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# REHABILITATION OF FRESHWATER FISHERIES

EDITED BY


I.G. COWX

*Hull International Fisheries Institute*
*University of Hull, U.K.*



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# Chapter 32
# The potential for enhancing the fishery of Lake Naivasha, Kenya

S.M. MUCHIRI[1], P. HICKLEY[2], D.M. HARPER[3] and R. NORTH[2]

[1] *Fisheries Department, Moi University, P.O. Box 3900, Eldoret, Kenya*

[2] *National Rivers Authority, Severn–Trent Region, 550 Streetsbrook Road, Solihull, B91 1QT, UK*

[3] *Department of Zoology, University of Leicester, Leicester, LE1 7RH, UK*

Lake Naivasha is a freshwater lake situated in the eastern rift valley of Kenya. Only five species of fish, *Oreochromis leucostictus, Tilapia zillii, Micropterus salmoides* (largemouth black bass), *Barbus amphigramma* and *Poecilia reticulata* (guppy), are present, all of which have been introduced. The first three form the basis of an important gill net fishery and bass are also taken by rod and line for sport. The feeding regimes of the commercially exploited fish were examined and assessment was made of potential food supply, in particular the benthic fauna. Small bass depend heavily on *Micronecta* and large bass mostly take crayfish. Detritus predominates in the diet of *Oreochromis leucostictus* and *Tilapia zillii*, but the former also eats significant amounts of algae, and the latter also eats *Micronecta* and macrophytes. Various food resources, especially the benthos, appear to be underutilized and so it is possible that further species could be stocked to both enhance ecological diversity and increase commercial catches. A recommendation is made that the principle of further fish species introductions be accepted and that species should be selected for feasibility appraisal.

## 32.1 Introduction

Lake Naivasha is a freshwater lake, approximately 150 km$^2$ in area, situated in the eastern rift valley of Kenya about 100 km north of Nairobi. It lies in a closed basin at an altitude of 1890 m above sea level and receives 90% of its water from the perennial River Malewa. The remaining input comes from two ephemeral streams, rainfall and ground seepage. The lake is very shallow, being, for the most part, between 4 and 6 m deep, and is subject to considerable fluctuations in water level. Dominant vegetation types are belts of papyrus (*Cyperus papyrus* L.) around the margins, large stands of submerged macrophytes, of which the principal species is *Najas pectinata* (Parl.), and mats of floating plants comprising *Salvinia molesta* Mitch. and, recently, *Eichhornia crassipes* (Mart.). An overview of the lake and its ecology can be found in Harper *et al.* (1990).





Resulting from a probable history of occasional drying out, Lake Naivasha when first studied (c. 1900) had only one species of fish present, the endemic *Aplocheilichthys antinorii* (Vinc.) which was last recorded in 1962 (Elder *et al.*, 1971). Since 1925 various fish introductions have been made, some successful and some not (Litterick *et al.*, 1979; Muchiri & Hickley, 1991). Present today are *Oreochromis leucostictus* (Trewavas), *Tilapia zillii* (Gervais), *Micropterus salmoides* Lacepede (largemouth black bass), *Barbus amphigramma* Blgr. and *Poecilia reticulata* Peters (guppy). The two tilapias and the bass form an important fishery (Muchiri & Hickley, 1991), with all three species being commercially exploited using gill nets and the bass also being taken by rod and line for sport.

Estimates of both actual and theoretical fish yields (Muchiri & Hickley, 1991) suggest that Lake Naivasha has a potential for greater output than is realized at present. Maximum sustainable yield (MSY) was found to be 418.8 t yr$^{-1}$ whereas estimates of theoretical yield, based on the morphoedaphic index (Henderson & Welcomme, 1974) and primary production models (Melack, 1976), ranged between 495 and 720 t yr$^{-1}$. (This excludes an exceptional value of 5649 t yr$^{-1}$ for 1988). In addition, the level of fishing pressure is indicative of possible underperformance, perhaps as a result of the low number of target species. Throughout the history of the commercial fishery, Lake Naivasha has had less than 0.7 fisherman km$^{-2}$ whereas, of 31 lakes examined by Henderson & Welcomme (1974), 18 had more than 1 fisherman km$^{-2}$. Accordingly, Muchiri & Hickley (1991) advised that it would be appropriate to reconsider earlier suggestions (e.g. Naivasha Fisheries Department, pers. comm.; Siddiqui, 1977) that additional fish species should be stocked. Further introductions could both diversify the ecosystem and increase commercial catches.

