain instances enhances the speed and scale of change or deviates the direction of change in fish populations. The magnitude of change in exploited fish populations is therefore dependent upon the combined effects of natural and human disturbances and the capacity of such populations to absorb these effects. Some of the disturbances arise from farther afield and become manifested through linking systems. For example, the ecology of lake or floodplain fish populations will invariably be influenced by activities occurring in the whole catchment as well as variations occurring within the ecosystems. Management of exploited fish populations may, therefore, ultimately depend on how accurately we can predict the responses of such populations to variations in their environments.

Analyses of the fisheries of three lakes (Turkana, Baringo and Naivasha) lying within Kenya's portion of the Great Rift Valley (Fig. 1) help to illustrate the foregoing. The fisheries of these three lakes support an estimated total of 10 000 fishers plus people engaged in fishing industry-related activities. These fisheries, however, exhibit wide fluctuations in landings (Fig. 2). The reasons for these fluctuations and factors that have allowed the persistence of the fisheries of Lakes Turkana, Baringo and Naivasha are the subject of this paper.

THE LAKES AND THEIR FISH COMMUNITIES

Lake Turkana

The recent status of Lake Turkana ecosystem has been described in greater detail by Hopson (1982) and Kolding (1989). Lake Turkana is a large (265 km long, 30 km wide and up to 115 m deep) endorheic lake lying at between 2°27'N and 4°40'N and at an altitude of 375 m a.s.l. (metres above sea level). Surface water temperature varies slightly at between 27.2 and 29.4°C while the lake bottom temperature ranges between 25.4 and 26.4°C (Kolding 1989). The lake is surrounded by land falling in class VI of Pratt *et al.* (1966), who described it as very arid and of very low ecological potential. Lake Turkana receives the largest proportion (80–90%) of its water from the perennial River Omo, which drains the highlands of south eastern Ethiopia and enters the lake through a marshy delta in the north. Other smaller rivers enter the lake seasonally. The Turkwell flows from the slopes of Mt. Elgon on the border of Kenya and Uganda in the west and is seasonal in its lower reaches. With the recent construction of a hydroelectric dam across its gorge, the river has practically ceased flowing into the lake, except during exceptionally heavy rains. The Kerio river collects its water from the Tugen and Marakwet Hills in the south of Lake Turkana.

The fish community of Lake Turkana is the richest of the Rift Valley lakes. It comprises 18 families of fish with a total of 48 species, 7 of which are endemic to the lake. The present fish community of Lake Turkana is typically nilotic and there is zoogeographical evidence that suggests past connections of the Omo-Turkana basin with the Nile system (Roger 1944; Butzer 1971). The cichlids, cyprinids and characids are the more dominant species having 7, 7, and 9 species, respectively; 12 of the 48 species feature frequently in the fishery of Lake Turkana. Tilapias, *Lates* spp. *Citharinus*, *Distichodus*, *Labeo* and *Hydrocynus* are the more important.

Lake Baringo

Lake Baringo is a shallow (average 3.5 m in depth) freshwater lake on the floor of the Rift Valley at an altitude of 975 m a.s.l. and about 150 km south of Lake Turkana (*cf.* Fig. 1). The lake has an average surface area of 130 km^2 but is subject to wide variations in size, which are dependent on rainfall on the highland areas of its catchment. Lake Baringo has no surface outlet but may have a subterranean outlet as suggested by Beadle (1932), which may explain the freshness of the lake water. The principal rivers that flow into Lake Baringo are the Perkerra, Molo and Endao, all of which flow from the highlands south of the lake. The other smaller rivers include Tangulbei, Mukutan and Ol Arabel, which drain the eastern scarp of the Baringo section of the Rift Valley and flow generally southward into Lake Baringo. The first three rivers have been perennial in the past, albeit with greatly varying volumes of water. These rivers flow through very dry land that is severely eroded by flood water during periods of high rainfall upon which huge torrents bring with them heavy loads of silt and debris.

Silt that enters the lake has very low organic content and therefore tends to remain in suspension aided by wind which is more prevalent in the afternoons. The suspended silt gives Lake Baringo a brown colour resulting in very low transparency. The average secchi depth readings for March 1996 was 3.5 cm. This is one of the lowest records of secchi depth transparency recorded in Lake Baringo. Kallqvist (1987) recorded secchi readings of 5–7 cm in 1976–77 and 20 cm in 1979. The 1979 figure had also been observed by Beadle (1932) in 1931. The present low transparency is as a result of the shallow sediments (average 2 m deep of lake water) being kept in suspension rather than from high productivity.

Plankton primary production is based mainly on the blue-green alga *Microcystis aeruginosa* which dominates the phytoplankton community at times forming blooms on the water surface. The macrophyte community of lake Baringo is sparse and confined mainly on the southern shoreline at river entry points. *Cyperus* spp. dominate the large emergent plant community, while *Potamogeton* spp. are the more common submerged macrophytes.

