Chapter 34
The fishery of Lake Naivasha, Kenya

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Lake Naivasha is a freshwater lake situated in the eastern rift valley of Kenya. Only five species of fish are present, all of which have been introduced. They are *Micropterus salmoides*, *Oreochromis leucostictus*, *Tilapia zillii*, *Barbus amphigramma* and *Lebistes reticulata*. The first three of these form the basis of a commercial gill net fishery. Bass are also taken by sport fishermen and *Barbus* are occasionally caught by dip net. Catch data for the Lake Naivasha fishery are presented. The fish populations are shown to be under pressure from overfishing, fluctuating water levels, changes in aquatic macrophyte densities and inadequate species diversity. Potential yields are discussed and some management options proposed.

34.1 Introduction

Lake Naivasha is a freshwater lake, about 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 shallow, having, for the most part, a maximum depth of about 8 m, and is subject to wide fluctuations in level. Marginal vegetation is dominated by papyrus (*Cyperus papyrus* L.). *Salvinia molesta* Mitch. covers large areas of water surface and submerged macrophytes occur to varying degrees, the principal species being *Najas pectinata* (Parl.). A detailed description of Lake Naivasha is given by Litterick *et al.* (1979) and updated by Harper *et al.* (1990).

Tropical lakes generally have a diverse fish fauna but, due to a probable history of drying out, Lake Naivasha had only one, the endemic *Aplocheilichthys antinorii* (Vinc.) which was last recorded in 1962 (Elder *et al.*, 1971). Various fish introductions have been made since 1925, the details of which are given in Table 34.1. The fish population of the present day comprises five species: *Micropterus salmoides* Lacepede (largemouth black bass), *Oreochromis leucostictus* (Trewewas), *Tilapia zillii* (Gervais), *Barbus amphigramma* Blgr. and *Lebistes reticulata* Peters (guppy). The two tilapias and the bass form the basis of an important commercial gill net fishery which opened in 1959. Bass are also caught by sport fishermen and, in recent years, some *Barbus* have been taken with dip nets.

Table 34.1 Summary of changes to the fish population of Lake Naivasha

Species	Date and success of introduction
Aplocheilichthys antinorii (Vinc.)	Endemic. Probably extinct; last reported in 1962.
Oreochromis spirulus niger (Gunther)	Introduced in 1925. Disappeared by 1971.
Micropterus salmoides (Lacepede)	Introduced in 1929, several times during 1940s and in 1951. Present today.
Tilapia zillii (Gervais)	Introduced in 1956. Present today.
Oreochromis leucostictus (Trewevas)	Introduced unintentionally in 1956 with *T. zillii*. Present today.
O. leucostictus x O.s.niger hybrid	Abundant in the early 1960s but due to back-crossing with *O. leucostictus* disappeared by 1972.
Oreochromis niloticus L.	Introduced in 1967. Disappeared by 1971.
Gambusia sp. and *Poecilia* sp.	Introduced but dates unknown. Absent since 1977.
Lebistes reticulata Peters	Introduced; date unknown. Recorded since 1982. Present today.
Oncorhyncus mykiss (Walbaum)	Introduced into the River Malewa; dates unknown. Caught in the lake on rare occasions.
Barbus amphigramma Blgr.	Natural invader from inflowing rivers. Recorded since 1982. Present today.

34.2 Methods

Fishing on Lake Naivasha is controlled by the Fisheries Department of the Kenya Government. For commercial fishing, gill nets are set from wooden or glass-fibre canoes which are driven either by sail and oar or by outboard motor. Every commercial fisherman is allowed to use up to 10 multi-filament gill nets of 100 m in length and with a minimum stretched mesh size of 100 mm. Netsmen must land their catch at a single landing station near Naivasha town where fisheries personnel record the weight of the catch from each vessel. Data collection commenced in 1963 but sorting of the catches into bass and tilapia has only taken place since 1974. Separate recording of *Oreochromis leucostictus* and *Tilapia zillii* began in 1987. In addition, bass are taken by sport fishermen using rod and line; the bait usually being artificial lure. *Barbus amphigramma* is captured by fishermen using locally made scooping nets when ripe fish attempt to ascend the River Malewa to spawn and are unable to cross a weir constructed about 5 km from the river mouth.

