HABITAT CHARACTERISTICS, FEEDING HABITS AND FOOD PREFERENCES BY A TILAPIINE FISH, *Oreochromis niloticus baringoensis*, (Trewavas, 1983) IN TURBIDITY- STRESSED SITES OF LAKE BARINGO, KENYA

BY

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Master of Science Thesis submitted to the Graduate school in partial fulfilment for the requirements of the Degree of Master of Science in Environmental Science

Egerton University

March, 2003

DECLARATION

DECLARATION BY THE CANDIDATE

This thesis is my original work and has NOT been presented for a degree in any other University.

Signature _____ Date 10th March 2003

Wilson Busienei

APPROVAL BY SUPERVISORS

This Master of Science thesis has been presented for examination with our approval as University Supervisors.

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DEDICATION

To my Brother George and friend Naomi in memory

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ABSTRACT

This study was carried out to determine water physico-chemical variables, biometrics, condition, food preferences and feeding habits of *Oreochromis niloticus baringoensis* in Lake Baringo, Kenya from December 2000 to May 2001. The turbidity ranged from 58.0-1327.9 NTU, temperature from 21.2-33.3° C whilst conductivity ranged from 221.0-5920 μS/cm. The condition of the fish ranged from 1.4 to 2.5. The dorsal and anal fin formulas were, DXVI, 12 and AIII, 9, respectively. The major components in the pelagic zone were zooplankton 3.6% and phytoplankton 96.3%. *Microcystis* and *Nitzschia sp.* contributed 41.3% and 35.5%, respectively, while *Mesocyclops sp.*, the most abundant zooplankton, contributed 1.3% of all the zooplankton. In the gut, zooplankton contributed 9% and phytoplankton 54.4%. In addition, detritus material contributed 22%, higher plant remains 12% and insect remains, 2%. The major components of the benthos were Diptera (1%), Molluscs (80%), Hemiptera, (18%), Plecoptera (0.9%) and Hirudinea (0.2%). Since there was no commonality between the benthos and the gut contents, pelagic zone was taken as the major contributor to the diet of *Oreochromis niloticus baringoensis*. The fish rejected about 66% of the possible food items, indicating a high degree of selectivity.

The major issue that emerged in this study is that turbidity, exacerbated by the anthropogenic activities in the lake catchment, has a profound effect on the diversity of the live food items of the *Oreochromis niloticus baringoensis* fish in Lake Baringo. With increased turbidity and catchment activities, the fish may encounter inadequate food supply leading to low fish productivity. The riparian communities, which depend on the lake water resources, will eventually have insufficient protein resources. Therefore there is need to control turbidity levels in Lake Baringo through proper management of the catchment resources.

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CHAPTER 1.0

INTRODUCTION

Lake Baringo is a shallow endorheic lake in the central part of the eastern branch of the East African Rift Valley. Clearance of vegetation cover for agricultural and other anthropogenic activities in its catchment has caused severe sediment loading to the extent that the lake water appears brown in colour. Annually, huge amounts of eroded soils are washed into the lake and LANDSAT images have clearly shown increased siltation in the lake (De Groot *et al.*, 1992).

Increases in suspended sediment loads alter aquatic habitats in several ways. For instance, increased turbidity reduces light penetration and result in reduced levels of primary productivity (Cohen *et al.*, 1993). In addition, incoming sediments may bind or release nutrients or toxins into the water, altering energy flows through communities by killing important species within the food chain (Alin *et al.*, 1999). Cracks and crevices may fill with fine sediments, reducing habitat heterogeneity and interstitial spaces (Waters, 1995; Alin *et al.*, 1999). This reduces the range of potential habitat types and predation refuges for many juvenile fish and invertebrate species (Alin *et al.*, op. cit.). Nevertheless, depending on the geological source of the sediments, high proportion of fine grain size particles probably have softening effects on the coarse

granite sandy sediments and hence provide habitats for burrowing invertebrates (Shivoga, 1999). Furthermore, burial of rocky substrates decreases the surface area available for epilithic algal growth and invertebrate colonisation. Bruton (1985) reviewed the effects of turbidity on fish and noted the most important effects as reduction in light penetration and consequently photosynthesis resulting in reduced food availability and plant biomass. Further, reduced visibility of pelagic prey, reduced availability of benthos food due to smothering, clogging of gillrakers and gill filaments were noted as some of the effects. Kotellat and Whitten (1996) further noted that freshly laid eggs are covered and deprived of oxygen and nursery grounds for the juveniles are also reduced. These impacts on biodiversity and fish productivity have not received ample attention from ichthyologists in developing countries but are well documented in the developed countries (Waters, 1995). In the tropics similar studies have been carried by Cohen *et al.*, (1993) and Alin *et al.*, (1999) in Lake Tanganyika in East Africa.

The fishing trends in Lake Baringo from 1983 to 1985 show that over 300 tonnes of fish were caught per year in the lake (De Groot *et al.*, 1992). The catches have been falling since 1986 from 141 tonnes to 70 tonnes in the 1987/88 and this trend has continued to the present day. The fish species found in the lake include *Oreochromis niloticus*

baringoensis (Trewavas, 1983), *Protopterus aethiopicus* (Heckel, 1851), *Labeo cylindricus* (Peters, 1852) and *Barbus intermedius* (Ruppell, 1836). *Aplocheilichthyes sp.*, which used to be abundant in the lake, is now rare in the catches (Republic of Kenya, 1996, Baringo District Development Plan, 1997-2001).

The most important commercially exploited fish species in Lake Baringo, *Oreochromis niloticus baringoensis,* has also shown declining population trends over the years perhaps due to changing environmental conditions and over fishing. *Labeo cylindricus,* an endangered species, was absent in the catches of 1991-1995 (Republic of Kenya, 1996, Baringo District Development Plan, 1997-2001). This decline in the population size of some fish species may be due to increased siltation/sedimentation in the lake (Republic of Kenya, 1996, Baringo District Development Plan, op.cit.).

Table 1: Fish Production Trends (Kgs) from 1991- 1995

Species	1991	1992	1993	1994	1995
Oreochromis	57510.7	164327.0	20484.4	4281.5	19507.3
P. aethiopicus	35897.1	50749.2	10629.8	3267.5	65934.0
C. gariepinus	28995.8	28591.0	6823.5	1755.0	30722.8
Barbus sp.	5827.8	5852.2	800.1	466.0	6040.55
L. cylindricus	–	20	–	–	–

Source: Department of Fisheries, Kabarnet, 1996

In 1981, the depth had reduced by 0.4 m because of deposition of 64 million m^3 of silt (De Groot *et al.*, 1992). The report estimated that 5 Million m^3 of sediment were removed from the catchment area of 5,000 square Kilometres each year. The effects of settlements and other activities in the in the islands could also be contributing to sediment loading in the lake. This was however not covered in this study. This situation probably has adverse effects on the quantity and quality of fish food resources, particularly the plankton and benthic organisms. No study has been done on the effect of sediment loading, turbidity and other physico-chemical water characteristics on the condition and feeding habits of *Oreochromis niloticus baringoensis* in Kenya. The results from this research are relevant to other lakes facing siltation problems due to poor basin management. Recommendations have been put forward on how highland areas through which the rivers flow could be protected from deforestation. Further, recommendations include how areas adjacent to the lake could be established as protected areas particularly where watersheds are easily eroded to prevent further sedimentation damages to this lake.

2.3 Problem Statement

Clearance of vegetation cover for agricultural and other anthropogenic activities in the watershed of Lake Baringo has resulted in severe sediment loading and turbidity, with consequent changes in other water

physico-chemical variables. Devastating ecological consequences on the biodiversity of the water body has been evident over the last decade. The high silt content results in reduced light penetration and consequently reduced photosynthesis. It further reduces visibility, fish food availability and quality and quantity of fish. High turbidity also modifies lake characteristics thus changing the physical and chemical variables such as the levels of pH and the general environment. Lake Baringo fish catch data indicate that some species are threatened with extinction such as *Labeo cylindricus* while others like *Aplocheilichthys* sp. are rare in the catches (Republic of Kenya, Baringo District Development Plan, 1994- 1996). *Oreochromis niloticus baringoensis* decline in catch, reduction in size and quality as observed in the recent years may be attributed to this problem.

The present study was therefore carried out with the general objective of looking at the effect of sediment loading and turbidity on the habitat, feeding habits and food preferences of *Oreochromis niloticus baringoensis.*

1.2 Objectives of the study

1. To determine the water characteristics at the three (low, moderate and high) turbidity study sites in Lake Baringo.

2. To determine the condition of *Oreochromis niloticus baringoensis* at the three sites with varying turbidity levels.
3. To analyse the gut contents of *O. niloticus baringoensis* at the three sites with varying sediment and turbidity intensities in the lake.
4. To compare the gut contents of *O. niloticus baringoensis* with the organisms in the pelagic zone and benthos at the three sites in the lake.
5. To provide a summary of biometrical characteristics, feeding habits and food preferences of *O. niloticus baringoensis* in the Lake Baringo ecosystem.
6. To provide fisheries managers and other stakeholders with information on the effects of turbidity on habitat characteristics and fish feeding habits in the lake.

1.3 Hypotheses

H_{o1} There is no significant difference in water characteristics between the low, moderate and high turbidity sites in Lake Baringo.

H_{o2} There is no significant difference in the fish condition between the low, moderate and high turbidity sites in the lake.

H_{03} There is no significant difference in the gut contents of the fish in sites with low, moderate and high turbidity levels.

H_{04} There is no significant difference between the gut contents and the same diet items in the pelagic zone and in the benthos at the three sites in the lake.

1.4 Justification

The impact of excess sediment loading and turbidity on the population and biodiversity of fish in the aquatic systems in the tropics has received scanty attention. In Lake Baringo, there has been no detailed study on the effect of sediment loading and turbidity on fish despite the fact that sediment loading is hypothesised to be one of the main causes of reduced fish size, population and species in the lake.

The lake basin is being deforested, which has led to increased soil erosion. Large volumes of sediment are being discharged and this has caused concern about potential effects of the anthropogenic disturbances in the catchment because of the economic and social importance of the lake as a source of water, fish and tourism. For instance, there are between 100-150 fishermen who depend on the fishery of this lake; they in turn support an estimated 500 families. Economically, the fishery contributed Ksh. 2 million from the sale of 249 tonnes of fish in 1992 and in the subsequent years, Ksh. 7 million was fetched from the sale of 1082 tonnes of fish (Republic of Kenya, 1996,

Baringo District Development Plan, 1997-2001). This catch is also supplied to other areas in Baringo District such as Kabarnet town and also the neighbouring Nakuru District, particularly Nakuru town. If this fishery is not properly managed then the town populations, which depend on this fishery, will miss the supply of this protein rich food. In addition, fishermen and entrepreneurs who are engaged in fisheries for income will be affected socially and economically.

Little knowledge of the aquatic ecosystem and the apparent increase in sediment loading and turbidity in Lake Baringo, accruing from increased human activities in its catchment, made Lake Baringo a suitable choice for the study. *Oreochromis niloticus baringoensis* was chosen for the study because, apart from being the most important commercially exploited fish species, it is also endemic to the lake. Further, the species is sensitive to changing habitats, especially those with increased sediment and turbidity levels (Lowe McConnell, 1958). *Oreochromis niloticus baringoensis* has been reported to be relatively smaller and matured early in comparison to the same species in other lakes in Kenya and East Africa (Ssentongo, 1974). A plausible explanation could be that the fish might be stressed by the increasing sediment and turbidity. The species was therefore a suitable choice for this study.

1.5 Definition of Terms

Benthos: This refers mainly to the organisms living at the bottom of a hydrosystem.

Condition factor: Derivative of growth mostly used in fishery biology in investigation of seasonal differences in the same species, differences between habitats and the fitness of fish. Dividing the weight (W) and the length (L) of fish gives the condition (K).

$K = W_t / L^3_t$, where t is time.

Diet: Refers to the food eaten by the fish.

Disturbance: In this study the term refers to the presence of excess soil particles in the water which disrupts/upsets the normal functioning of the ecosystem and consequently adversely affects its biota.

Endemic: Refers to the species restricted to a particular geographical region, owing to factors such as response to climatic conditions.

Feeding habits: Refers to what, how, when and where the fish in question feeds.

Sediment: Materials in a lake or river, which are either suspended in the water column or deposited on the bottom. They usually consist of the remains of aquatic organisms, precipitated minerals and eroded materials from the watershed.

Species: A group of organisms that resemble one another or one/more groups of individuals that can interbreed within the group and produce viable offspring but cannot exchange gene with other groups. Members of a species have a common ancestor and share features unique to the group.

Standard length: The distance from the most anterior projection of the lips to the origin of the caudal fin.

Stress: A physiological condition, usually affecting behaviour. It is produced by excess environmental pressure or change in environmental conditions.

Total length: The length from the tip of the mouth to the end of the caudal fin.

Turbidity: Optical property by which light penetration is inhibited by the presence of insoluble material.

Transparency: The ease with which light is able to penetrate the body of water.