The purpose of this study was to examine fish feeding regimes and to relate this information to data on potential food supply so as to identify whether or not the resources are currently being underutilized.

## 32.2 Methods

The majority of fish specimens were obtained by gill netting, with the remainder of samples being taken by electric fishing. Collections were made annually from major habitat types including open water, submerged macrophyte beds, rocky shoreline and the marginal vegetation fringe for the years 1987–91, inclusive. The feeding of bass and the two tilapias was studied directly but information on *Barbus* and the guppy, both relatively unimportant in the catches, was sought from the literature. Stomachs were removed from representative samples from across the size range captured, for each habitat type from each sampling year. Larger material was examined with the aid of a $\times 20$ binocular microscope. Contents consisting of fine particles, such as from the tilapias, were shaken in water and drops of the suspension viewed at $\times 400$ magnification. Ingested matter was identified and placed into food item categories ranging from broad taxonomic groups to individual genera. The categories were determined in part by the limits of identification but, more critically, according to a subjective appraisal of those that would enable a classification of feeding habits.

For each sample of each fish species, the number of guts in which each food item occurred was recorded and expressed as a percentage of the number of guts containing food (% *occurrence*). For bass the % *abundance* of different foods in individual guts was calculated as the count of a food item expressed as a percentage of the total count for all food items. For the tilapias the % abundance was assessed on a proportion basis using relative volumes estimated from the area occupied by each food item in the microscope field of view. Finally, to assess the relative importance of each dietary taxon consumed, a prominence value (*PV*), based on the scheme of Wilhm (1967), as adopted by Hickley & Bailey (1987), was calculated from the product of its % abundance and the square root of its % occurrence.

During 1988, macroinvertebrates were sampled in accordance with the two methods detailed by Clark *et al.* (1989), a 15 × 15 cm Ekman (1911) grab being used for zoobenthos and a hand net for littoral fauna. Data for 1987 and 1989 were provided by Clark (unpublished).

## 32.3 Results

### 32.3.1 *Feeding habits of fish*

#### *Micropterus salmoides*

Analysis of stomach contents of *M. salmoides* showed that fish <260 mm fork length are almost totally dependent on invertebrate food organisms. Thereafter, crayfish (*Procambarus clarkii* (Girard)), fish and frogs are also consumed (Table 32.1). By far the most important invertebrate prey species is the water boatman (*Micronecta scutellaris* (Stal.)). Other predominant insect prey items include dipteran pupae, especially those of chironomids and mosquitos. Zooplankton is consumed, but only in significant quantity by fish smaller than 80 mm. For bass in the larger length category the crayfish appears to be the preferred food.

The largemouth bass in Lake Naivasha can, therefore, be classed as a generalized macropredator, principally feeding on free-living animals typical of littoral zones.

#### *Oreochromis leucostictus*

Detritus is the principal component of the diet of *O. leucostictus* (Table 32.1). It is the most abundant food material available to fish in Lake Naivasha and its importance has been previously noted by Malvestuto (1974) and Siddiqui (1977). Of the other dietary constituents, various algae, especially planktonic forms, are predominant. Chironomid larvae and pupae are also taken, as are some oligochaete worms, but free-living insects such as *Micronecta* feature infrequently.

In terms of feeding category classification, *O. leucostictus*, whilst in the main a detritus feeder, can also be described as a microherbivore.