Gill net catch statistics were fitted to a version of the Schaefer model (Ricker, 1975; Pauly, 1983):

$$C = a + bE$$

where C is the catch per unit effort, E the effort (measured as the number of canoes licensed to fish in a given year), and a and b are constants.

Maximum sustainable yield (MSY), optimum effort and equilibrium yields were calculated as:

$MSY = a^2/4b$

$optimum\ effort = a/2b$

$equilibrium\ yield = aE - bE^2$

Theoretical potential yield of fish was estimated using, firstly, a mo edaphic index (MEI; the ratio of total dissolved salts to mean lake depth) secondly, a primary productivity model.

Yield based on MEI was calculated according to the regression equati Henderson and Welcomme (1974):

$$Y = 8.7489\ M^{0.3813} \qquad (r^2 = 0.5073)$$

where Y is the fish yield (kg ha^{-1} $year^{-1}$) and M the morpho-edaphic i (N.B. In this study conductivity was used rather than total dissolved salts.)

The regression equation of Melack (1976) was used to predict yield primary production data:

$$\log Y = 0.113\ P + 0.91 \qquad (r^2 = 0.57)$$

where Y is the fish yield (kg ha^{-1} $year^{-1}$) and P the average daily photosynt rate.

34.3 The gill net fishery

34.3.1 *Fish catches*

The total annual fish catches landed from the gill net fishery of Lake Naiv during the period 1963–1988, and the number of canoes that were used, w known, are given in Table 34.2. Over the years there have been great fluctuati in both the amount of fish landed and the number of vessels. The former ran from 37 to 1150 t yr^{-1} and the latter from 6 to 104 canoes with catch per ca varying between 1.1 and 24 t yr^{-1}. The overall species composition of the ca (since 1987) was *Oreochromis leucostictus* 84.7%, *Tilapia zillii* 0.5% *Micropterus salmoides* 14.8%. The mean fork length of *Oreochromis* was 225 r (S.D. = 16.18) and that of bass 298 mm (S.D. = 17.00). Figure 34.1 shows regression plot of computed catch per unit effort on effort from 1974 to 19 together with the resulting equilibrium yield curve.

A summary of events for the gill net fishery is presented in Fig. 34.2. T fishery can be divided into two main phases with the first being the period development of the new fishery from 1959 to the time when it collapsed in t early 1970s. During this phase the maximum catch recorded was 1150 t yr^{-1}. T second, recovery, phase from 1975 to the present day is typified by mark fluctuations in fish catches. Some of these fluctuations can be attributed to thr main causes; fishing pressure, fluctuating lake levels and, more recently, effec related to the loss and subsequent return of submerged vegetation.

Table 34.2 Fish catches from the commercial gill net fishery of Lake Naivasha for the years 1963–88 inclusive

Year	Number of canoes	Total catch tonnes	Catch per canoe tonnes
1963		183	
1964		550	
1965		650	
1966		950	
1967		955	
1968		885	
1969		929	
1970		1150	
1971		484	
1972		117	
1973		62	
1974	8	62	7.8
1975	6	144	24.0
1976	12	252	21.0
1977	10	67	6.7
1978	17	255	15.0
1979	33	529	16.0
1980	52	471	9.1
1981	32	269	8.4
1982	80	89	1.1
1983	76	576	7.6
1984	104	277	2.7
1985	49	206	4.2
1986	75	478	6.4
1987	85	224	2.6
1988	30	37	1.2
1989*		96	

* First seven months of 1989 only

34.3.2 *Fishing pressure*

Although there were restrictions imposed on the maximum number of gill nets allowed under each fishing licence, the number of licensed canoes was at times very large, the maximum being 104 (in theory a total length of 104 km of netting) in 1984. In practice, however, not all fishermen were able to use their full legal entitlement of net but the increase in the number of canoes engaged in fishing still led to a general decline in catch per canoe (Table 34.2). A similar trend in the relationship of fish catches with fishing effort has been described by Fryer and Iles (1972) for the fishery of Lake Victoria (Kenya waters).