CHAPTER 2.0

LITERATURE REVIEW

2.1 Physico-chemical variables

The physico-chemical variables play an important role in determining the type of fauna and flora inhabiting a water body. The question of which of the variables are most important, has been and still remains a central concern of ecologists (Hynes, 1970). Mathooko (1988) identified dissolved oxygen, temperature, transparency and turbidity as the most important factors influencing the presence of mayfly *Caenis kungu* in the Naro Moru River, Kenya. The study also noted that food quantity, quality and predation were equally important. Thomas *et al.*, (1992) noted that increased turbidity caused by an increase in mineral materials; brings changes in transparency in lakes. This was probably caused by turbid inflows resulting from watershed erosion rates and/or resuspension of bottom sediment by wave action in shallow lakes.

Lake Baringo has not been studied as intensively as other lakes in Kenya. Beadle (1932) found that secchi disc visibility was 5-7 cm. Worthington (1932) recorded a pH range of 8.7-8.9. Further, Talling and Talling (1965) recorded a low conductivity of 416 µs/cm. In more recent years, Kiplagat (1989) measured a high conductivity ranging from 980-1200 µS/cm. Kallqvist (1987) carried out a detailed analysis of physical and chemical

properties of the lake water and found that the water temperature and dissolved oxygen were on average 25^0 C and 6 mgl^{-1}, respectively. It was concluded that the uniform temperature and dissolved oxygen over time was due to the efficient mixing of the lake. Kallqvist (op. cit.) further found the secchi disc visibility values similar to those measured by Beadle in 1976-1977 of 5-7 cm, but had increased to 20 cm in March 1979. The above transparency of the lake water was found to be very low and this was attributed to the high content of the suspended silt. The silt, which causes low transparency of lake water and gives it a brown colour, is derived from the surrounding eroded landscape.

2.2 Fish species found in Lake Baringo

The Cambridge expedition to the East African lakes in 1930-31 recorded four species of fish, *Tilapia nilotica*, *Barbus gregorii, Clarias mossambicus* and *Labeo cylindricus* (Worthington & Ricardo, 1936). In the 1969 Cambridge survey, two more species were identified, *Aplocheilichthys* sp. and *Barbus lineamaculatus.* Fish species of Lake Baringo have so far been redescribed by Ssentongo (1974). The following are the fish species known to be found in Lake Baringo to date:

a) ***Oreochromis niloticus baringoensis*** (Trewavas, 1983)

It was first identified as *Tilapia nilotica* by Trewavas (1933). During subsequent surveys no other tilapia species has been identified. However, further reviews by the same author redescribed the species as *Oreochromis niloticus baringoensis* (Plate 1) because of its uniqueness compared with other *Oreochromis* species in the region.

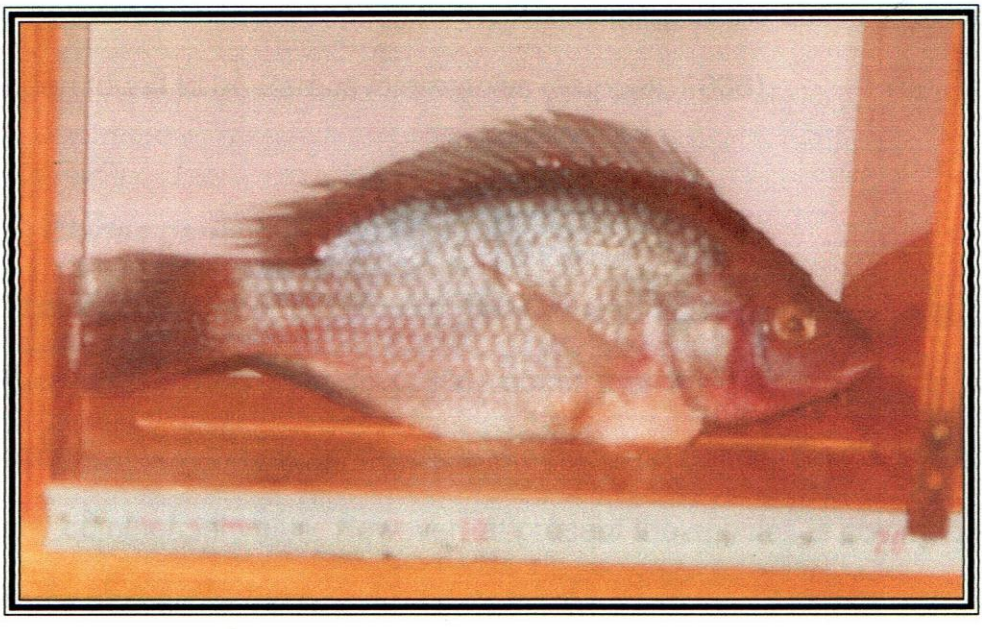


Plate 1: *Oreochromis niloticus baringoensis*, (average length, 20cm).

b) *Barbus Species*

There are two species of *Barbus* in Lake Baringo, *Barbus gregorii* Boulenger, 1902 and *Barbus lineamaculatus* Boulenger, 1903. *B. gregorii* was found to be abundant in the lake by Worthington and Ricardo (1936) and grew to a length of 68.0 cm. It was further observed that the species

was a bottom feeder and its gut contents consisted of benthos diatoms, zooplankton, algae and small weed and seed fragments. Chironomid larvae and aquatic insect remains were also found. Mann (1971) comments on *B. lineamaculatus* that were first recorded in the Baringo basin as small species with standard length of 1.8 to 6.6 cm. It was abundant near the river mouths with only a few in the open water. However, in the recent past, further description of the above species have been found to be *Barbus intermedius* (Ruppell, 1836).

c) *Clarias gariepinus* (Burchell, 1822)

The species was thought to be *Clarias mossambicus* Peters, 1852. Worthington and Ricardo (1936) noted that the species was in a poor condition with very large heads and emaciated bodies, hence it was not of any commercial value. However, at present the species is common and of high commercial value.

d) *Labeo cylindricus* (Peters 1852)

Worthington and Ricardo (1936) identified *Labeo* species from Lake Baringo. They noted that the species was more abundant in the affluent streams and also at the bottom of the rocky shores of Parmalok Island.

e) *Protopterus aethiopicus* (Heckel, 1851)

The species is of much commercial value. It is more abundant in the open water near the Kokwa Islands (R. Kulal, pers.com.).

f) *Aplocheilichthys sp.*

Mann (1971) noted that the species was found mostly in the rivers and on the rapids, shallow pools and muddy backwaters. It was also observed that they were abundant among the thick stands of *Typha* on the shores of the lake.

2.3 General effects of sediment loading and turbidity on fish, fish food and habitat

Several researchers through laboratory and field experiments have reported decreased feeding and growth by fish in turbid conditions resulting from suspended sediment. For example, Cleary (1956) and Larimore (1975), cit. in Waters (1995) noted that turbidity in small mouth bass caused very young fry to be displaced due to the loss of visual orientation. Experimental research on feeding and growth has elucidated impaired feeding ability by most species (Mcleay *et al.*, 1987; Redding *et al.*, 1987; Reynolds *et al.*, 1989 cit. in Waters, 1995). Mathooko (1993) observed that during periods of high water clarity in the Naro Moru River, *Caenis kungu* Kimm., a caenid mayfly, was high in the drift hence more

available to rainbow trout compared to periods of high discharge and poor water clarity.

Fine sediment originating from a broad array of human activities constitutes one major environmental factor in the decline of fishes. Cordone and Kelly (1961) concluded that adult fishes could survive suspended silt concentrations, which are usually encountered in natural conditions but would succumb when concentrations reach high levels that damage or coat the gill surfaces. Further, they raised concern about several sub-lethal effects of suspended sediment on fish, such as lowered body condition, slower growth and reduced productivity. Wallen (1951) found direct mortality of fish at high sediment concentrations mostly due to clogging of opercula cavities and gill filaments, which impaired respiration. Gill damages leading to respiratory impairment by suspended sediment concentrations have also been reported by Berg and Northcote (1985). In addition, Berkman and Rabeni (1987) studied the effect of sedimentation in streams located in an agricultural area of Missouri and found that silt reduced the abundance of the riffle feeding fish. Fish species have been known to disappear as a result of prolonged high turbidity in their habitats (Smith 1940; Larimore and Smith 1963; Trautman 1981).

Algae and other plants in aquatic ecosystems constitute the base for the food chains (Kallqvist, 1987). Thus there is a connection between primary

production and potential fish yields. Suspended sediments affect light availability to photosynthesising plants and visual capacity of aquatic animals (Waters, 1995). It affects the habitat available for invertebrates, quality of gravel for spawning and amount of habitat for fish rearing (Kallqvist, 1987; Cohen *et al.*, 1993). A major concern in the relationship between sediment and invertebrates is the question of the effect on fish production as a result of reduced invertebrate production due to sediment disturbance. In the Klamath River and tributaries in California, lower abundance of invertebrates were observed in streams subjected to sedimentation from mining operations (Taft and Shapovalov, 1935). Sumner and Smith (1940) reported substantial reductions in fish food organisms in tributaries of the American and Yuba Rivers, California, as a result of suspended sediment. The streams had been subjected to hydraulic gold mining, a process that produced enormous quantities of sediment. Waters (1995) found that turbidity was one factor that had an impact on the fish species richness and abundance in Green Bay, Lake Michigan. The study attributed this to reduced plankton productivity.

Several laboratory experiments have been conducted to demonstrate the effect of sediment on fish. Brusven and Rose (1981) reported that feeding efficiency of sculpin fish reduced with increasing percentages of smaller sediment particles. Alexander and Hansen (1986) found that benthos

densities and abundance of brook trout decreased to less than half with the addition of large quantities of sand to a trout stream in Michigan. Furthermore, the bottom fauna densities and biomass in Truckee River, California, were reduced by 10% of the former levels when fine sediments from a gravel washing operation were increased at the streambed. Shivoga (1999) showed that the relative proportions of larger sediment grain sizes in fine sediment streams are more important determinants of distribution of the benthos fauna.

Cohen *et al.*, (1993), in their study on the impact of sediment pollution in Lake Tanganyika, concluded that suspended sediment reduces light penetration hence the rate of photosynthesis. In addition, they concluded that settling sediments might blanket benthic algae thus have an indirect effect on the fish particularly herbivorous fishes. Physical damage may also occur when particles abrade the fish body surfaces.

2.4 Other factors that affect fish condition and feeding

Food supply, food quality, feeding rate, parasites and reproductive activity play an important role in fish condition and feeding (Le Cren, 1951; Bowen, 1979 cit. in Abebe and Getachew, 1992; Getachew, 1987). Although many fishes are adapted to their environments, such adaptations involve local movements thus avoiding the adverse conditions

(Welcomme, 1983). Lack of dissolved oxygen leads to catastrophic mortalities. Most fish will die when oxygen falls below 20% saturation thus it is one of the most important factors that determine the distribution of individual fish (Welcomme, op. cit.). Relatively high water temperatures of less than 30°C are preferred by most tropical species especially the juveniles and in the nursery grounds because of faster growth and food availability. However, extremely high temperatures will kill most species though it is limited to specific species. Whereas haplochromine species die at 38° C, *Oreochromis* species would still survive at this temperature (Welcomme, 1983.). Transparency of water limits phytoplankton abundance and distribution. This is due to its effect on photosynthetic activity, which will be limited by depth. The pH has important implications for fish health. Preferred ranges are 6.4-8.4 for most fish species and fluctuations are extremely stressful and a sudden drop in pH causes severe damage to the gills (Welcomme, 1983.).

Abebe and Getachew (1992) have shown that growth and/ or condition of *Oreochromis niloticus* in Lake Ziway is affected by its feeding rate, which they found to be generally low. They attributed the low feeding rate of the fish population in the lake to high temperature fluctuations and wind-induced mixing of the lake that forces the fish to spend most of its time and energy on maintaining its balance rather than feeding. Because of the poor condition they mature early (Lowe-McConnell, 1982 cit. in Abebe and

Getachew 1992). Male and females of 16.2 cm and 13.8 cm length, respectively, have been observed to be mature in Lake Ziway (Tadese, 1988 cit. in Abebe and Getachew, 1992).

The body of fish prior or during reproductive period spends most of its energy for production of sperm and egg for male and female, respectively. In mouth brooders such as *Oreochromis niloticus,* the females do not eat during the early stages and/ or during the whole brooding period and this significantly affect the condition of the females (Abebe and Getachew, 1992).

2.5 Biology and ecology of *Oreochromis niloticus baringoensis*

Oreochromis niloticus baringoensis (Family: Cichlidae) is endemic to Lake Baringo and has characteristics that place it under the subspecies *baringoensis* (Trewavas, 1983). According to Trewavas (op.cit.), the features that place it with other fish belonging to *Oreochromis niloticus* species include 32 or 33 scales in the lateral line, 20 - 24 gill rakers on the lower part of the first arch, and black and dark grey colour on the upper dorsal fin.

The characteristics that distinguish *O. niloticus baringoensis* include tricuspid jaw-teeth. Its colour is very pale compared with the other

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populations of *Oreochromis niloticus*, although this may be an environmental factor because of lack of shed in the lake. The red flush characteristics of the males in other populations are usually absent (Trewavas, 1983).