The fish fauna of Lake Baringo comprises six naturally occurring species and one introduced species. This is atypical of tropical lakes, which normally support many species of fish (Lowe-McConnell 1987). This may suggest a recent drying up of the lake and only being replenished by riverine species. Based on previous studies (Okorie 1974) and available preliminary data (unpublished), the trophic ecology of Lake Baringo fishes is comprised of short food chains arising from:

- **detritus** where *Clarias gariepinus* feeds both on detrital aggregates associated with the bottom and predates on the other detritivores, *Oreochromis niloticus* and *Labeo gregorii*. *Protopterus aethiopicus* is also a detritivore but there is no evidence of it falling prey to *Clarias*.
- **plankton** provides forage for *Oreochromis* and *Barbus* spp. *Barbus* is mainly a zooplankton feeder but is also a facultative insectivore.

Oreochromis niloticus, *C. gariepinus*, *P. aethiopicus* and *B. gregorii* form the basis of a commercial fishery at Lake Baringo.

Lake Naivasha

Like Baringo, Lake Naivasha is a freshwater lake, covering an area of approximately 150 km^2. The lake is the highest of the

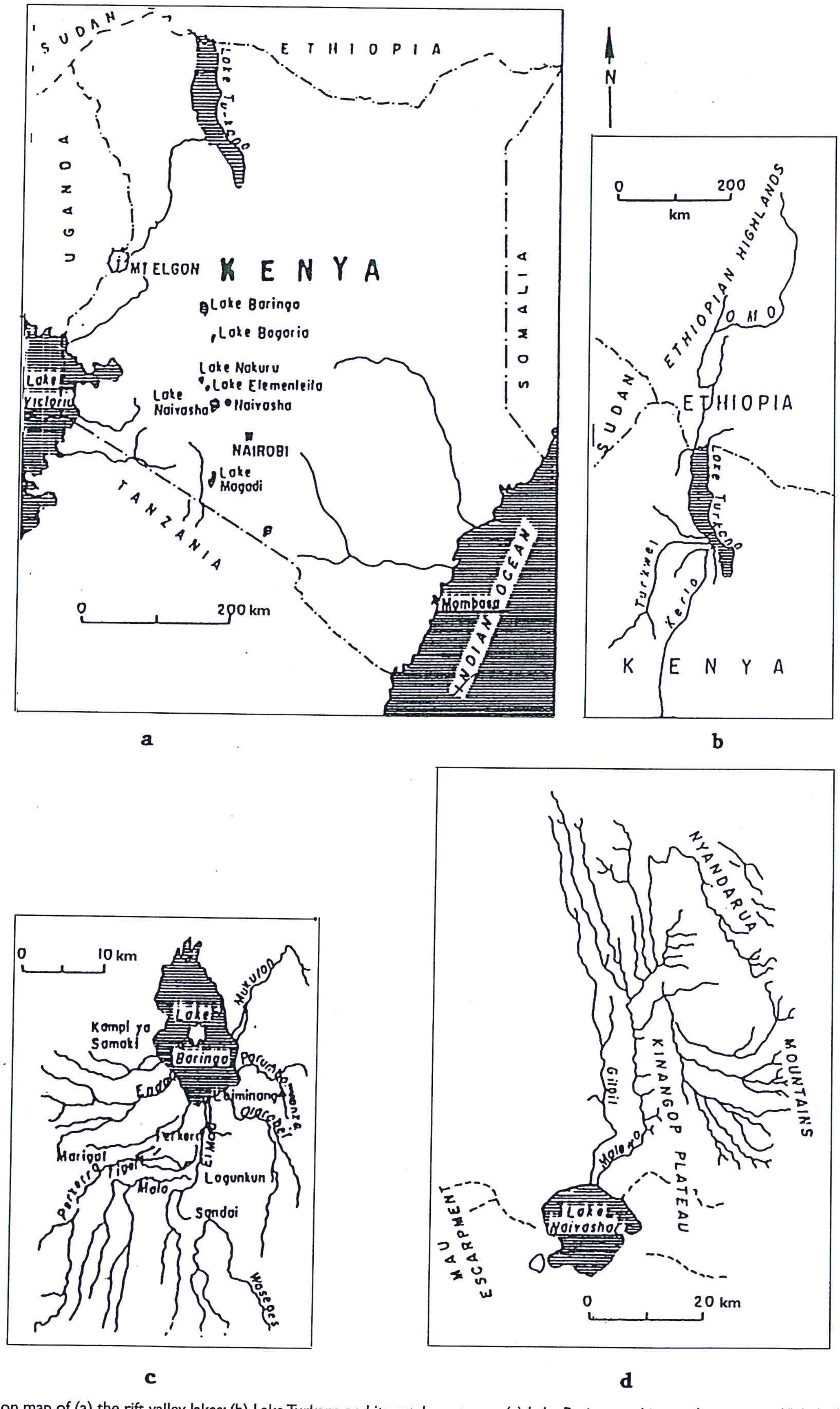

Fig. 1. Location map of (a) the rift valley lakes; (b) Lake Turkana and its catchment area; (c) Lake Baringo and its catchment area; (d) Lake Naivasha and its principal rivers.