Factors that led to the increase in the number of fishermen were two-fold. Firstly, there was a considerable demand for fish in the neighbouring urban centres whose populations have recently recognized the importance of including fish protein in their diet following the launch, in 1960, of a nationwide 'Eat more fish' campaign. Originally, the Maasai and Kikuyu inhabitants of the Naivasha

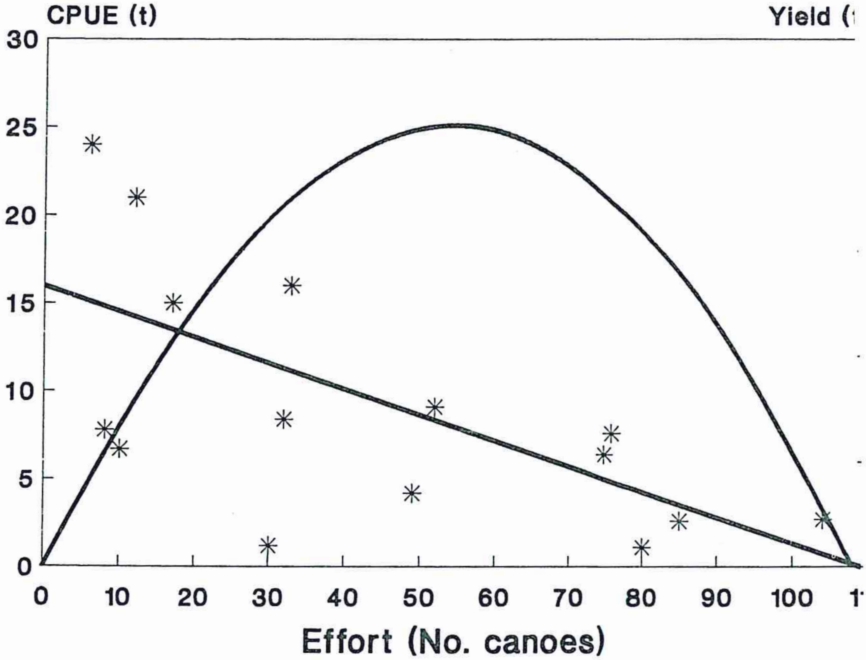

Fig. 34.1 Regression relationship (* and solid straight line) of catch per unit effort (CPUE) or (E) and the resulting equilibrium curve (solid curved line) for total gill net catches from Naivasha for the period 1974–1988 inclusive (see also Table 34.3)

area were not fish eaters. Secondly, the fishing pressure on the Lake Nai fishery has increased for economic reasons. More and more people have sc employment, some of whom have been absorbed into the fishing industry.

Another detrimental influence on the lake fishery has been non-compli with restrictions on gill net mesh size. Occasional inspection surveys of fi gear indicate that there is often contravention of the minimum (100 mm) size regulations by some licensed fishermen. Surveys carried out between and 1989 showed that nets with stretched mesh down to 75 mm were in com usage.