The maximum size reported is 36 cm in total length and the fish start maturing at 18 cm (Worthington and Ricardo, 1936). In comparison, the maximum length of *Oreochromis niloticus* is 40 cm and the length at maturity 28 cm in Lake George whilst in Lake Turkana, the maximum length is 64 cm and maturity length is 39 cm (Ssentongo, 1971 cit. in Ssentongo, 1974). Lowe-McConnell (1958) noted that the species in Lake Baringo are smaller compared to the *Oreochromis* species in other East African lakes. He suggested that this could be due to inadequate food supply as well as the little vegetation, turbid water and few epiphytic diatoms, which were noted as important items in the diet of the species.

Fish are selective to some extent in what they eat and once a particular fish has started feeding on one type of organism it tends to continue to do so (Mathooko, 1988). It was further shown that even though a given food item is plentiful in the environment, it might not be selected and consumed as expected. Contrary, food items minimal in the environment may be selected and consumed readily with total or partial rejection of most abundant potential food items.

O. niloticus has been described as a microphagous species that feed on seston from suspension or from water-sediment interface. Studies on the feeding habits of this species carried out by Lowe-McConnell (1958) reported phytoplankton and diatoms as major food items of this species. In addition to blue green algae, Ganf (1972) and Moriarty and Moriarty (1973) observed that zooplankton dominated by copepods constituted the diet of the species. In contrast, Worthington and Ricardo (1936) found crustacea, chironomids and algae in the stomachs of *O. niloticus* in Lakes Edward, George and Albert, but only phytoplankton in those of fish from Lake Victoria. Detritus, phytoplankton, invertebrates, diatoms and protozoa were found in the stomach contents of the same fish species in Lake Turkana (Harbott, 1975) as well as in Lake Victoria (Balirwa 1990; Getabu 1994; Balirwa 1998). Seasonal cycles are very important in the determination of the availability of food particularly the phytoplankton. Getachew *et al.*, (2000) in Lake Ziway, Ethiopia, observed that towards the end of the rainy season phytoplankton bloom developed which was stimulated by nutrients carried by streams to the lake.

CHAPTER 3.0

MATERIALS AND METHODS

3.1 The study area

Lake Baringo (0^0 37' N, 36^0 04' E; elevation: 975 m above sea level) (Fig. 1) lies in an endorheic basin in the central part of the eastern branch of the East African Rift Valley. The catchment area of Lake Baringo is about 4926 km^2, covering mostly the western and southern regions and its actual lake surface area is 132 km^2 though with a lot of fluctuations, which have been attributed to the changing climatic conditions. To the west of the lake are the Tugen Hills, Loyamarok Hills to the north, Karau Escarpment to the east and Laboi Plains to the southwest. On the lake itself are a number of islands with Kokwa (with hot springs) being the largest. Longicharo, Parmalok, Samatian and Lesekut islands are situated at the centre of the lake whilst to the north are Rongena and Lekoros Islands.

A number of rivers discharge into the lake, most of them from the southern end. The Molo River flows throughout the year although it does not reach the lake on extremely dry seasons and thus more or less permanent while the Perkerra River is intermittent as it occasionally dries up though always with remnant pools of water. Ol-arabel, Endao and Mukutan Rivers are

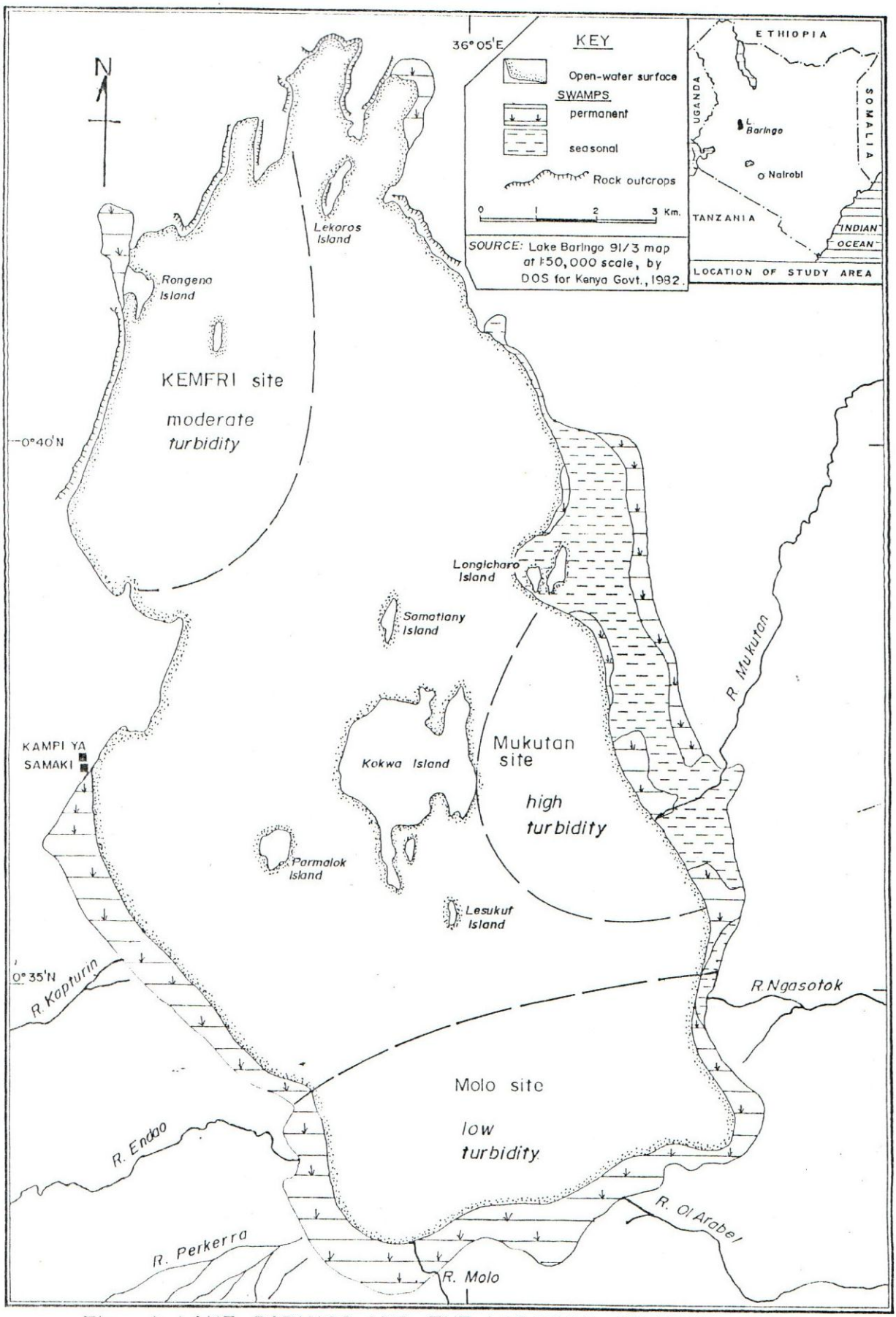


Fig. 1: LAKE BARINGO AND THE LOCATION OF STUDY SITES.

also intermittent. In addition, several other streams drain directly into the lake from the Tugen Hills.

Lake Baringo is situated within the arid part of Kenya. Average rainfall in the catchment area is estimated at 500-700 mm per annum although the highland areas receive 1000-1500 mm of rain (De Groot *et al.,* 1992). The rainfall is unreliable and fluctuates over time. The wet season in the area is from April - August. Rains falling outside this season are short erratic storms that cause severe erosion. The silty clay soils of the catchment have been severely eroded. This has caused siltation in the lake, thus its shrinkage. In 1981, the depth had reduced by 0.4 m because of deposition of 64 million m^3 of silt (De Groot *et al.* op. cit.). It is believed that the lake loses water via some intermittent underground outlets (Kiplagat, 1989). The air temperatures in the area range between 10-37 ^{0}C.

3.2 Study sites

The locations of the study sites within Lake Baringo are shown in Figure 1. For the analysis of the effect of the turbidity and other factors on the condition and feeding habits of *Oreochromis niloticus baringoensis*, three distinct sectors were chosen depending on the turbidity disturbance levels. Further, the lake was considered as an ecosystem and condition and feeding habits of the fish considered generally for the whole lake. Based

on the visually obvious differences in the extent of watershed deforestation, human and livestock population densities as well as inflowing rivers, the following three sites were discerned.

3.2.1 *Mukutan site (High turbidity):*

The site is located to the northeast of the lake. It is characterised by the presence of a seasonal swamp and in some areas permanent swamps. The sub-catchment has relatively low human population. Mukutan River enters the lake through this site. This is a high turbidity-stressed site even though the sub-catchment is relatively less disturbed. Consequently, it has a relatively low transparency.

3.2.2 *Kenya Marine and Fisheries Research Institute (KMFRI) site (Moderate turbidity):*

KMFRI is located to the north of the lake. The watershed on this side is characterised by low human and livestock population densities, relatively low deforestation and steep rocky cliff on the lakeshore (Plate 2). This is a complete contrast to the more disturbed Kampi ya Samaki side, which has a high human population, livestock and a landing beach (Plate 3). There are no rivers entering the lake at this site.

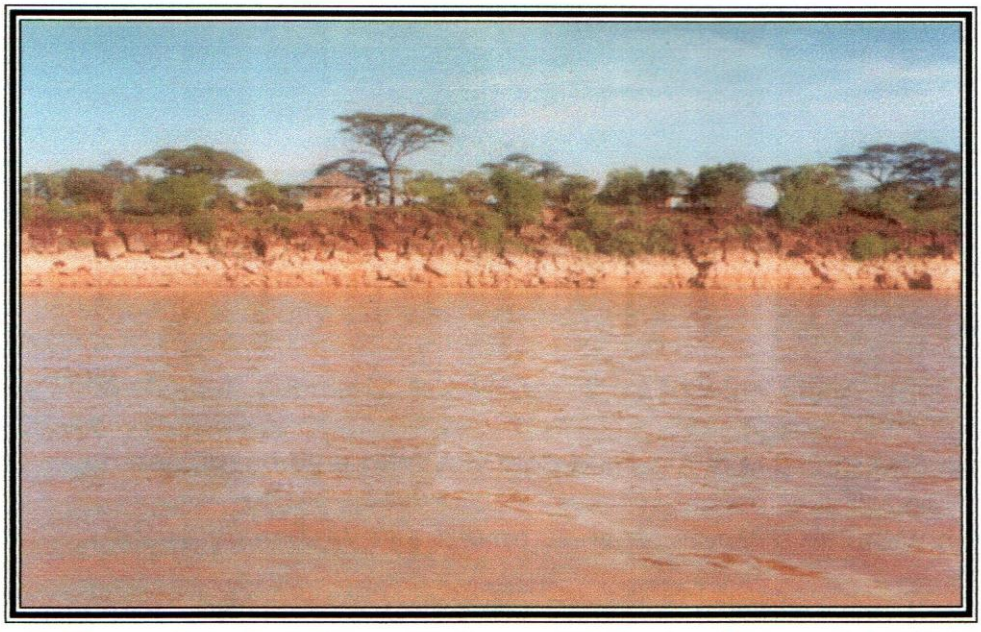


Plate 2: The undisturbed Kenya Marine and Fisheries Research Institute site

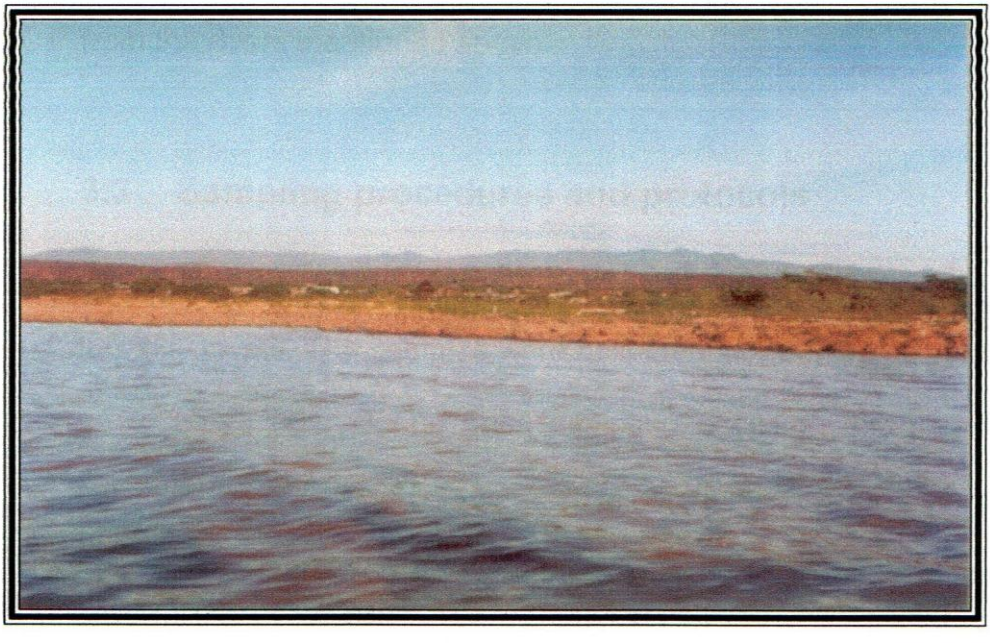


Plate 3: The highly populated Kampi ya Samaki

3.2.3 Molo River mouth (Molo) site, (Low turbidity):

The low turbidity site was located to the south of Lake Baringo. The sub-catchment popularly known as the 'Njemps flats' (Plate 4) area is characterised by a relatively high human and livestock population density. The watershed in this region is large, mostly deforested and heavily grazed by livestock unlike the Parmalok (Plate 5) and Kokwa (Plate 6) Islands. The five main rivers (Endao, Perkerra Molo, Ol Arabel and Ngosotok) draining into Lake Baringo enter the lake from the south. The site has a comparatively high transparency because of input of fresh water from the rivers mentioned above.