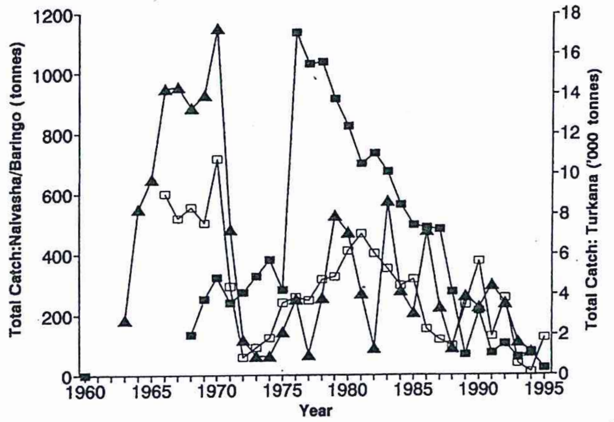

Fig. 2. Changes in total fish catches from the rift valley lakes (Data obtained from the Department of Fisheries, Nairobi).

Rift Valley lakes at an altitude of 1890 m a.s.l. It lies in a closed basin and receives 90% of its water from the perennial River Malewa (1533 km^2 drainage area) and the rest from one ephemeral stream (River Gilgil, drainage area = 151 km^2), direct rainfall and ground seepage. The lake is very shallow, being, for the most part, between 4 and 6 m in depth, and exhibits considerable fluctuations in water levels with a history of complete drying out in the last century. Water temperatures are generally in the range of 20–25°C. Vegetation cover has varied considerably in the last few years. Belts of *Cyperus papyrus* dominate the margins, but these are often reduced by harvesting and burning. Gaudet (1977) recorded 25 species of shallow-water macrophyte community, 10 submerged, 8 floating and 7 associated with floating vegetation. Between 1975 and 1983 submerged and floating-leaved macrophytes were absent from the lake. The reasons for this variation are discussed by Harper *et al.* (1990) and Harper (1992).

Lake Naivasha hosts a total of five species of fish which are a remnant community from two native species and several introductions (Muchiri and Hickley 1991). Muchiri *et al.* (1995) have found an average persistence time to be 36.9 to 29.7 years for the species whose start and end of their presence in the lake can be deduced with any certainty. The food and feeding habits of the fish species of Lake Naivasha have been described by Hickley *et al.* (1994), Muchiri *et al.* (1994) and Muchiri *et al.* (1995). The tilapias were shown to consume large amounts of detrital aggregates comprising fine silt, decaying vegetable debris and leaf litter together with associated animal communities. *O. leucostictus* also takes small proportions of green algae and diatoms. The submerged macrophytes are consumed by *T. zillii* together with the dedicated invertebrate macroherbivore, crayfish, *Procambarus clarkii*, (Harper *et al.* 1990). *T. zillii* also feeds on *Micronecta* and other insects when not consuming detritus and macrophytes. The largemouth bass has a mixed diet starting with zooplankton and as it grows larger consumes macroinvertebrates (especially *Micronecta* and crayfish), fish and frogs. *Barbus* and the guppy, *Lebistes reticulata,* feed on insects and zooplankton. Muchiri *et al.* (1994) identified several unexploited or underexploited fish feeding niches at Lake Naivasha and consequently suggested consideration of careful introduction of more species to diversify the ecosystem and enhance the fishery potential. Presently, the two tilapias (*O. leucostictus* and *T. zillii*), the largemouth bass (*M. salmoides*) and the invertebrate *P. clarkii* support an important canoe-based commercial fishery. The bass also provides a sport fishery.

CAUSES OF FISHERIES FLUCTUATIONS

Water level fluctuations

Historical changes in water levels of the Rift Valley lakes have been reviewed by Hopson (1982). He suggested that lakes in the eastern arm of the Rift Valley, in Kenya, show similar trends. Fluctuations in the levels of Lake Turkana since 1888 parallel those of Lake Naivasha (Butzer 1971; Richardson and Richardson 1972). On the other hand total fish landings from lakes Turkana, Baringo and Naivasha appear to correspond fairly closely with water level changes (Fig. 3). Regression of fish catches against lake levels of Turkana and Naivasha (whose water level data are more or less complete) show significant positive relationships (at $P < 0.05$).

1. Turkana

   Total catch (t) = 8774 + 1202 water level ($r = 0.47$)

2. Naivasha

   Total catch (t) = 216 + 82.6 water level ($r = 0.40$)

In Lake Turkana, the wide recession of water has led to the loss of large littoral areas including the tilapia-rich Ferguson's Gulf. Due to the shallow depth of Lake Baringo and Naivasha, any change in water level is reflected in wide recession or flooding of large areas of lake margins. These wide changes in horizontal movement have important ecological implications for fish habitats particularly for those important fish communities that occur in the shallow littoral zones. Lowe-McConnell (1982) listed habitat drying and flooding as some of the important factors that control tilapia numbers in fish communities. Tilapias were also shown by Fryer and Iles (1972) to find shelter from predation and fishing pressure in flooded marginal terrestrial vegetation on the shores of Lake Victoria during rising water.