34.3.3 *Effects of lake level fluctuations*

Fish catches appear to be related to water level changes (Fig. 34.2). Rise in level is followed by increased catches whilst a fall in lake level is followed corresponding decline in fish catch. Lake level fluctuations influence fish num through effects on food, breeding grounds and predator-prey relationships. food has been shown not to be a limiting factor for the fish in Lake Naiv (Muchiri, 1990), a more probable effect is that on the breeding behaviour; tila being particularly sensitive to fluctuating water levels since they breed in sha

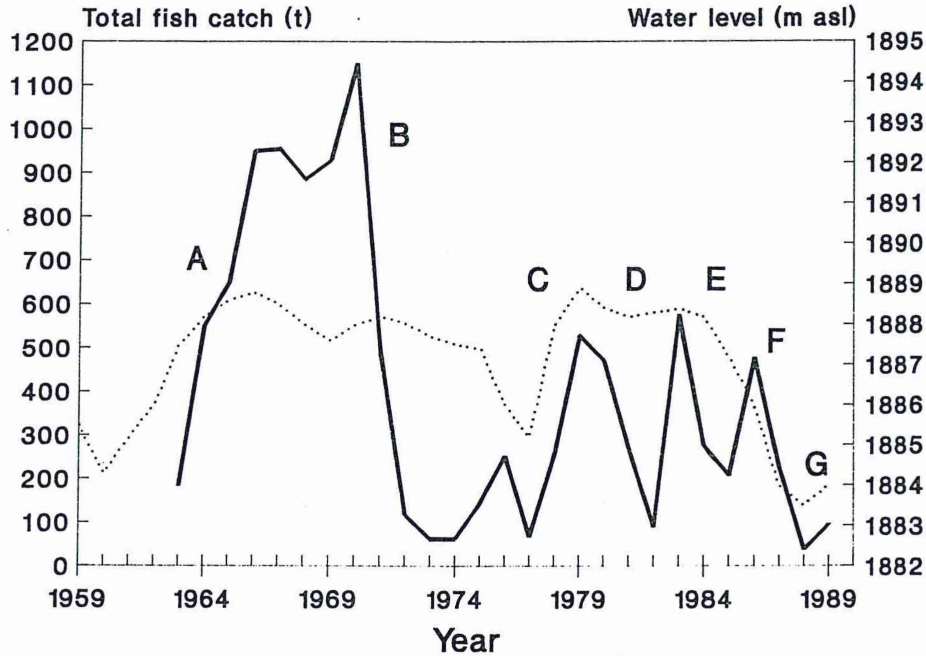

Fig. 34.2 Total catches (solid line) from the gill net fishery and water level changes (dotted line) for Lake Naivasha during the period 1963–1988 inclusive. Commercial fishing started in 1959 and records were kept from 1963. (A = period of development of the new fishery; B = period of receding lake level. Also, pressure to supply fish for processing factory led to the use of small meshed nets; C = small fishing effort (6–17 canoes) coupled with a rise in water level allowed the fishery to recover; D = period of high water but with loss of submerged plants; E = sudden decline in lake level combined with highest effort (104 canoes); F = recovery of aquatic plants but sustained high effort (49–75 canoes) and further decline in water level; G = small effort (30 canoes). Lake level starting to rise, flooding terrestrial vegetation and providing good nursery areas

water. Habitat drying and flooding were listed by Lowe-McConnell (1982) as factors controlling tilapia numbers within fish communities. Also cited was predation by piscivorous fish and birds. Fryer and Iles (1972) described how predation and fishing pressures on tilapias of Lake Victoria were minimized by flooding of marginal terrestrial vegetation and it appears likely that the fluctuating water levels of Lake Naivasha have similar effects.

Based on the past history of the lake it is unlikely that levels will stabilize in the near future and human interference is bound to exacerbate the problem. Lakeside farms irrigate with water from the lake and, although abstraction may not significantly affect the water levels, this lake level/farming relationship is potentially detrimental. When the lake recedes the farmers extend their boundaries thus acquiring more land for cultivation, consequently needing more water for irrigation. In addition, there is a proposal to dam the River Malewa which may create yet further instability in the future.