3.3 Sampling procedures and protocols

Samples were collected from three delineated sites, which varied in turbidity levels. The samples were collected monthly from December 2000 up to May 2001. During each sampling occasion three samples were collected from each site. Physico-chemical variables including temperature, turbidity, transparency, total dissolved solids, conductivity, dissolved oxygen concentration and saturation and pH were measured in all the sampling sites. Plankton and benthos samples were collected using plankton net and a grab sampler, respectively, for the analysis of species composition while the fish were collected using a gill net for biometrics and the analysis of the gut contents.

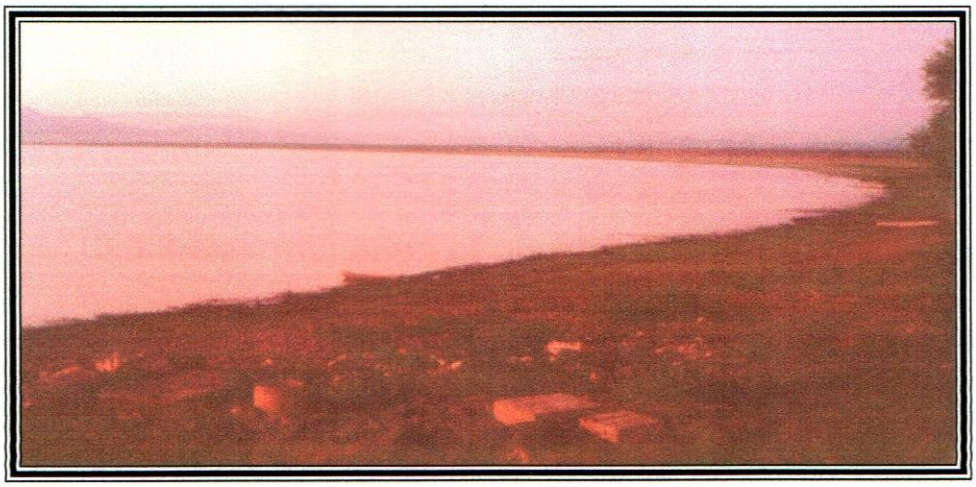


Plate 4: The highly grazed 'Njemps flats' located to the south of the lake

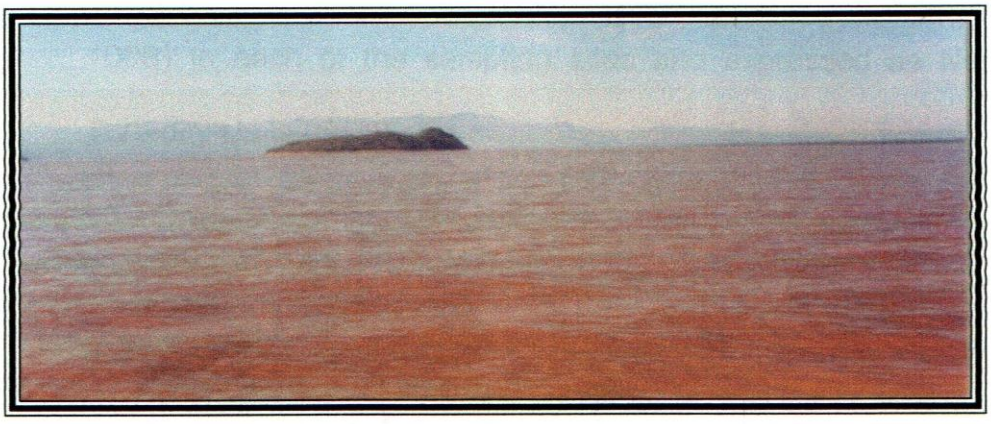


Plate 5: Parmalok Island located to the middle of the lake

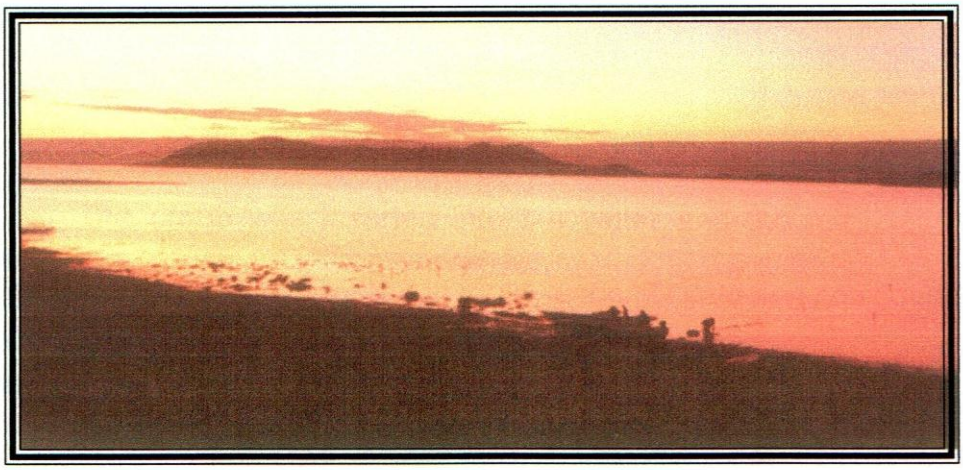


Plate 6: Kokwa Island which has hot springs

3.3.1 Determination of physical and chemical variables

Water temperature was measured to two decimal places using a water temperature meter (Model OXI92). The temperature was recorded at the three randomly selected positions within the site by inserting a probe into the water.

Turbidity readings were measured using a turbidity meter (model DRT 100B) in each of the sampling sites and expressed as Nephelometric Turbidity Units (NTU).

The transparency of the lake water was determined by use of a secchi disk. The disk was lowered into the water to a point where it was just not visible any more and the depth noted. It was then raised to yet another point where it was slightly visible and the depth noted. The average of the two readings were then computed and noted for three randomly selected positions in each site.

Conductivity was determined by use of a conductivity meter (WTW, LF90). The probe was inserted into the water and the readings noted. Three readings were recorded in three randomly selected positions in each site.

The pH of water was determined using a pH meter (JENWAY 3071) in three selected positions in each sampling site by insertion of the probe and then taking the readings.

Dissolved oxygen was determined in three randomly selected positions in each site using a DO meter (OXI92) for both % saturation and concentration in mg/l.

TDS was determined three times from each site using a TDS meter (JENWAY 4076) and the readings recorded.

3.3.2 Collection of pelagic, benthos and fish samples

3.3.2.1 Pelagic and benthic samples

Samples from the pelagic zone were collected in each of the study sites using plankton net of mesh size 37 μm (mouth area: 0.015 m^2). The net was towed for about 1 minute along the transect several times at the rate of 0.006 m^3 /min for the sample. The contents were then transferred to labelled sample bottles. They were preserved using lugol's solution prior to transportation to the laboratory for sorting, identification and enumeration.

In the laboratory, a sample of 1 ml of the contents was drawn after thorough mixing, transferred to a slide, and covered with a cover slip. The

cells or colonies and other materials present were observed, sorted and identified using a microscope with magnification 40X, 100X and 400X, respectively. The number of algae, zooplankton, insects and other items were also observed, enumerated and recorded. For storage, the pelagic samples were preserved in 70% alcohol.

The benthic samples were collected by use of a grab sampler. The samples were placed in labelled polythene bags and preserved in 5% formalin. They were then transported to the laboratory for sorting, identification and enumeration.

Once in the laboratory, sediments were thoroughly washed in tap water with the help of sieves of 100 and 250 μm, respectively, making sure that none of the animals were lost in the process. Once sieved the organisms were transferred to petri dishes and observed under a dissecting microscope, identified to the lowest taxonomic level possible and enumerated.

3.3.2.2 Fish samples

Fish were caught at the low, moderate and high turbidity sites using a 72-mm mesh size gill net. Fishing was done between 0600 and 1400 hours. This was important because based on the index of stomach fullness as observed by and Moriarty and Moriarty (1973) and Getachew (1993),

Oreochromis sp. are known to feed actively shortly before dawn until dusk. The collected fish were kept in a cool-box and transported to the laboratory for examination of their diet and biometrics. The biometrics included total length, standard length, head length, head width, eye diameter, snout length and the number of the various spines and rays.

The fish were dissected and the gut contents removed. A sub-sample of 1 ml of the gut contents was drawn after thorough mixing, transferred to a slide, and covered with a cover slip. The organisms, cells or colonies and other materials present were observed, sorted and identified using a microscope with magnification 40X, 100X and 400X, respectively. The number of algae, zooplankton, insects and other items were observed, sorted, enumerated and recorded accordingly. For storage, the gut contents were kept in labelled bottles and preserved in 70% alcohol.

3.4 Data Analysis

The standard length (L) and weight (W) of fish were determined using a measuring board and a weighing balance to the nearest 0.1centimetre and gram, respectively. The measurements were then used in the computation of the length-weight relationship (equation 1) and the condition (K) of fish (equation 2):

$$W = aL^b \quad (1)$$

$$K = W_t/L_t^3 \quad (2)$$

where W_t = total weight of fish in grams and L_t = total length of fish in cm, a and b are constants.

To determine the selection and availability of the food items for fish in the pelagic zone and benthos at the three sites of Lake Baringo, the electivity index (E) of Ivlev (1961) was used:

$$E = R_i - P_i / R_i + P_i \quad (3)$$

where R_i = relative percentage of any food item in the gut and, P_i = relative value in percentage of the same food item in the pelagic zone or benthos. The values of E lie between –1 to +1 for total rejection and highly selected prey species, respectively.

The sexes of the fish were determined prior to the removal of the gonads. The weight of the gonads was determined for evaluation of the maturity (M) of the fish and calculated as follows:

$$M = (W_{gon.} / W_t) * 100 \quad (4)$$

where W_{gon} = weight (g) of the gonads and W_t = weight (g) of the fish.

Statistical analyses were carried out using selected tests of the Statistical Package for Social Sciences (SPSS for Windows, 1992). The means were

compared for the sampling sites (1-3) and sampling dates (1-6) using one-way analysis of variance (ANOVA) after logarithmic transformations. Comparisons of means were carried out with Tukey's honestly significance difference (HSD, α=0.05). Regression analysis was done for the relationship between the length and the weight of fish.

CHAPTER 4.0

RESULTS

4.1 Physical and chemical characteristics of water at the different sites of Lake Baringo, Kenya

4.1.1 Total dissolved solids (TDS)

Physico-chemical variables play an important role in the nature of an aquatic system. TDS ranged from 627-1045 mg/l with a mean (±se) of 928±24 at KMFRI site and 627-1132 mg/l with a mean of 898±24 at Mukutan site whilst at the Molo site it ranged from 95-1114 mg/l with a mean of 569±57. TDS was significantly different among the three sites (one-way ANOVA, $F_{(2, 105)} = 26.61$, $P<0.001$). Post-hoc comparisons showed that differences between mean TDS in the three sites were significantly higher at KMFRI site than at the Molo site (Tukey's honestly significance difference (HSD) test, $\alpha = 0.05$). TDS was significantly different among the sampling occasions (one-way ANOVA, $F_{(5, 102)} = 7.82$, $P<0.001$). Tukey's HSD test ($\alpha = 0.05$) showed that the months of December (627±0.0), January (747.18±48.39), April (724.06±88.17) and May (698.83±97.72) were significantly lower from those of February (947.22±13.95) and March (1045±12.76).

4.1.2 Temperature

Temperature ranged from 24.1-33.3^{0}C with a mean of 27.5±0.5^{0}C at the KMFRI site and at the Mukutan site it ranged from 21.2-31.7^{0}C with a mean of 25.3±0.5^{0}C. At the Molo site, mean temperature was 26.6±0.2^{0}C and ranged from 24.3-28.9^{0}C (Fig. 2). There was a highly significant difference in the water temperature among the three sites (one-way ANOVA, $F_{(2, 105)} = 7.40$, $P<0.001$). Post-hoc comparisons showed that mean temperatures were higher at the KMFRI site than at the other sites (Tukey's HSD test, $\alpha = 0.05$).