The offshore species of Lake Turkana are not so much directly affected by fluctuations of lake water levels as by the discharge of the affluent rivers flowing into the lake. Beadle (1981) suggests that the River Omo, having a large catchment well covered with forests and other vegetation provides a rich source of nutrients that form the basis of the lake's productivity. Harbott (1982) and Talling (1986) demonstrated that the production of *Microcystis aeruginosa*, the dominant alga in Lake Turkana, is influenced by the seasonality of the River Omo flow regime. This production then supports secondary production based on zooplankton and other planktivores (Ferguson 1982) which would be reflected in the pelagic fish production. Although Melack (1976) did not include Lake Turkana in the determination of a relationship between fish yields and primary productivity, he demonstrated that the two parameters have a good positive correlation.

Aquatic vegetation

No data are available for the Rift Valley lakes to categorically link fish yields with variability of aquatic vegetation. However, it has

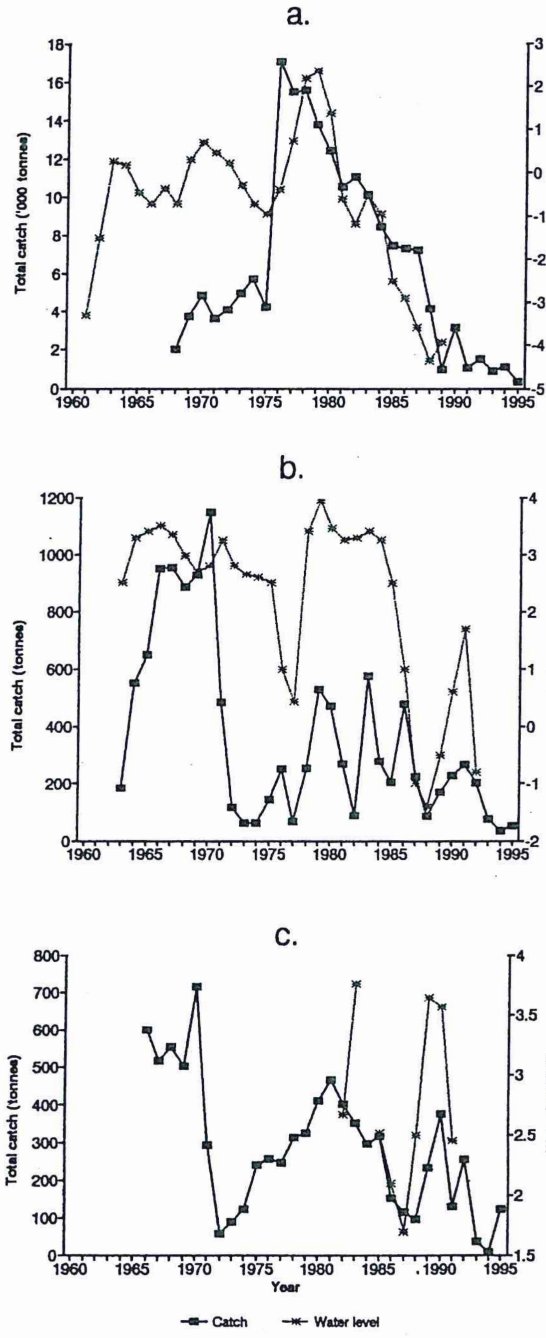

Fig. 3. Total catch and water level changes in the Rift Valley lakes. (a) Lake Turkana - 375 m a.s.l is taken as 0 metres; (b) Lake Naivasha - 1890 m a.s.l. taken as 0 metres; (c) Lake Baringo - 975 m a.s.l is taken as 0 metres. (Lake level data obtained from the Ministry of Water Development, Nairobi).

been possible to adduce evidence of such a relationship based on direct observation and results of studies carried out elsewhere. Of the three Rift Valley lakes, Lake Naivasha has proportionately greater abundance of macrophytes. But, as discussed above, the macrophyte community at Naivasha has had mixed fortunes over the years. The role of aquatic plants in the success of fish populations through feeding and breeding has been shown in Lake Naivasha for tilapia (Muchiri and Hickley 1991; Muchiri *et al.* 1995) and for largemouth bass (Hickley *et al.* 1994). It has been shown that during periods of total absence of submerged macrophytes catches generally declined but as the macrophytes recovered there was evidence of upward trends in fish abundance.

A similar relationship was also demonstrated from 30 Texas reservoirs (Durocher *et al.* 1984) where 'a highly significant positive relationship ($P < 0.01$) was found between percent submerged vegetation (up to 20%) and both the standing crop of largemouth bass and numbers being recruited to harvestable size.' It is desirable, however, to consider the total trophic status of the water body. This is particularly important because extensive aquatic macrophytes have the effect of reducing chlorophyll a and total phosphorus concentrations and increase in secchi disc transparencies which may yield underestimated trophic status (Canfield *et al.* 1983; Harper 1992).