**Table 32.1** The prominence values (*PV*) of food items found in the stomachs of bass and tilapias in Lake Naivasha where *PV* > 1 (*PV* = % abundance × square root % occurrence)

| | *Micropterus salmoides* | *Micropterus salmoides* | *Oreochromis leucostictus* | *Tilapia zillii* |
|---|---|---|---|---|
| Sample size | 1086 | 133 | 384 | 347 |
| Food item Fork length (mm) | 60–260 | 260–500 | 100–265 | 85–265 |
| Detritus | – | – | 425.42 | 379.20 |
| Desmids | – | – | 71.76 | – |
| *Botryococcus* | – | – | 47.55 | – |
| Filamentous diatoms | – | – | 8.00 | 8.03 |
| Colonial algae | – | – | 14.78 | – |
| Benthic diatoms | – | – | 9.13 | 1.67 |
| Epiphytic algae | – | – | 7.05 | 8.92 |
| Macrophyte | – | – | – | 65.12 |
| Tricladida | – | – | 6.85 | – |
| Oligochaeta | – | – | 28.02 | 16.84 |
| Conchostraca | 8.68 | – | – | – |
| Zooplankton | 39.65 | – | 7.50 | 6.64 |
| Ostracoda | – | – | 5.23 | – |
| *Procambarus clarkii* | 42.24 | 399.93 | – | – |
| Zygopteran nymph | 2.26 | – | – | – |
| Trichopteran larva | 3.67 | – | – | – |
| Chironomid larva | 28.09 | 20.68 | 53.23 | 17.32 |
| Dipteran pupa | 169.94 | 84.31 | 13.71 | 11.46 |
| *Micronecta* | 619.34 | 225.19 | 6.69 | 202.73 |
| Other Hemiptera | 8.21 | 1.40 | – | – |
| Gastropoda | – | 2.12 | – | 3.30 |
| Fish | 6.43 | 46.67 | – | – |
| Anuran tadpole | 2.79 | – | – | – |
| Anuran adult | – | 81.73 | – | – |

#### *Tilapia zillii*

The principal food of *Tilapia zillii* is similar to that of *O. leucostictus*, i.e. detritus (Table 32.1). However, unlike its counterpart, *T. zillii* consumes considerable amounts of macrophyte (mostly *Najas* and *Potamogeton*), rather than algae, and relatively large quantities of insect material, notably *Micronecta*. Oligochaetes form a minor part of the diet.

*Tilapia zillii* is, therefore, a detritus feeder but with a secondary classification of an omnivorous browser. It is important to note that examination of niche overlap by Muchiri (1990) demonstrated that, assuming detritus not to be limiting, the requirement for other items is such that the two tilapias are not in competition with each other for food resources.

#### *Barbus amphigramma*

A few *Barbus* samples examined in 1986 (Muchiri, 1990) indicated that the fish is an insectivore, especially when in the afferent river. In the lake, zooplankton becomes an important dietary item and small quantities of phytoplankton and detritus are also taken.

*Poecilia reticulata*

As the guppy was introduced in an attempt to control mosquito larvae (Litterick *et al.*, 1979), it is presumed that this is a preferred food. The continued use of the guppy for control of mosquito larvae in the tropics supports this assumption (e.g. Costa, 1985), although it is likely that the fish will take any other similarly sized aquatic invertebrates found in the littoral zone.

### 32.3.2 *Invertebrate fauna*

The benthic fauna of Lake Naivasha comprises oligochaetes and chironomid larvae, a biota typical of many tropical lakes (e.g. Burgis *et al.*, 1973; Green, 1979; Marshall, 1982). The worms most commonly found in samples were the tubificids *Limnodrilus hoffmeisteri* (Clarepede) and *Branchiura sowerbyi* (Beddard). The predominant chironomid was *Chironomus formosipennis* Keiffer. The estimated densities of these benthic organisms are given in Table 32.2. The numbers of oligochaete worms and chironomid larvae in samples were regressed against distance from shore and water depth. No significant relationships ($P > 0.05$) were found, suggesting that the horizontal distribution of the benthos throughout the lake is uniform.

The littoral macroinvertebrate fauna shows greater species diversity with approximately 50 species being present at any one time (this study; Clark *et al.*, 1989). By far the most abundant organism recorded in all habitats, ranging from flooded farmland to open water, was the hemipteran *Micronecta scuttellaris* (Stal.). Table 32.2 gives the mean numbers of *Miconecta* present in Lake Naivasha as estimated by Clark (1992).