34.3.4 *Effects of submerged macrophytes*

Submerged macrophytes disappeared during the early 1980s and this appea have contributed to the decline in fish catches. Following the recovery of subme and swamp macrophytes in 1987 and 1988, in spite of the low lake level, ca in 1989 showed an upward trend which seems to be continuing in 1990. Sinc three main commercial fish species use vegetation-rich spawning grounds, the of macrophytes in the early 1980s severely affected recruitment of new indivi to sustain the fishery. The return of aquatic plants provides extensive bree and nursery grounds as well as offering abundant food and cover from preda

34.3.5 *Fish yields*

The computed maximum sustainable yield (MSY) is 418.8 t yr^{-1} with an opti effort of 54 canoes (Table 34.3). During the early years of the commercial fis the catch was maintained at a much higher level until 1970 when the maxi

Table 34.3 Estimates of actual and theoretical fish yields calculated for Lake Naivasha:
(a) Regression of catch per unit effort (CPUE) on effort (E).
(b) Morpho-edaphic index (MEI) model.
(c) Gross primary production model.
Figures in brackets indicate sources of data, (1) Melack 1979; (2) Harper 1987; (3) Muchiri (1990 Harper 1990, in prep.

(a)

Year	CPUE =	r^2	Optimum E (Canoes)	MSY t
1974–88	15.541–0.14418E	0.456	54	418

(b)

Year	Area km^2	Mean Depth m (Z)	Conductivity (K) uS^{-1} cm^{-1}	ME1 (K/Z)	Total Fish Y t yr^{-1}
1974	160	4.7	345 (1)	73.4	720.0
1982–3	150	8	259 (2)	32.4	495.0
1984	150	6	350 (2)	58.3	618.4
1987–8	130	5	430 (3)	86	621.4

(c)

Year	Area km^2	Gross Production ($g\ O_2\ m^{-2}\ d^{-1}$)	Total Fish Y t yr^{-1}
1973–4	160	4.08–6.84 (1)	573.5
1982	150	4.20–7.56 (2)	617.7
1988	120	15.6 (4)	5649.0

fish landing (1150 t yr^{-1}) was recorded. Since that time the fish catches have been close to or below the MSY (Table 34.2).

The fish yield estimates for Lake Naivasha calculated from published limnological data using the morpho-edaphic index and gross primary production models are given in Table 34.3. Most of the estimates show little variability, ranging between 495 and 720 t yr^{-1}, except for 1988 when the yield calculated by the primary production model was particularly large at 5649 t yr^{-1}.

34.4 The Barbus fishery

Exploitation of *Barbus amphigramma* on the River Malewa commenced in 1983. In 1983 and 1984 there were no records of catches but in 1985 60 t of *Barbus* were taken. In 1986 the catch amounted to 62.9 t but this decreased considerably in 1987 to 26.1 t. No fishing took place during 1988 because the annual spawning run did not occur. Only a small number of fish were caught in 1989.

34.5 Discussion

Since commercial fishing started, fish have been taken with gill nets which, in theory, should make regulating the fishery easier than in multi-gear fisheries. As gill nets are selective, desired mesh sizes can be imposed and effort controlled by limiting numbers and lengths of nets in addition to regulating the numbers of fishing vessels. Unfortunately, the task of enforcing such regulations is often the difficult part for the fisheries manager. This is particularly true for Lake Naivasha owing to its proximity to the towns of Nairobi and Nakuru with their great demands for fish. The most serious problem to be addressed is that of curbing illegal fishing by unlicensed fishermen who have no regard for the gill net regulations. This is, however, as much a social concern as a fisheries one and requires a combined effort by the Fisheries Department, the administrative officials and social workers in the Naivasha region in order to educate and rehabilitate those people involved.

With regard to the sport fishery, fishermen are supposed to make monthly returns of their catches, but this has met with little success. Spot checks by fisheries personnel reveal that substantial amounts of fish are landed by anglers but not reported.