Influences of aquatic macrophytes on fish populations through feeding and breeding can either be direct or indirect. Direct macrophyte consumers are likely to be influenced by variation in macrophyte abundance. In the Rift Valley lakes, only *T. zillii* consumes macrophytes. However, as demonstrated in Naivasha, *T. zillii* is not an absolute macrophyte feeder and is able to consume other food items even in the presence of an abundance of aquatic plants. Indirectly, macrophytes provide a source of detritus for the detritivores. In Naivasha largemouth bass was found to feed in areas more closely associated with macrophytes but did not consume the plants. Aquatic macrophytes play a more crucial role in providing nesting grounds for fish, and refugia for fish threatened by predators. Since the macrophyte feeders are able to take alternative prey items, it appears that the role of macrophytes in aquatic ecosystems in influencing fish populations is more important to reproduction than feeding.

Human impacts

Human impacts on fisheries yields come in various forms. In the Rift Valley lakes the more important impacts are overexploitation of the fisheries resources, introductions of alien species and catchment degradation in the wider catchment areas. The Lake Turkana Fisheries Project (Hopson 1982) indicated some degree of overfishing for certain stocks (especially those of *Citharinus, Distichodus, Lates* and the tilapias). While Kolding (1989) acknowledges overexploitation of tilapias, he does not accept the whole concept of overfishing in Lake Turkana and instead has put more weight on the effects of variability in water levels as the major influencing factor of fish yields. In Naivasha, and Baringo there are indications of overfishing. Muchiri and Hickley (1991) have shown this for Naivasha, while in Baringo overfishing has been cited several times in the *Annual Statistical Bulletins* of Kenya's Fisheries Department. As the number of fish to catch decreases, the fishers respond by reducing the mesh sizes of the gill-nets used. This results in recruitment overfishing where a large proportion of fish is caught before reaching spawning size or having spawned only once (Siddiqui 1977). Muchiri *et al.* (1994) have demonstrated that overfishing in Naivasha only occurs because of the presence of a small number of target fish whereas more than 60% of the lake ecosystem is not utilized by fish (hence the suggestion of a careful introduction of more fish species to enhance the fishery).

The impacts of species introductions are well documented (see for example Pitcher and Hart 1995). Most introductions have resulted in negative impacts as many authors have suggested for the Nile perch situation in Lake Victoria. In the Rift Valley lakes, results of introductions can be viewed as positive from the fisheries point of view. The introduction of *Protopterus aethiopicus* into Lake Baringo has enhanced the fishery in that lake, while in Naivasha the entire fishery is dependent on introduced species. There have not been any species introductions into Lake Turkana.

Poor land uses in agriculture and pastoralism in areas that are steeply sloping and in areas that already have sparse vegetation cover have resulted in extensive soil erosion. Erosional effects in Baringo area are especially noteworthy. The clearing of extensive areas of papyrus at Naivasha has substantially reduced the buffer zone that helps trap silt and nutrients from agricultural runoff. More and more land that constitutes the catchment area of Lake Naivasha is being cleared for agriculture. This is also true for Lake Baringo area where more land is being put under irrigation.

Damming of rivers for irrigation and hydroelectric power generation is a feature common to the catchments of the three Rift Valley lakes. The result of this damming is a reduction of water that reaches the lakes. With the present extensive use of the River Omo water for irrigation in Ethiopia and the damming of the Turkwell River for hydroelectric power generation, the important sources of nutrients for the open water of Lake Turkana may be severely affected. The remaining recourse for the open water productivity in this lake is the frequent mixing of water, caused by the prevailing south-east winds (Hopson 1982), that brings up nutrients occurring at the bottom.

REASONS FOR PERSISTENCE OF THE FISHERIES

The fisheries of the three Rift Valley lakes have at all times been predominantly inshore, at Lake Turkana within water less than 15 m deep. Yet it is the littoral zones that are affected most by agents of habitat change. To survive in this kind of habitat, the fish species have to be adaptable to such changes. Across the Rift Valley lakes, tilapias appear to be the most successful in occupying this rapidly changing environment and hence supporting the fisheries (Fig. 4). The key to their success lies in their flexibility in feeding and breeding. *Oreochromis niloticus* (the more important species in Turkana and the only tilapia in Baringo), has been reported to take varying food types in different water bodies or at different times in the same lakes (e.g. Moriarty and Moriarty 1973; Moriarty *et al.* 1973; Balirwa 1990). *O. niloticus* is able to consume phytoplankton, detritus and epiphytic algae. Similarly, *O. leucostictus* (the species that dominates the fishery of Lake Naivasha), consumes a wide variety of food items which include phytoplankton, detritus and macroinvertebrates. In Lake Naivasha, as well as Albert and George, in lagoons fringing Lake Victoria and in ponds and dams where the species has been introduced, the importance of bottom deposits has been stressed (Fish 1955; Lowe-McConnell 1958; Welcomme 1970; Muchiri *et al.* 1995). The ability to consume detritus is an important adaptation that allows dependence on a rich and almost unlimited food source (Bowen