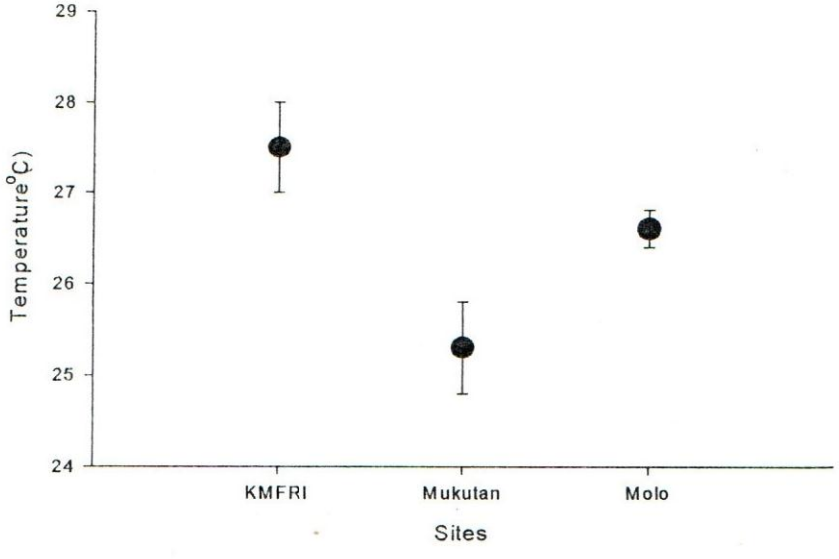


Fig. 2: Mean water temperature at the different sites of Lake Baringo, Vertical lines: ±se

Water temperature of Lake Baringo over the sampling occasions is presented in Fig. 3. Although water temperature was significantly different

temporally, (one-way ANOVA, $F_{(2, 105)} = 2.59$, $P<0.05$) multiple comparisons using Tukey's HSD at $\alpha = 0.05$ showed that water temperature of only two sampling months were significantly different from each other, i.e. December and February with 27.5°C and 24.9 ° C, respectively.

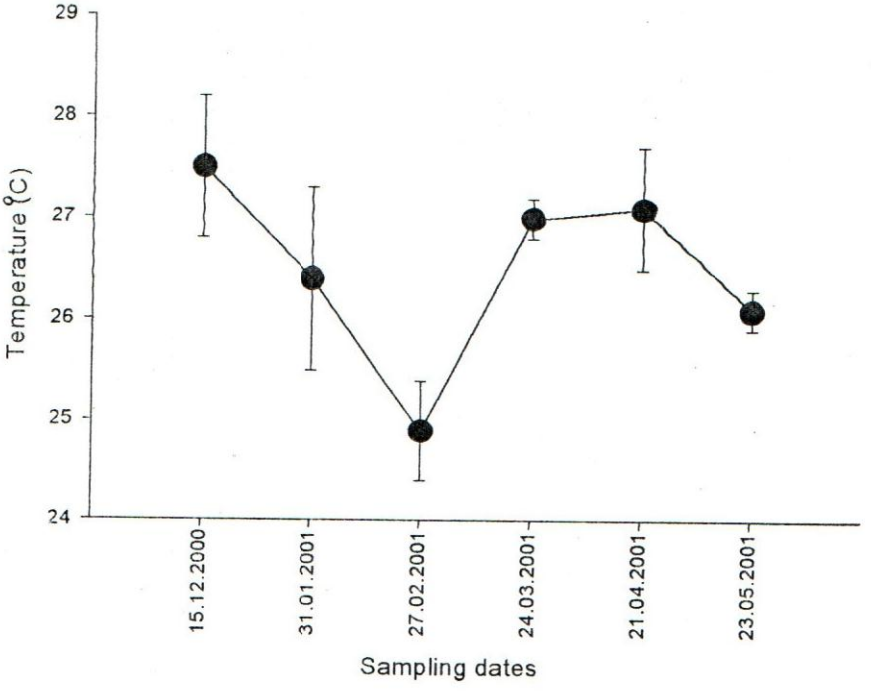


Fig. 3: Variations of water temperature in Lake Baringo, over the study duration. Vertical lines: ±se

4.1.3 Secchi depth

A mean of 4.9±0.2 cm and range of 3.0-6.5 cm was recorded at the KMFRI site whilst at the Mukutan site the mean was 4.4±0.2 cm and

ranged from 2.2-6.3 cm. At the Molo site, the mean was 9.0±1.4 cm and ranged from 2.2-32.0 cm. Secchi depth was significantly different among the sites (one-way ANOVA, $F_{(2,\ 105)} = 9.36$, $P<0.001$). Post-hoc comparisons showed that mean secchi depths were higher at the Molo site than at the other sites (Tukey's HSD test, $\alpha = 0.05$).

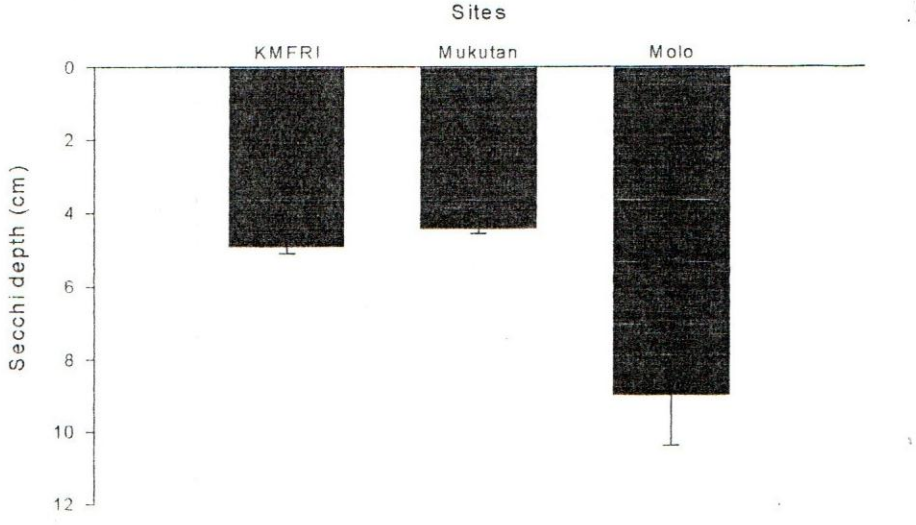


Fig. 4: Secchi depth at the three sites of Lake Baringo, Vertical lines: ±se

Secchi depth was significantly different among the sampling occasions (one-way ANOVA, $F_{(5,\ 102)} = 6.66$, $P<0.001$. Tukey's HSD test ($\alpha = 0.05$) showed that the months of December (4.44±0.19) January (5.14±0.20), February (2.88±0.10) and March (4.82±0.21) had lower secchi depths than April (8.98±1.31) and May (10.23±2.35).

4.1.4 Turbidity

Turbidity ranged from 449.4-973.8 NTU, with mean of 841.6±19.6 NTU at the KMFRI site while at the Mukutan site it ranged from 463.7-1327.9 NTU and a mean of 920.7±37.0 NTU. The Molo site had low mean turbidity (Fig. 5). The turbidity readings ranged from 58.0-1327.9 NTU with a mean of 320.1±17.2 NTU. Turbidity was significantly different among the sites (one-way ANOVA, $F_{(2, 105)}=156.05$, $P<0.001$). Tukey's HSD test, ($\alpha= 0.05$) showed that turbidity among the three sites was high at the Mukutan site than at the other sites. Turbidity was not significantly different among the sampling occasions (one-way ANOVA, $F_{(5, 102)}=1.92$, $P>0.05$).

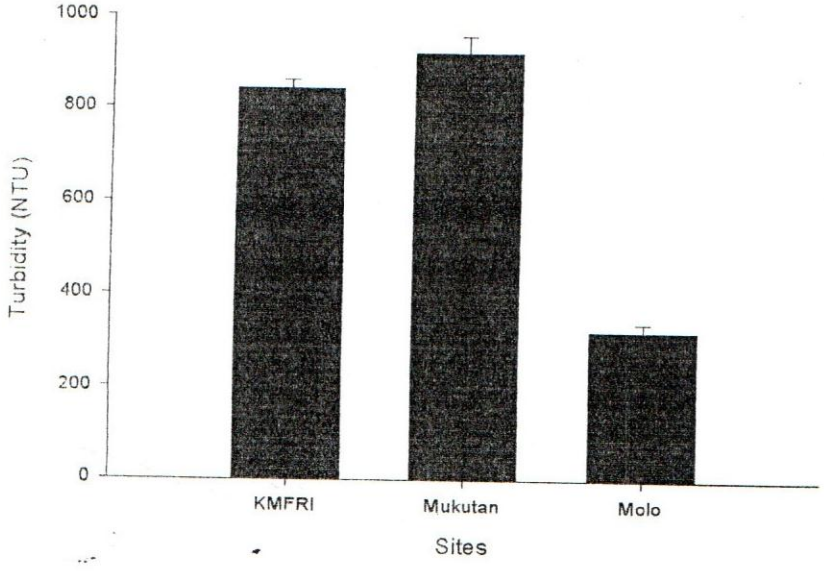


Fig. 5: Turbidity at the three study sites of Lake Baringo, Vertical lines: ±se

4.1.5 Dissolved oxygen

Dissolved oxygen saturation in the three sites is depicted in Figure 6. At KMFRI site dissolved oxygen (DO) and oxygen saturation ranged from 4.7-8.2 mg/l and 85-145%, respectively. Further, saturation ranged from 75-127% and dissolved oxygen concentration from 4.9-7.8 mg/l at the Mukutan site. At the Molo site, saturation ranged from 45-112% whilst dissolved oxygen concentration ranged from 2.2-10.8 mg/l. DO% saturation was significantly different among the three sites (one-way ANOVA, $F_{(2, 105)} = 20.61$, $P<0.001$). Post-hoc comparisons showed that mean DO saturation was highest at the KMFRI site (Tukey's HSD test, $\alpha = 0.05$).

Dissolved oxygen concentration was significantly different among the sites (one-way ANOVA, $F_{(2, 105)} = 3.54$, $P<0.05$). Post-hoc comparisons showed that mean DO concentration was highest at the KMFRI site (Tukey's HSD test, $\alpha = 0.05$). DO% saturation was also significantly different among the sampling occasions (one-way ANOVA, $F_{(5, 102)} = 7.89$, $P<0.001$). Tukey's HSD test ($\alpha = 0.05$) showed that the saturation recorded in the month of December (113.56±5.73) was significantly higher from that of January (83.22±2.85), February (91.11±3.99), March (93.72±2.19), April (92.22±2.76) and May (85.67±4.32). Dissolved oxygen concentration was also significantly different among the sampling occasions (one-way

ANOVA, $F_{(5, 102)}$ =6.79, P<0.001), with the highest concentration in the month of December of 7.02± 0.23 (Tukey's HSD test, α= 0.05).

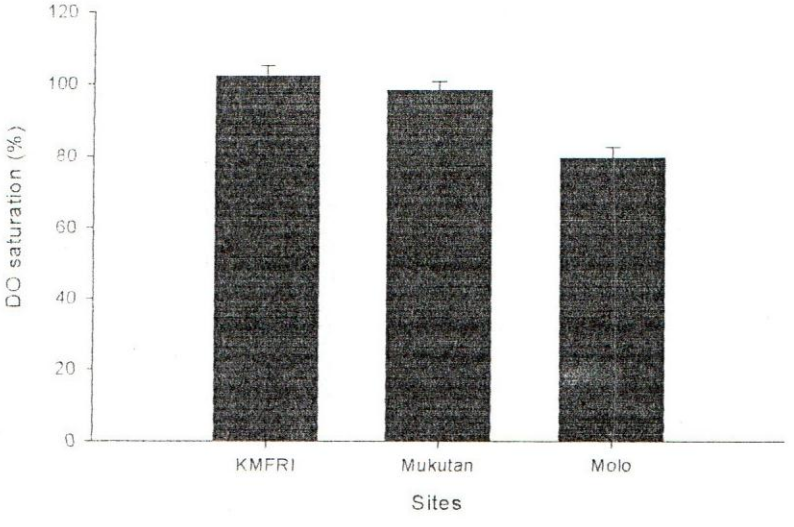


Fig. 6: Dissolved oxygen saturation at the different sites in Lake Baringo, Vertical lines: ±se

4.1.6 Conductivity

Mean water conductivity in the three sites is shown in Fig. 7, with conductivity at the KMFRI and Mukutan sites ranging from 1045-4968 with mean of 1803.40±42.30 µS/cm and 1633-5920 µS/cm, with mean of 2048.00±155.50, respectively. At the Molo site, a mean of 1280.49±114.28 µS/cm was recorded over the study period with ranges of 221-1999 µS/cm. Conductivity was significantly different among the three sites (one-way ANOVA, $F_{(2, 105)}$ =12.79, P<0.001). Post-hoc comparisons showed

that conductivity was highest at the Mukutan site (Tukey's HSD test, α= 0.05).

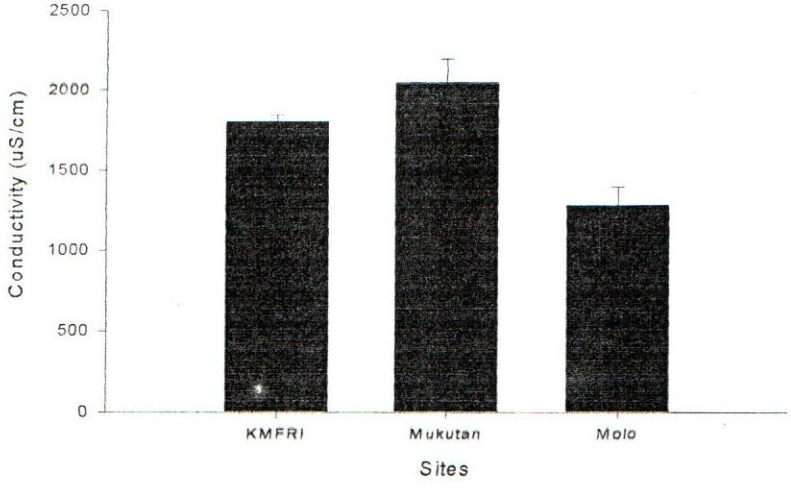


Fig. 7: Variations in conductivity at the different sites in Lake Baringo, Vertical lines: ±se

Fig. 8 shows the variation of water conductivity of Lake Baringo. It was significantly different among the sampling occasions (one-way ANOVA, $F_{(5\ 102)} = 4.26$, $P<0.001$). Tukey's HSD test showed that the water conductivity in the months of March and April, March and May were the only sampling months that were significantly different from each other.