Although fish caught by unlicensed fishermen and through sport fishing were mainly unrecorded, information on catches brought to the central landing station was more or less complete. Therefore, in spite of difficulties in obtaining accurate data, the commercial catch statistics can provide a good representation of the pattern of exploitation. In the future, the ratio of reported to unreported catch could be calibrated and yield figures could be adjusted accordingly. It may be that the catch per unit effort for illegal fishing is similar to that for legal fishing, in which case working on just the legal data by way of a sub-sample would still give a reliable insight into the status of the fishery.

The *Barbus* fishery is relatively easier to monitor since all the fishing activi concentrated on one short section of the River Malewa just below the weir. T is difficulty, however, in predicting the consequences of this new fishery as litt known of the biology and ecology of *Barbus amphigramma* in Naivasha or inc elsewhere. The intensive fishing that took place between 1985 and 1987 may l drastically reduced the population of breeding individuals to a level that require several spawning seasons before recovery. In an effort to have as m fish as possible reach their breeding grounds upstream, fishermen are now requ to release one scoop net-full of fish in five into the river on the upper side of weir. A more lasting and dependable solution would be to construct fish passe ensure adequate migration and escape from fishermen's nets.

When potential fish yields were calculated from limnological data (Table 34 in each case values were higher than the 418.8 $t\,yr^{-1}$ MSY value obtained fr catch data. In particular, the gross primary production model provided a v high estimate for 1988 (5649 $t\,yr^{-1}$). These high theoretical fish yield estima suggest that Lake Naivasha may have a potential for a larger fisheries output th is realized at the present time. Of 31 lakes examined by Henderson and Welcom (1974), 18 had more than one fisherman per km^2. By contrast, Naivasha has h less than 0.7 fisherman per km^2 throughout the history of its commercial fishe and yet has experienced overfishing from time to time. This is possibly due to t low number of target species. It is likely, therefore, that the potential fisheri resources of Lake Naivasha are at present underutilized. The hypothesis that fi yields are below potential is also supported by results obtained by the authors c the feeding of the two tilapias and the largemouth bass. It appears that zooplankto and off-shore benthic macro-invertebrates remain uncropped, yet studies o zooplankton (Mavuti & Litterick, 1981; Harper, 1984, 1987) and macro invertebrates (Clark, *et al.*, 1989; Muchiri, 1990) indicate that the off-shor secondary production is high.

With the fishery based on species that depend to a large extent on the stabilit of the water levels, and which do not utilize all available resources in terms o food and space, it becomes tempting to support earlier suggestions (e.g. the Fisheries Department; Siddiqui, 1977) to introduce additional fish species to exploit the remaining niches. The option of further introductions is attractive not only in diversifying the ecosystem, but the subsequent increase in the commercial catches would provide greater availability of much needed protein and a useful increase in employment opportunity.

Early consideration should be given to assessing the suitability of those fish that could be contenders for introduction. Possible species are: *Limnothrissa miodon*, *Stolothrissa tanganyikae* or *Alestes* spp. to occupy the open water and feed on zooplankton; *Heterotis niloticus* to consume phytoplankton; *Mormyrus* spp. or *Haplochromis angustifrons* to feed on the benthos. The feasibility appraisals must carefully consider all aspects of biology and ecology such as recommended in the EIFAC (1988) code of practice.

Due to the very unstable conditions that continually affect the ecology of Lake

Naivasha there is need for continuous appraisal of the fishery in order to facilitate implementation of appropriate management measures. Meaningful assessment of the fishery calls for more precise data collection in relation to the commercial catch and the MSY and optimum effort should be determined regularly in order to maintain the fishing pressure within the capacity of the fishery. It is suggested that, in future, numbers of gill nets be the measure of effort when determining the optimum exploitation rather than the number of canoes licensed. As a result, the number of craft could remain high (thus accommodating more fishermen) whilst the number of actual gill nets would be maintained at the optimum level. It is more difficult to keep away a fisherman who depends on the fishery for his livelihood than it is to adjust the number of nets he is allowed to use.