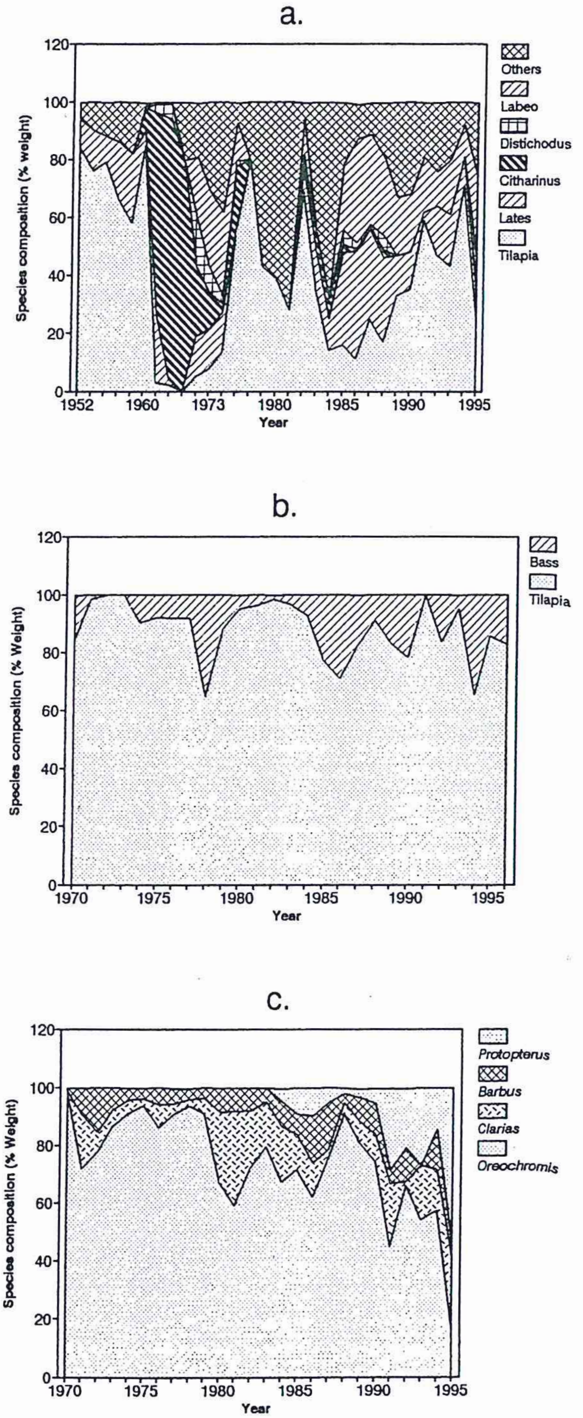

Fig. 4. Species composition from the fishery of the rift valley lakes, Kenya; (a) Lake Turkana, (b) Lake Naivasha, (c) Lake Baringo (Data obtained from the Department of Fisheries, Nairobi. For Lake Turkana between 1952 and 1970 data after Kolding, 1989).

1980; Mann 1988) which dampens out effects of food limitation in aquatic ecosystems (Muchiri *et al.* 1995).

A common feature of breeding in cichlids is that of parental care (Fryer and Iles 1972). This feature allows rapid reproduction. Mouthbrooders, particularly of the genus *Oreochromis* have been more successful in the Rift Valley lakes because of their ability to reproduce even with receding water levels, thus overcoming variations in their habitats. Presence of macrophytes appears to be more crucial in breeding of substrate spawners such as *Tilapia zillii* (Fishelson 1966; Spataru 1978) which also occurs in Lakes Turkana and Naivasha.

The future

Overfishing notwithstanding, fluctuating water level has been demonstrated as a major factor in the performance of the fisheries of the Rift Valley lakes. The effects of water fluctuations are more pronounced in shallow aquatic ecosystems such as the gently sloping shore of Lake Turkana and whole lake areas of Lake Baringo and Naivasha. As the Rift Valley lakes depend almost entirely on water received in the wider catchment areas, it is imperative that management of lake communities (including fish) be linked to whole catchment management. With regard to the Rift Valley lakes, attention should be paid to choice of appropriate land uses in the catchment areas. The need to provide suitable land for agriculture is in direct conflict with conservation needs of these areas. It is the forested highland areas that are suitable for agriculture because of their good soils and rainfall, and whereas the areas immediately in the vicinity of the lakes have rich soils (especially around Naivasha and Baringo), the soils are too dry to support any crops except under irrigation. Water used in agriculture in these regions is often indeterminate (although in certain cases official abstraction quotas exist) so that even with accurate hydrological data (which are scarce) it is difficult to accurately predict amounts of water that reach the lakes. In Naivasha some of the water that eventually reaches the lake is also abstracted for irrigation of large export-oriented floricultural farms.

The major obstacle to integrated catchment management in Kenya's Rift Valley basins is that several groups have vested interests in the resources, yet there is a lack of co-ordination in their use and management. The River Omo catchment is entirely within the boundaries of Ethiopia which means that international goodwill is important in the management of the Lake Turkana ecosystem. For those falling within the borders of Kenya (as it is with Baringo and Naivasha catchments), several government bodies and private groups have interests in the resources. The ministries in charge of water, agriculture, forestry, fisheries and rural development are all stakeholders with individual priorities. At Naivasha, there is the influential Lake Naivasha Riparian Owners Association which has on several occasions in the past influenced the direction of management for the Lake Naivasha ecosystem.