### 32.3.3 *Food web*

From the information obtained on fish diets, a food web was constructed (Fig. 32.1). In order to facilitate recognition of any underutilized resource, only the most important of the feeding relationships are shown. In addition, the reasonable

**Table 32.2** Density (number $m^{-2}$) of the two most abundant macroinvertebrates in the benthos of Lake Naivasha. 1982/3 and 1984 data are from Clark *et al.* (1989). The numbers ($m^{-3}$) of *Micronecta scutellaris* present in the littoral areas during 1987 and 1989 are given for comparison (Clark, 1992)

| | 1982/3 | 1984 | 1987 | 1988 | 1989 |
|---|---|---|---|---|---|
| Oligochaeta | 792 | 1153 | 841 | 981 | 2380 |
| Chironomid larva | 405 | 364 | 362 | 347 | 177 |
| *Micronecta* | — | — | 568 | — | 227 |



assumptions have been made that the zooplankton feeds on the phytoplankton and that the crayfish, which is a predominantly herbivorous species (Penn, 1943), consumes macrophyte.

Figure 32.1 includes the labels 'A?', 'B?', 'C?' and 'D?'. These represent possible positions within the food web for fish types not yet in Lake Naivasha but which could become subjects of feasibility studies with regard to further introductions.

## 32.4 Discussion

Tropical lakes typically support many species of fish undertaking a wide range of feeding strategies (Lowe-McConnell, 1987). By modifying the classification scheme proposed by Matthes (1964), Hickley & Bailey (1987) identified five major feeding categories for common species of fish found in the large, shallow, papyrus-fringed lagoons which form the perennial waters of the Sudd swamps (R. Nile). Whilst not necessarily fully applicable to a lake like Naivasha, such a classification serves to indicate the types of fish that could be expected in a shallow-water tropical system. The categories are mud-feeders, microherbivores, macroherbivores, omnivores and carnivores. Carnivores can be further subdivided into zooplanktivores, bottom-feeders, browsers in vegetation, generalized macropredators and piscivores. Relative to such a classification it could be considered that the Naivasha fish fauna is not sufficiently diverse. Indeed, it would be difficult for any fish population comprising only five species to fully exploit all potential food resources.

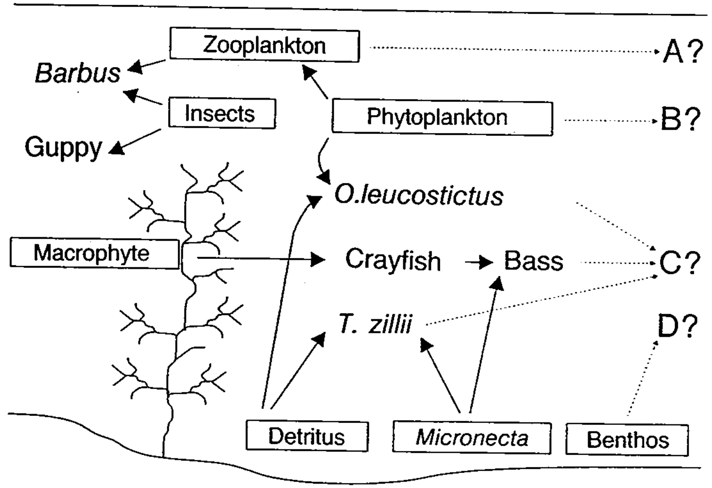


**Fig. 32.1** Food web for fishes of Lake Naivasha showing the most important of the feeding relationships. The labels A?, B?, C? and D? represent possible positions within the web for fish types not yet present.

The mud-feeders category represents those fish that eat silt and detritus. Foods taken include fine silt, vegetable debris and leaf litter together with any associated animal communities, micro-organisms and decaying organic matter. In Lake Naivasha the tilapias, *Oreochromis leucostictus* and *Tilapia zillii*, with their large uptake of detritus occupy this feeding niche.

The role of microherbivore, taking green algae and diatoms, is filled in part by *Oreochromis leucostictus* although, as indicated by the placing of 'B?' in Fig. 32.1, this species alone might not be capable of fully exploiting the phytoplankton production.