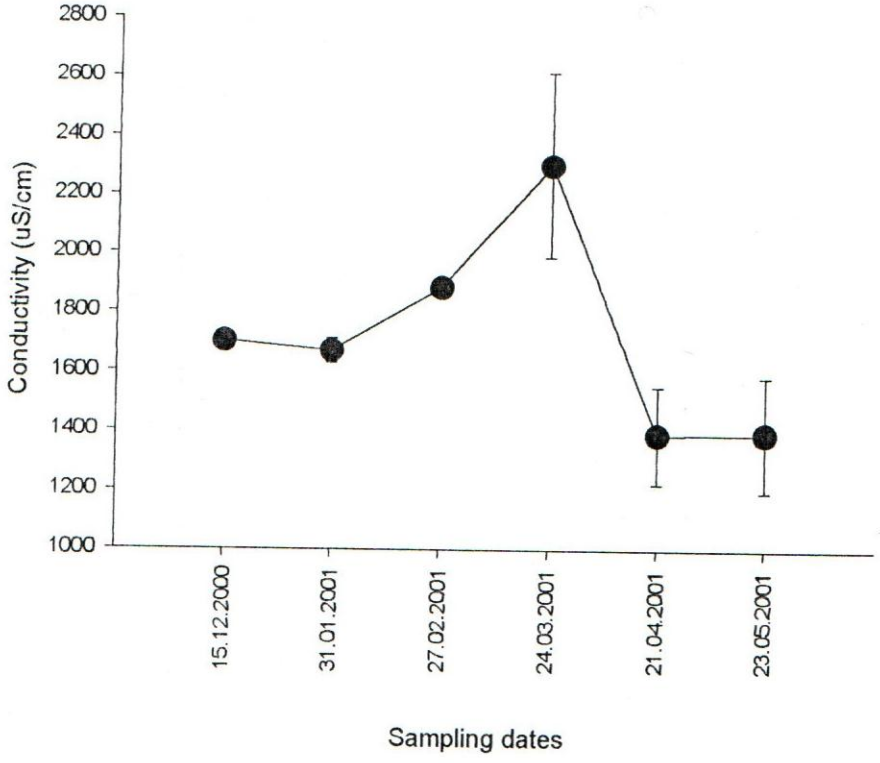


Fig. 8: Monthly variations in water conductivity in Lake Baringo over the study duration. Vertical lines: ±se

4.1.7 pH

The mean pH at the KMFRI site was 8.6±0.2 with a range of 7.3-9.9 while at the Mukutan site it ranged from 7.3-9.9 with a mean of 8.7±0.1. The pH recorded at the Molo site was 8.1±0.1 and a range of 6.1-9.4. pH was significantly different among the three sites (one-way ANOVA, $F_{(2, 105)} = 8.39$, $P<0.001$). The reading was highest at the Mukutan site (Tukey's HSD test, $\alpha = 0.05$). There was a significant difference in the pH readings (one-way ANOVA, $F_{(5, 102)} = 11.99$, $P<0.001$) with the pH in the months of

December (7.61±0.06) and January (7.93±0.12) being significantly higher from those of the February (9.13±0.12), March (8.78±0.19), April (8.83±0.22) and May (8.34±0.24).

4.2 Characteristics of *Oreochromis niloticus baringoensis* in the study sites

4.2.1 KMFRI site

The mean standard length of *Oreochromis niloticus baringoensis* was 13.5±0.5 cm and ranged from 9.8-21.5 cm (Table 1). The mean peduncle length was 1.4±0.1 and 10.5% of the standard length. Similarly, the head length was 32.1% of the standard length whilst the head width was 15.3% standard length. The length proportions of the snout, eye diameter and upper jaw lengths to the standard length were 10.1%, 7.5% and 8.0%, respectively. The mean total length was 16.8±0.6 cm and ranged from 12.0-26.5 cm while fish mean weight was 99.3±13.4 g and ranged from 35.9-374.8 g. The fish condition (K) was 1.85±0.04 and ranged from 1.43-2.20. The mean number of dorsal spines was 16±0.1 and dorsal rays 12±0.1. The dorsal fin formula was therefore D.XVI, 12. The mean number of anal spines was 3±0.05 and the soft rays 9±0.1, giving the anal fin formula as A.III, 9. Other characteristics of *Oreochromis niloticus baringoensis* are summarised in Table 1.

Table 2: Characteristics of *Oreochromis niloticus baringoensis* at the KMFRI site, Lake Baringo. (± Standard error), N = 31

Character	Mean ±se	Range
Standard length (cm)	13.5±0.5	9.8-21.5
Total length (cm)	16.8±0.6	12.0-26.5
Caudal peduncle length (cm)	1.4±0.1	0.8-2.4
Head length (cm)	4.3±0.2	2.9-7.0
Head width (cm)	2.1±0.1	1.3-3.6
Snout length (cm)	1.4±0.1	0.8-2.2
Eye diameter (cm)	1.0±0.0	0.7-1.6
Upper jaw length (cm)	1.1±0.1	0.5-1.9
Fish weight (g)	99.3±13.4	35.9-374.8
Gonad weight (g)	0.5±0.1	0.1-2.0
Condition factor (K)	1.85±0.0	1.4-2.2
Maturity factor (M)	0.6±0.1	0.1-2.3
Dorsal spines	16±0.1	15-17
Dorsal soft rays	12±0.1	10-13
Anal spines	3±0.1	2-4
Anal soft rays	9±0.1	8-11
Total pectoral rays	12±0.2	9-13

The length-weight relationship was linear and is depicted in Figure 9.

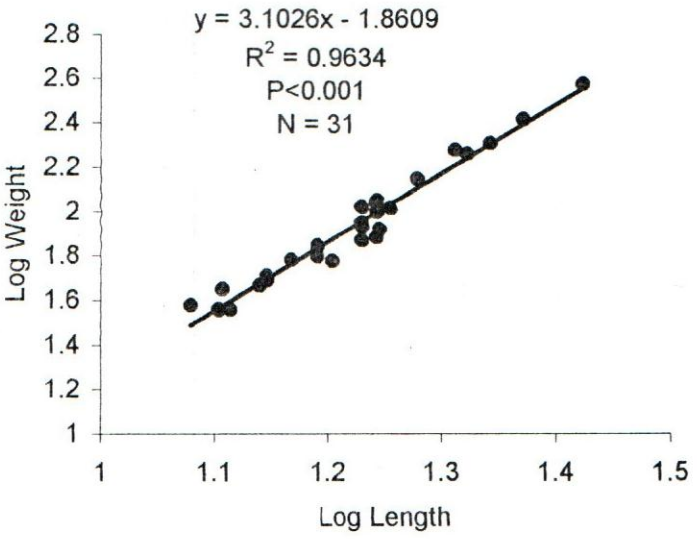


Fig. 9: Fish length-weight relationship at the KMFRI site of Lake Baringo

4.2.2 Mukutan site

Table 2 gives details of the characteristics of *Oreochromis niloticus baringoensis* at the Mukutan site in Lake Baringo. The mean standard length of the fish was 16.3±0.4 cm and ranged from 11.5-25.0 cm. The mean head length and width were 32.0% and 16.1% standard length, respectively. The mean total length was 19.9±0.4 cm and ranged from 14.2-30.0 cm while the mean fish weight was 170.9±12.3 g and ranged from 53.0-516.1 g.

Table 3: Characteristics of *Oreochromis niloticus baringoensis* at the Mukutan site of Lake Baringo. (± Standard error), N = 51.

Character	Mean ±se	Range
Standard length (cm)	16.3±0.4	11.5-25.0
Total length (cm)	19.9±0.4	14.2-30.0
Caudal peduncle length (cm)	1.64±0.0	1.0-2.3
Head length (cm)	5.2±0.1	2.5-7.5
Head width (cm)	2.6±0.1	1.5-4.4
Snout length (cm)	1.6±0.1	1-2.6
Eye diameter (cm)	1.1±0.0	0.9-1.8
Upper jaw length (cm)	1.3±0.1	1.0-2.4
Fish weight (g)	170.9±12.3	53-516.1
Gonad weight (g)	0.9±0.1	0.001-2.8
Condition factor (K)	2.0±0.0	1.6-2.5
Maturity factor (M)	0.6±0.1	0.001-3.4
Dorsal spines	16±0.1	15-18
Dorsal soft rays	12±0.1	10-13
Anal spines	3±0.02	3-4
Anal soft rays	9±0.1	8-10
Total pectoral rays	12±0.2	9-14

The length-weight relationship was similar to that of the fish at KMFRI site (Fig. 10). The fish condition factor (K) for the fish at the Mukutan site ranged from 1.57-2.48 with a mean of 2.02±0.03. The mean and ranges of dorsal spines, dorsal rays, anal spines, anal rays and total pectoral rays were similar as those of the fish at KMFRI site.

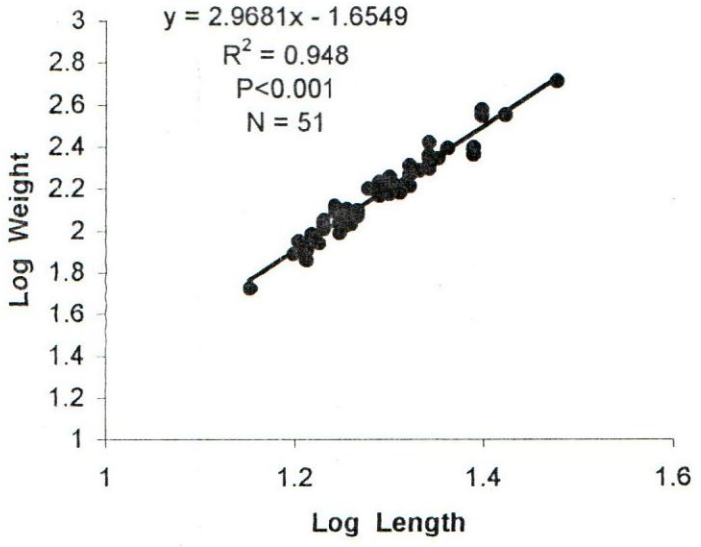


Fig. 10: Fish length-weight relationship at the Mukutan site of Lake Baringo. Vertical lines: ±se

4.2.3 Molo site

The mean standard length of the fish at the Molo site was 15.0±0.4 cm and ranged from 9.5-22.5 cm. The peduncle length was 10.6% of the standard length. The head length and width were 32.3% and 14.8% of the standard length, respectively. The snout length, eye diameter and upper jaw length proportions to the standard length were 10.3%, 7.2% and 8.0%, respectively. The fish weights ranged from 34.0-470.4 g and the mean weight was 132.5±10.4 g. Details of the fish characteristics at the Molo site are given in Table 3. The gonad weight ranged from 0 because some of the fish caught had not developed the gonads

Table 4: Characteristics of *Oreochromis niloticus baringoensis* at the Molo site of Lake Baringo. (± Standard error), N = 58.

Character	Mean ±se	Range
Standard length (cm)	15.0±0.4	9.5-22.5
Total length (cm)	17.9±0.5	0-26.5
Caudal peduncle length (cm)	1.6±0.1	0-3.0
Head length (cm)	4.8±0.1	3.0-7.5
Head width (cm)	2.2±0.1	1.3-5.0
Snout length (cm)	1.5±0.1	0.9-3.0
Eye diameter (cm)	1.1±0.0	0.8-1.6
Upper jaw length (cm)	1.2±0.0	0.8-2.0
Fish weight (g)	132.5±10.4	34.0-470.4
Gonad weight (g)	0.8±0.1	0.0-4.3
Condition factor (K)	1.95±0.1	0-2.71
Maturity factor (M)	0.7±0.1	0.0-4.0
Dorsal spines	16±0.09	15-17
Dorsal soft rays	12±0.1	10-13
Anal spines	3±0.02	3-4
Anal soft rays	9±0.1	8-11
Total pectoral rays	12±0.2	9-14

The fish condition factor (K) ranged from 1.33-2.71 and a mean of 1.95±0.05. The K was 0 for one species because the total length could not be measured because a predator had eaten part of the fish. The fish length-weight relationship is shown in Fig. 11. It shows that this relationship was highly significant.