Enforcement of the fisheries regulations is essential if accurate catch statistics are to be obtained. Also, until the problem of illegal fishing is resolved, there can never be effective management. Accordingly, attempts need to be made to increase the numbers of trained personnel engaged in the management of the fisheries resource, to upgrade transport, to improve communication and to ensure that fish catches are landed at the central landing station only.

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References

Clark, F., Beeby, A. and Kirby, P. (1989) A study of the macro-invertebrates of Lakes Naivasha, Oloidien and Sonachi, Kenya. *Rev. Hydrobiol. Trop.* **22**: 21–23.

Elder, H.Y., Garrod, D.T. and Whitehead, P.J.P. (1971) Natural hybrids of the African cichlid fishes *Tilapia spirulus nigra* and *T. leucosticta*, a case of hybrid introgression. *Biol. J. Linn. Soc.* **3**: 103–146.

EIFAC (European Inland Fisheries Advisory Commission) (1988) Code of practice and manual of procedures for consideration of introductions and transfers of marine and freshwater organisms. *FAO EIFAC Occ. Pap.* No. **23**, 23 pp.

Fryer, G. and Iles, T.D. (1972) *The cichlid fishes of the great lakes of Africa: their biology and evolution*. Neptune City, New Jersey, T.F.H. Publ.; also Edinburgh, Oliver and Boyd.

Harper, D.M. (1984) Recent changes in the ecology of Lake Naivasha, Kenya. *Verh. Internat. Verein. fur Theor. Ang. Limnol.* **22**, 1192–1197.

Harper, D.M. (1987) The ecology and distribution of the zooplankton in Lakes Naivasha and Oloidien. In D.M. Harper (Ed.) University of Leicester studies on the Lake Naivasha ecosystem, 1982–1984; Final Report to the Kenya Government, 101–121.

Harper, D.M. (1990) Primary production in Lake Naivasha, Kenya. In prep.

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. *Env. Conserv.*, in press.

Henderson, H.F. and Welcomme, R.L. (1974) The relationship of yield to morphoedaphic index and number of fishermen in African inland fisheries. *UN/FAO CIFA Occ. Pap.* No. **1**, 19 pp.

Litterick, M.R., Gaudet, J.J., Kalff, J. and Melack, J.M. (1979) The limnology of an African lake, Lake Naivasha, Kenya. Manuscript prepared for the SIL-UNEP Workshop on Tropical Limnology, Nairobi. 73 pp. Mimeo.

Lowe-McConnell, R.H. (1982) Tilapias in fish communities. In *The Biology and Culture of Tilapias* (Ed. by R.S.V. Pullin and R.H. Lowe-McConnell), ICLARM Conference Proceedings **7**, 83–113.

Mavuti, K. and Litterick, M.R. (1981) Species composition and distribution of zooplankton in a tropical lake, Lake Naivasha, Kenya. *Arch. Hydobiol.* **93**: 52–58.

Melack, J.M. (1976) Primary production and fish yields in tropical lakes. *Trans. Am. Fish. Soc.* **105**: 575–580.

Melack, J.M. (1979) Photosynthetic rates in four tropical African fresh waters. *Freshwat. Biol.* **9**: 444–571.

Muchiri, M. (1990) The feeding ecology of tilapias and the fishery of Lake Naivasha, Kenya. PhD Thesis (unpublished), University of Leicester, UK.

Pauly, D. (1983) Some simple methods of assessing fish stocks. *F.A.O. (Rome) Fish. Tech. Pap.* No. **234**, 52 pp.

Ricker, W.E. (1975) Computation and interpretation of biological statistics of fish populations. *Bull. Fish. Res. Bd Can.* **191**: 382 pp.

Siddiqui. A.Q. (1977) Lake Naivasha (Kenya, East Africa) fishery and its management together with a note on the food habits of fishes. *Biol. Conserv.* **12**: 217–218.