Of the larger plant material, some is eaten by *Tilapia zillii*. However, a dedicated macroherbivore is present in the form of *Procambarus clarkii* which, although an invertebrate rather than a fish, is capable of cropping the macrophytes to a major extent and also forms the basis of a commercial crayfish fishery (Lowery & Mendes, 1977; Harper *et al.*, 1990). In addition, hippopotamuses (*Hippopotamus amphibius*) have been seen (pers. obs.) to consume submerged aquatic plants on occasion, especially when terrestrial grazing is in short supply.

Omnivores can be described as feeding mainly on insects, insect larvae and zooplankton. In Lake Naivasha, *Barbus* and the guppy come closest to representing this group.

Zooplankton features in the diet of both *Barbus* and juvenile bass. Neither species, however, could be considered as filling the role of zooplanktivore to a degree commensurate with reported high offshore secondary production (Mavuti & Litterick, 1981; Harper, 1984, 1987), hence the placing of 'A?' in Fig. 32.1.

Of the other carnivorous subgroups, that of browser in vegetation is approximated by *Tilapia zillii* and its consumption of *Micronecta* and other insects when not taking detritus or macrophyte. The largemouth bass, having a mixed diet of macroinvertebrates, fish and frogs, is a typical generalized macropredator. This leaves the bottom-feeder and piscivore categories underrepresented ('C?' and 'D?' in Fig. 32.1).

Thus four areas in terms of food and space have been identified with respect to the potential for stocking additional species of fish. By far the most convincing case, and that which would best be addressed in the first instance, is the bottom feeder ('D?'). When the distribution of benthos is considered relative to fish diets, it is clear that the benthic oligochaetes and chironomid larvae are underutilized and that this food resource would be considered for exploitation. Also, any bottom-feeding fish would not be restricted to the littoral zone as benthic organisms appear to be located throughout the lake.

With regard to introducing fish to consume more phytoplankton and zooplankton than is currently taken by the existing species, there is scope but the proposal is less robust. The introduction of a dedicated piscivore is the least favoured as it might be better to leave all the cropping of fish to be carried out not by a top predator but by the activities of the commercial fishermen.

If the introduction of more fish species into Lake Naivasha is to be contemplated, the types of fish will have to be chosen with great care. A decision must be made as to whether to draw exclusively from the fauna of East Africa or to allow exotic species from, for example, Asia and the Far East. Assuming African fish to be the priority, possible candidates include *Limnothrissa miodon* or *Alestes lateralis* to occupy the open water and take zooplankton, *Heterotis niloticus* (Cuvier) to consume phytoplankton and *Mormyrus* to feed on the benthos.



The necessary feasibility appraisals of each potential species must address all aspects of suitability or otherwise. In this context the EIFAC (1988) Code of Practice, which deals with procedures for consideration of introductions, has much to commend it. Although no group of biologists, ecologists or fishery managers is able to predict with certainty the results of stocking, if the assessment of benefits and drawbacks of a proposed new species can be based on the fullest possible information, the risk is much reduced. Some of the more important details that need to be addressed are:

- feeding habits
- growth rates and size attained
- reproductive strategy
- environmental conditions required
- likely competition with resident species
- potential implications of the fishery for the new species
- type of population control method to be used if necessary.

When considering the balance of risks with regard to making further introductions into Lake Naivasha, the overall species composition and present ecological nature of the lake must be taken into account. On this basis it is likely that any unforeseen detrimental effects of stocking would be less serious in the long term than if they occurred elsewhere. Also, it has been suggested (T.J. Pitcher, pers. comm.) that if, for Lake Victoria, the commercial catch economy can be considered by some to be more important than ecology (Ochumba, 1992; Ogari, 1992), then a similar attitude might be appropriate with respect to Lake Naivasha.

## 32.5 Conclusions and recommendations

It is concluded that the fish population of Lake Naivasha does not fully exploit the available food resources. In particular, the benthic fauna, comprising oligochaete worms and chironomid larvae, is underutilized owing to the complete lack of bottom-feeding fishes. Other identifiable absentees include specialist consumers of phytoplankton, zooplankton and fish.

It is recommended that:

(1) the principle of further fish species introductions to Lake Naivasha be accepted
(2) potential species be selected and full feasibility analysis as to their suitability be carried out

(3) particular emphasis be placed upon the introduction of a bottom-feeding species capable of exploiting oligochaete worms and chironomid larvae.

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