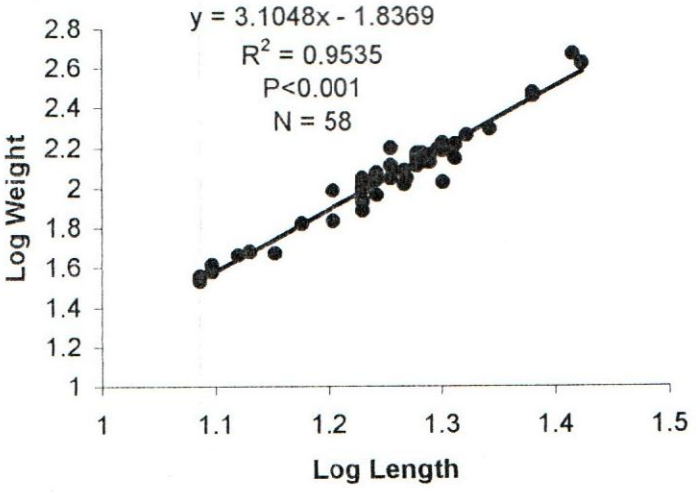


Fig.11: Fish Length-weight relationship at the Molo site of Lake Baringo, Vertical lines: ±se

4.3 Analysis of some selected fish characteristics

Total length of fish was found to be significantly different among the three sites (one-way ANOVA, $F_{(2, 136)} = 10.20$, $P<0.001$). KMFRI site had fish which were smaller in size (16.8±0.6cm) than in the other sites (Tukey's HSD test, $\alpha = 0.05$).The fish at the Mukutan and Molo sites were 19.9±0.4 and 17.9±0.5 cm in total length, respectively.

Total length of the fish was significantly different among the sampling occasions (one way ANOVA, $F_{(5, 133)} = 5.57$, $P<0.001$), with the month of February having the highest mean of 20.1±1.2 cm.

The fish weight was significantly different among the three sites (one-way ANOVA, $F_{(2, 137)} = 7.84$, $P<0.05$). The mean fish weight at the Mukutan site were significantly higher than the mean fish weight at the the KMFRI site. KMFRI site had fish with lowest mean weight of 99.3±13.4 g, Mukutan site with 170.9±12.3 g and Molo site had 132.5±10.4 g (Fig. 12).

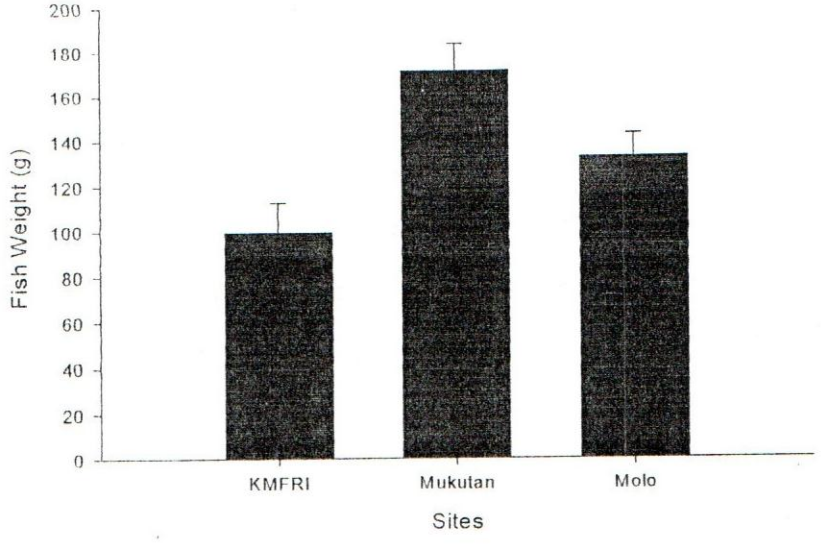


Fig.12: Fish weight at the different sites of Lake Baringo. Vertical lines: ±se

Fish weight was significantly different among the sampling months (one-way ANOVA, $F_{(5, 133)} = 4.76$, $P<0.001$), with the month of February having the highest mean of 201.9 ±24.9 g.

Fish gonad weight was significantly different among the three sites (one-way ANOVA, $F_{(2, 137)} = 3.35$, $P<0.05$). KMFRI and Mukutan site were

significantly different as discriminated by Tukey's HSD test (α= 0.05). Fish at KMFRI site had the lowest mean gonad weight of 0.5±0.1g whilst Mukutan site had 0.9±0.1g. Maturity factor was not significantly different among the different sites and among the sampling occasions (one-way ANOVA, $F_{(5, 133)}$=1.69, P>0.05 .

Condition factor (K) for the fish was significantly different among the three sites (one-way ANOVA, $F_{(2,136)}$ =6.37, P<0.05). Post-hoc multiple comparison using Tukey's HSD test (α= 0.05) showed that the condition (K) of fish at KMFRI was significantly different from the other sites. It had the lowest mean K of 1.85±0.04, Mukutan site 2.02±0.03 whilst the Molo site had K of 1.95±0.05 (Fig. 13).

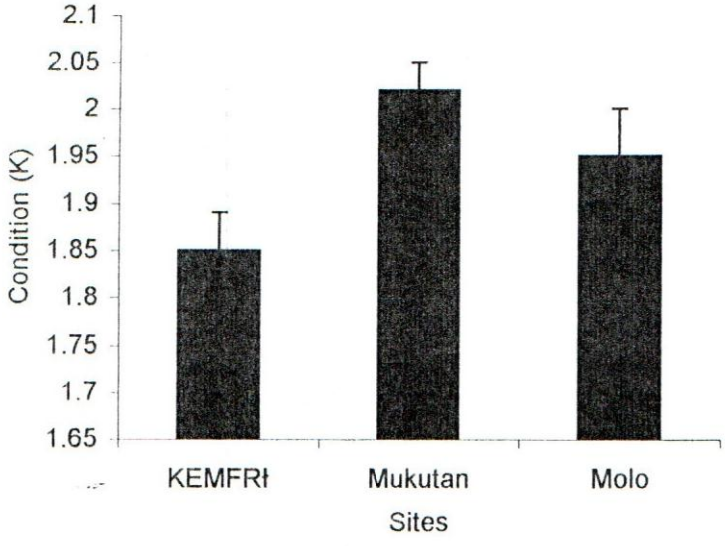


Fig.13: Fish condition in the three sites of Lake Baringo. Vertical lines: ±se

K was also significantly different among the sampling occasions (one-way ANOVA, $F_{(5, 133)} = 5.86$, $P<0.001$) with the highest condition recorded in January (Tukey's HSD test $\alpha=0.05$) (Fig. 14). The month of January was significantly different from the months of March, April and May.

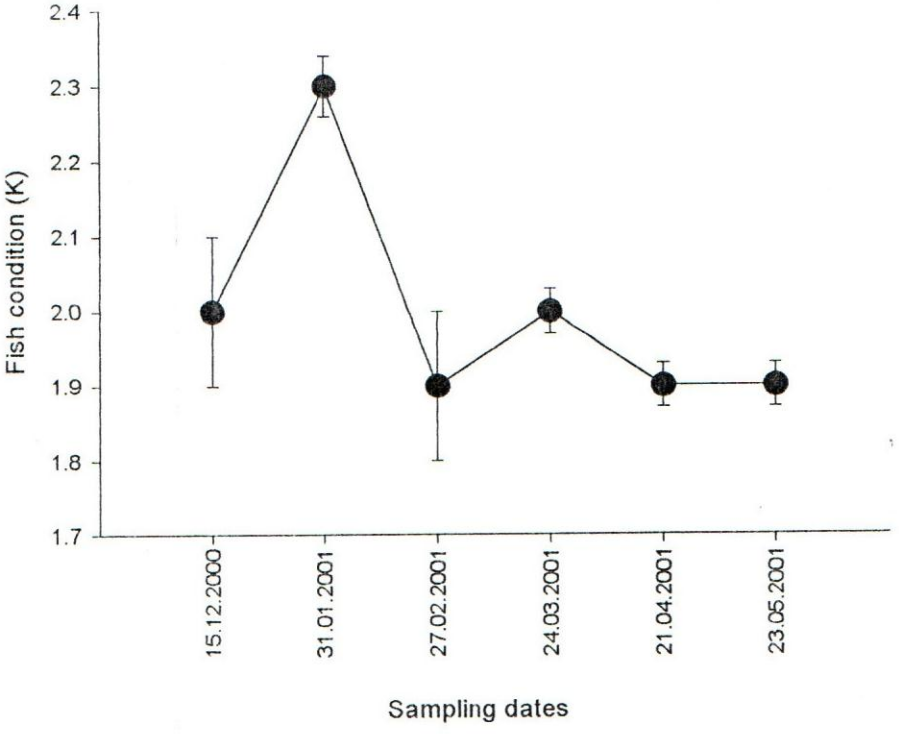


Fig. 14: Fish condition in Lake Baringo over the study duration. Vertical lines:±se

4.4 Composition of zooplankton and phytoplankton in the pelagic zone and benthos

4.4.1 KMFRI site

Zooplankton contributed 1.2% and phytoplankton 93.0% in the pelagic zone of this site (Table 5a). *Mesocyclops sp.* were the most abundant in the pelagic zone (0.42%), 2.5±1.0 individuals per net sweep.

Other zooplanktons that contributed appreciable proportions included *Keratella* and *Nauplius sp.* with 0.33% and 0.31%, respectively.

Of the phytoplankton in the pelagic zone, *Nitzschia* and *Microcystis sp.* contributed 42.1 and 34.2%, and 250.6±49.1 and 203.7±43.1 individuals per net sweep, respectively. Other phytoplankton that contributed appreciable proportions included *Synecocystis sp.* (7.7%) and *Protococcus sp.* (7.7%).

Table 5a: Summary for statistics for organisms in the pelagic zone at the KMFRI site of Lake Baringo. (± Standard error), * Mean number of individuals per net sweep

Pelagic organisms	* Mean number	Range	Total	%
Zooplankton				
Keratella	1.9±0.8	0-12	35	0.33
Brachionus	0.2±0.1	0-1	3	0.03
Filina	0.4±0.3	0-6	8	0.07
Daphnia	0.3±0.1	0-2	5	0.05
Nauplius	1.8±0.8	0-11	33	0.31
Mesocyclops	2.5±1.0	0-16	45	0.42
Eubranchibus	0.1±0.1	0-1	2	0.02
Phytoplankton				
Microcystis	203.7±43.1	0-600	3666	34.21
Nitzschia	250.6±49.1	0-700	4510	42.09
Phormidia	8.2±3.5	0-50	148	1.38
Navicula	18.3±10.6	0-160	330	3.08
Melosira	6.6±5.5	0-100	119	1.11
Pediastrum	0.2±0.1	0-1	3	0.03
Chlorella	3.0±2.2	0-36	54	0.50
Synecosystis	46.1±27.8	0-500	829	7.74
Closterium	0.1±0.1	0-1	2	0.02
Nostoc	0.1±0.1	0-1	1	0.01
Anabaena	6.2±5.6	0-100	112	1.05
Spirulina	0.1±0.1	0-1	1	0.01
Protococcus	44.4±29.4	0-500	800	7.74
Pseudoanabaena	0.2±0.2	0-4	4	0.04
Cladophora	0.2±0.1	0-2	4	0.04

The benthos had a totally different structure and composition (Table, 5b). It was dominated by *Lymnae sp.*, which contributed 97.7% of the benthos. Other macroinvertebrates contributed negligible proportions.

Table 5b: Summary of statistics for benthic organisms at the KMFRI site of Lake Baringo. (± Standard error), * Mean number of individuals per net sweep

Taxa	* Mean number	Range	Total	%
Diptera	0.1±0.1	0-2	2	0.3
Mollusca, *Lymnae sp.*	35.9±14.6	0-225	647	97.7
Hemiptera, *Notonecta sp.*	0.5±0.5	0-9	9	1.4
Plecoptera	0.2±0.2	0-3	4	0.6

4.4.2 Mukutan site

The dominant organisms in the pelagic zone were the phytoplankton, which comprised (94.0%) of the organisms (Table 6a). The dominant zooplankton in the pelagic zone were *Keratella* and *Mesocyclops sp.*, each contributing 2.0% of the organisms. *Brachionus sp.* contributed 0.8%. The other zooplankton contributed negligible percentages (<0.5%).

Microcystis and *Nitzschia sp.* contributed 53.3 and 28.7% of the phytoplankton, respectively. Other phytoplankton that contributed appreciable proportions included *Synecocystis sp.* (6.9%), *Navicula sp.* (2.3%) and *Chlorella sp.* (1.7%).

Table 6a: Summary of statistics for organisms in the pelagic zone at the Mukutan site of Lake Baringo. (± Standard error), * Mean number of individuals per net sweep

Pelagic organisms	*Mean number	Range	Total	%
Zooplankton				
Keratella	4.89±1.46	0-18	88	2.03
Brachionus	1.94±0.62	0-11	35	0.81
Filina	0.06±0.06	0-1	1	0.02
Diaptomus	0.06±0.06	0-1	1	0.02
Daphnia	0.44±0.2	0-3	8	0.18
Nauplius	2.11±1.6	0-16	38	0.52
Mesocyclops	4.89±1.59	0-23	88	2.03
Asplachna	0.06±0.06	0-1	1	0.02
Eubranchibus	0.06±0.06	0-1	1	0.02
Phytoplankton				
Microcystis	128.61±34.6	0-500	2315	53.32
Nitzschia	69.286±18.7	0-300	1247	28.72
Phormidia	1.22±3.49	0-50	148	0.51
Navicula	5.6±5.6	0-11	100	2.30
Melosira	0.11±0.11	0-2	2	0.05
Chlorella	4.07±3.03	0-50	75	1.73
Synecosystis	16.67±9.04	0-100	300	6.91
Anabaena	0.78±0.54	0-8	14	0.32
Oscillatoria	0.17±0.17	0-3	3	0.07
Ankistrodesmus	0.06±0.06	0-1	1	0.01

The structure and composition of the benthic invertebrate community (Table 6b) was different from that of the pelagic zone. *Notonecta sp.* and *Lymnae sp.* contributed the highest percentages.