Sound management proposals have been made in the past (e.g. Harper *et al.* 1990 for Lake Naivasha and its catchment areas, and Bryan 1994 for the Baringo basin). However, in the long-term, management of the Rift Valley fisheries, and by extension whole lake ecosystems, will depend on the formulation of mechanisms that will allow co-ordination of activities of the various interest groups. One parastatal body exists in Baringo that is meant to be an umbrella management body. However, the Kerio Valley Development Authority (KVDA), like the other regional development authorities in Kenya, is not an effective co-ordinating body. Also the KVDA appears to lay more emphasis on agricultural food, and hydroelectric and fuelwood energy production with less attention to other issues. It appears then that a more powerful body with wider interests is desirable. An inter-ministerial commission would in this case play a more meaningful role of coordinating the activities of various interest groups. The Inter-ministerial Commission on Marine Resources in Brazil provides a good example as it has played a more effective role in co-ordinating national and state activities that manage marine aquatic resources (Dugan 1990). The private sector should also be co-opted in such a commission to represent the greater majority of the resource users. The Omo-Turkana basin requires an inter-governmental commission similar to one created recently for Lake Victoria.

Acknowledgments

I am grateful to the Director of Fisheries for access to the fish catch data. Drs Barasa Wangila and Hussein Isaack read the manuscript and made useful comments. Funds to cover my expenses to the Second World Fisheries Congress were provided by the Canadian International Development Agency (CIDA) through a Memoral University (Canada) — Moi University (Kenya) linkship programme.

References

Balirwa, J S (1990). The effects of ecological changes in Lake Victoria on present trophic characteristics of *Oreochromis niloticus* in relation to species role as a stabilizing factor of biomanipulation. *International Agricultural Centre, Wageningen, Occasional Paper* No. 3, 58–66.

Beadle, L C (1932). Scientific results of the Cambridge Expedition to East African Lakes 1930 — 1. 4. The waters of some East African lakes in relation to their fauna and flora. *Journal of the Linnean Society (Zoology)* **38**, 157–211.

Beadle, L C (1981). 'The Inland Waters of Tropical Africa — An Introduction to Tropical Limnology.' 2nd edition, (Longman: London and New York). 475 pp.

Bowen, S H (1980). Detrital non-amino acids are the key to rapid growth in *Tilapia mossambica* in Lake Valencia, Venezuela. *Science* **207**, 1216–18.

Bryan, R B (1994). Land degradation and the development of land use policies in a transitional semi-arid region. In 'Soil Erosion, Land Degradation and Social Transition - Geological analysis of a semi-arid tropical region, Kenya'. (Ed R B Bryan) (Catena Verlag: Cremlingen-Destedt). 248 pp.

Butzer, K M (1971). 'Recent History of an Ethiopian Delta — The Omo River and the Level of Lake Rudolf.' *The University of Chicago, Department of Geography Research Paper* No. 136. 184 pp.

Canfield, D E Jr., Langland, K A, Maceina, M J, Haller, W T, Shireman, J V, and Jones, J R (1983). Trophic state classification of lakes with aquatic macrophytes. *Canadian Journal of Fisheries and Aquaculture Sciences* **40**, 1813–19.

Dugan, P J (Ed) (1990). 'Wetlands Conservation: a Review of Current Issues and Required Action.' (IUNC: Gland, Switzerland). 96 pp.

Durocher, P P, Provine, W C, and Kraai, J E (1984). Relationship between abundance of largemouth bass and submerged vegetation in Texas reservoirs. *North American Journal of Fisheries Management* **4**, 84–8.

Ferguson, A J D (1982). Studies on the zooplankton of Lake Turkana. In 'Lake Turkana. A report on the findings of the Lake Turkana Project 1972–1975'. Overseas Development Administration, London 1, 1334–55.

Fish, G R (1955). The food of *Tilapia* in East Africa. *Uganda Journal* **19**, 85–9.

Fishelson, L (1966). Cichlidae of the genus *Tilapia* in Israel. *Bamindgen* **18**, 67–80.
Fryer, G, and Iles, T D (1972). 'The Cichlid Fishes of the Great Lakes of Africa: Their Biology and Evolution.' (TFH Publications: Neptune City, New Jersey).
Gaudet, J M (1977). Natural drawdown on Lake Naivasha, Kenya, and the formation of papyrus swamps. *Aquatic Botany* **3**, 1–47.
Harbott, B J (1982). Studies on algal dynamics and primary productivity in Lake Turkana. In 'Lake Turkana. A report on the findings of the Lake Turkana Project 1972–1975'. Overseas Development Administration, London, **1**, 1331–55.
Harper, D M (1992). The ecological relationships of aquatic plants at Lake Naivasha, Kenya. *Hydrobiologia* **232**, 65–71.
Harper, D M, Adams, C and Mavuti, K M (1992). The aquatic plant communities of the Lake Naivasha wetland, Kenya: patterns, dynamics and conservation IV. *International Wetlands Conference*, Ohio, 1992.
Harper, D M, Mavuti, K M, and Muchiri, S M (1990). Ecology and management of Lake Naivasha, Kenya in relation to climatic change, alien species introductions and agricultural development. *Environmental Conservation* **17**, 228–36.
Hickley, P, North, R, Muchiri, S M, and Harper, D M (1994). The diet of largemouth bass, *Micropterus salmoides*, in Lake Naivasha, Kenya. *Journal of Fish Biology* **44**, 607–19.
Hopson, A J (Ed) (1982). 'Lake Turkana. A Report on the Findings of the Lake Turkana Project 1972–1975'. Overseas Development Administration, London, **1–6**. 1614 pp.
Kallqvist, T (1987). 'Primary production and phytoplankton in Lake Baringo and Naivasha.' *Norwegian Institute for Water Research (NIVA) Report No.* E-8041905. 59 pp.
Kolding, J (1989). 'The fish resources of Lake Turkana and their environment'. Candidate Scientific thesis, University of Bergen and Final Report of Project KEN 043, NORAD, Oslo. 262 pp.
Lowe-McConnell, R H (1958). Observations on the biology of *Tilapia nilotica* in East African waters. *Reviews Zoology and Botany of Africa* **57**, 129–70.
Lowe-McConnell, R H (1982). Tilapias in fish communities. In 'The Biology and Culture of Tilapias'. (Eds R S V Pullin and R H Lowe-McConnell), ICLARM Conference Proceedings 7, 83–113.
Lowe-McConnell, R H (1987). 'Ecological Studies in Tropical Fish Communities.' (Cambridge University Press). 382 pp.
Mann, K H (1988). Production and use of detritus in freshwater, estuarine and coastal marine ecosystems. *Limnology and Oceanography* **33** (4, part 2), 910–30.
Melack, J M (1976). Primary production and fish yields in trical lakes. *Transactions of the American Fisheries Society* **105**, 575–80.
Moriarty, D J W, and Moriarty, C M (1973). The assimilation of carbon from phytoplankton by two herbivorous fishes: *Tilapia nilotica* and *Haplochromis nigripinis*. *Journal of Zoology* (London) **171**, 41–55.
Moriarty, D J W, Darlington, J P E C, Dunn, L C, Moriarty, C M, and Terlin, M P (1973). Feeding and grazing in Lake George. Proceedings of the Royal Society of London, Series B, **184**, 299–319.
Muchiri, S M, and Hickley, P (1991). The fishery of Lake Naivasha, Kenya. In 'Catch Effort Sampling Strategies: Their Application in Freshwater Fisheries Management'. (Ed I G Cowx) pp. 382–92 (Blackwell: Oxford).
Muchiri, S M, Hickley, P, Harper, D M, and North, R (1994). The potential for enhancing the fishery of Lake Naivasha, Kenya. In 'Rehabilitation of Freshwater Fisheries'. (Ed I G Cowx) pp. 348–58 (Blackwell: Oxford).
Muchiri, S M, Hart, P J B, and Harper, D M (1995). The persistence of two introduced tilapia species in Lake Naivasha, Kenya, in the face of environmental variability and fishing pressure. In 'The Impact of Species Changes in African Lakes'. (Eds T J Pitcher and P J B Hart) pp. 299–319 (Chapman and Hall: London).
Okoric, O O (1974). On the ecology and exploitation of the fisheries of an East African Rift Valley Lake. Part 1. On the bionomics and population structure of *Tilapia nilotica*, Linnaeus, 1757 in Lake Baringo, Kenya. Unpublished report of the East African Freshwater and Fisheries Research Organisation, Jinja. 24 pp + 26 tables + 7 figures.
Pratt, D J, Greenway, P J, and Gwynne, M D (1966). A classification of East African rangeland. *Journal of Applied Ecology* **3**, 369–82.
Pitcher, T J, and Hart, P J B (1995). 'The Impact of Species Changes in African Lakes.' (Chapman and Hall: London). 601 pp.
Richardson, J L, and Richardson, A E (1972). History of an African rift valley lake and its climatic implications. *Ecological Monographs* **42**, 499–534.
Roger, J (1944). Mollusques fossiles et subfossiles du basin du lac Rudolphe. In 'Mission Scientifique de l'Omo, 1932–33'. (Ed C Armboug) *Bulletin of Museum of Natural History* (Paris) 2, 60–230.
Siddiqui, A Q (1979). Changes in fish composition in Lake Naivasha, Kenya. *Hydrobiologia* **64**(2), 131–8.
Spataru, P (1978). Food and feeding habits of *Tilapia zillii* (Gervais) (Cichlidae) in Lake Kinneret (Israel). *Aquaculture* **14**, 327–38.
Talling, J F (1986). The seasonality of phytoplankton in Africian lakes. *Hydrobiologia* **138**, 139–60.
Welcomme, R L (1970). Studies of the effects of abnormally high water levels on the ecology of fish in certain shallow regions of Lake Victoria. *Journal of Zoology* (London) **4**, 39–55.