Table 6b: Summary of statistics for organisms in the benthos in the Mukutan site of Lake Baringo. (± Standard error), *Mean number of individuals per net sweep

Sediment organisms	*Mean number	Range	Total	%
Diptera	0.17±0.12	0-2	3	1.1
Mollusca, *Lymnae sp.*	6.6±4.5	0-82	118	42.3
Hemiptera, *Notonecta sp.*	8.5±4.0	0-53	153	54.8
Hirudinea	0.06±0.06	0-1	1	0.4
Plecoptera	0.22±0.17	0-3	4	1.4

4.4.3 Molo site

The dominant organisms in the pelagic zone were the phytoplankton (91.7%) (Table 7a). *Microcystis, Nitzschia* and *Synecocystis sp.* contributed the largest percentage. *Mesocyclops* and *Brachionus sp.* contributed 3.6 and 2.0 %, respectively, of the zooplankton in the pelagic zone whilst *Keratella sp.* contributed 1.5%.

The benthos had a totally different invertebrate assemblage (Table 7b). *Lymnae sp.* contributed 70.1%, and *Notonecta sp.* 21.8%. The other invertebrates included Plecoptera (1.2%), Diptera (5.8%) and Hirudinea (1.2%).

Table 7a: Summary of statistics for organisms in the pelagic zone at the Molo site of Lake Baringo. (± Standard error), * mean number of individuals per net sweep

Pelagic organisms	*Mean number	Range	Total	%
Zooplankton				
Keratella	2.39±0.71	0-11	43	1.53
Brachionus	3.11±1.17	0-17	56	2.00
Filina	0.17±0.12	0-2	3	0.11
Diaptomus	0.33±0.23	0-3	6	0.21
Daphnia	0.06±0.06	0-1	1	0.04
Nauplius	1.00±0.41	0-5	18	0.64
Mesocyclops	5.67±2.54	0-41	102	3.64
Eubranchibus	0.28±0.28	0-5	5	0.18
Phytoplankton				
Microcystis	77.94±29.9	0-400	1403	50.04
Nitzschia	37.44±14.68	0-250	674	24.04
Phormidia	1.22±0.8	0-11	22	0.78
Navicula	0.67±0.67	0-12	12	0.43
Melosira	0.44±0.0.39	0-7	8	0.29
Pediastrum	0.06±0.06	0-1	1	0.04
Chlorella	3.33±2.8	0-50	60	2.14
Scenedesmus	0.11±0.08	0-1	2	0.07
Synecocystis	16.67±9.04	0-100	300	10.7
Cladophora	0.56±0.56	0-10	10	0.36
Anabaena	0.33±0.33	0-6	6	0.21
Oscillatoria	0.28±0.23	0-4	5	0.18
Oocystis	0.22±0.17	0-3	4	0.14
Closterium	0.39±0.39	0-7	7	0.25
Aphanocapsa	0.28±0.28	0-5	5	0.18
Protococcus	2.61±2.23	0-40	47	1.68
Spirulina	0.06±0.06	0-1	1	0.04
Spirogyra	0.11±0.11	0-2	2	0.07
Ankistrodesmus	0.06±0.06	0-1	1	0.04

Table 7b: Summary of statistics for organisms in the benthos at the Molo site of Lake Baringo (± Standard error), * mean number of individuals per net sweep

Sediment organisms	*Mean number	Range	Total	%
Diptera	0.28±0.28	0-5	5	5.7
Mollusca, *Lymnae sp.*	3.39±1.28	0-24	61	70.1
Hemiptera, *Notonecta sp.*	1.06±0.56	0-9	19	21.8
Hirudinea	0.06±0.06	0-1	1	1.2
Plecoptera	0.06±0.06	0-1	1	1.2

4.5 Diet of *Oreochromis niloticus baringoensis*: Gut contents, food selectivity and preferences

4.5.1 KMFRI site

Keratella sp. contributed about 2.1% of the zooplankton. In comparison with the other zooplankton, it contributed the highest number of the food items, with a mean (±se) of 7.2±2.0 individuals per fish and a range of 0-54 (Table 8). *Asplachna sp.* contributed the lowest percentage (0.02%) among the zooplankton eaten by fish with a mean of 0.03±0.03 per fish.

Microcystis and *Nitzschia sp.* were the most abundant phytoplankton eaten by the fish; contributing 31.1 and 9.5% with means of 66.3±9.1 and 16.8±5.9 individuals per fish, respectively. *Synecocystis sp.* (8.4%) and *Oscillatoria sp.* (7.3%) contributed appreciable proportions whilst other species contributed negligible proportions. Detritus material contributed

substantially to the gut contents (27.1%). Higher plant remains contributed 10.0% with a mean of 18.4±6.1 per fish and ranged from 0-128.

The major components of the gut contents of the *Oreochromis niloticus baringoensis* at the KMFRI site in Lake Baringo were therefore mostly phytoplankton (58.4%) and zooplankton (4.9%).

Table 8: Summary of statistics for some selected food items in the gut of *Oreochromis niloticus baringoensis* at the KMFRI site in Lake Baringo. (±Standard error), N= 31

Food item	Mean number/ fish	Range
Zooplankton		
Keratella	7.19 ±2.0	0-54
Brachionus	2.00±0.9	0-16
Filina	0.1±0.05	0-1
Daphnia	0.1±0.07	0-2
Nauplius	0.35±0.2	0-6
Mesocyclops	0.19±0.12	0-3
Eubranchibus	0.06±0.06	0-2
Asplachna	0.03±0.03	0-1
Phytoplankton		
Microcystis	66.3±9.1	0-170
Nitzschia	16.81±5.9	0-148
Navicula	1.94±1.6	0-50
Melosira	2.03±1.93	0-60
Pediastrum	0.03±0.03	0-1
Chlorella	0.03±0.03	0-1
Closterium	0.1±0.07	0-2
Oscillatoria	13.0±8.5	0-200
Synecosystis	18.19±7.2	0-148
Nostoc	0.16±0.1	0-3
Microspora	0.19±0.16	0-5
Others		
Detritus material	54.84±5.01	0-90
Insect remains	1.77±0.65	0-17
Higher plant remains	18.35±6.08	0-128

Electivity index of Ivlev (1961) is usually used to assess food selectivity by fish. As shown in Table 9, there was variation in the food preference by *Oreochromis niloticus baringoensis.* About 51.7% of the possible food items were rejected. The highly preferred food items were mostly the large-sized plant and animal materials. However, zooplanktons were also preferred with electivity ranging from +0.32 for *Eubranchibus sp.* to +1.00 for *Asplachna sp.* All the items that were highly rejected were missing in the gut and only found in the pelagic environment. They were mostly phytoplankton. It is important to note that although *Nitzschia* and *Microcystis sp.* were abundant in the pelagic zone, i.e. 42.1 and 34.2% of the total, respectively, the fish did not prefer them.

Composition of the food items and organisms in the gut and in the benthos, respectively, showed that there was no commonality. All the items in the benthos except insect remains were not at all contributing to the fish diet. Therefore, at the KMFRI site the fish was getting its food from the pelagic environment.

Table 9: Analysis of the diet of *Oreochromis niloticus baringoensis* at the KMFRI site in Lake Baringo using Electivity Index (E), N = 31

Gut contents			Pelagic organisms		
Food items	**Total**	**%**	**Total**	**%**	**Electivity index (E)**
Zooplankton					
Keratella	115	2.09	35	0.33	+0.70
Brachionus	27	0.49	3	0.03	+0.90
Filina	3	0.05	8	0.07	-0.16
Daphnia	3	0.05	5	0.05	+0.08
Ceriodaphnia	0	0.00	1	0.01	-1.00
Nauplius	8	0.15	33	0.31	-0.36
Mesocyclops	6	0.11	45	0.42	-0.59
Eubranchibus	2	0.04	2	0.02	+0.32
Asplachna	1	0.02	0	0.00	+1.00
Phytoplankton					
Microcystis	1707	31.05	3666	34.21	-0.05
Nitzschia	521	9.48	4510	42.09	-0.63
Phormidia	8	0.15	148	1.38	-0.81
Navicula	59	1.07	330	3.08	-0.48
Melosira	62	1.13	119	1.11	+0.01
Pediastrum	1	0.02	3	0.03	-0.21
Chlorella	1	0.02	54	0.50	-0.93
Oscillatoria	401	7.29	0	0.00	+1.00
Cladophora	0	0.00	4	0.04	-1.00
Synecocystis	464	8.44	829	7.74	+0.04
Closterium	2	0.04	2	0.02	+0.32
Nostoc	5	0.09	1	0.01	+0.81
Anabaena	0	0.00	112	1.05	-1.00
Microspora	6	0.11	0	0.00	+1.00
Spirulina	0	0.00	1	0.01	-1.00
Pseudoanabaena	0	0.00	4	0.04	-1.00
Protococcus	0	0.00	800	7.74	-1.00
Others					
Detritus material	1490	27.1	0.00	0.00	+1.00
Insect remains	55	1.00	0.00	0.00	+1.00
Higher plant remains	551	10.02	0.00	0.00	+1.00

4.5.2 Mukutan site

Keratella sp. contributed the highest density among the zooplankton in the gut (Table 10), with a mean (±se) of 11.6 ±2.3 individuals per fish and a range of 0 to 91. *Eubranchibus sp.* contributed the lowest percentage (0.01%) among the zooplankton eaten by fish.

Microcystis and *Nitzschia sp.* were the most abundant phytoplankton eaten by the fish, contributing 36.4 and 13.1%, respectively. *Synecocystis sp.* and *Oscillatoria sp.* contributed < 2%. Other phytoplankton species contributed negligible proportions, i.e. <1.0% (Table 11).

Detritus material contributed a significant proportion to the gut contents (17.0%). Higher plant remains contributed 2.9% with mean (±se) number per fish of 22.3±8.0 and insect remains 2.9% with mean (±se) of 4.5±1.3 per fish.

In summary, the major components of the gut contents of the *Oreochromis niloticus baringoensis* at the Mukutan site of Lake Baringo were therefore phytoplankton (54.0%) and zooplankton (11.5%).

Table 10: Summary of statistics for some selected food items in the gut of *Oreochromis niloticus baringoensis* at the Mukutan site in Lake Baringo, Kenya. (± Standard error), N=51

Food item	Mean number/ fish	Range
Zooplankton		
Keratella	11.63 ±2.32	0-91
Brachionus	5.06±1.14	0-30
Filina	0.3±0.11	0-4
Daphnia	0.29±0.09	0-3
Nauplius	0.35±0.12	0-5
Mesocyclops	0.02±0.02	0-1
Eubranchibus	0.06±0.06	0-2
Asplachna	0.04±0.03	0-1
Phytoplankton		
Microcystis	56.08±11.18	0-260
Nitzschia	20.14±5.58	0-207
Phormidia	0.14±0.07	0-3
Navicula	0.06±0.06	0-3
Melosira	1.02±0.36	0-12
Synedra	0.49±0.23	0-8
Pediastrum	0.04±0.03	0-1
Chlorella	0.53±0.31	0-11
Oscillatoria	2.04±1.70	0-86
Synecocystis	1.80±1.26	0-60
Anabaena	0.14±0.08	0-3
Nostoc	0.02±0.02	0-1
Microspora	0.63±0.21	0-6
Others		
Detritus material	26.18±3.34	0-70
Insect remains	4.47±1.33	0-50
Higher plant remains	22.45±7.95	0-240

Based on the results presented in Table 11, there was much variation in the food preference by *Oreochromis niloticus baringoensis* at the Mukutan site. There was high selection of most of the food items, i.e. 55.5% of the

Table 11: Analysis of the diet of *Oreochromis niloticus baringoensis* at the Mukutan site in Lake Baringo, using Electivity Index (E), N = 51

Gut contents			Pelagic organisms		
Food items	**Total**	**%**	**Total**	**%**	**Electivity index (E)**
Zooplankton					
Keratella	593	7.5	88	2.03	+ 0.57
Brachionus	258	3.28	35	0.81	+0.61
Filina	15	0.19	1	0.02	+0.78
Daphnia	15	0.19	8	0.18	+0.02
Diaptomus	0	0.00	1	0.02	-1.00
Asplachna	2	0.03	1	0.02	+0.05
Nauplius	18	0.23	38	0.52	-0.44
Mesocyclops	2	0.03	88	2.03	-0.98
Eubranchibus	1	0.01	1	0.02	-0.29
Phytoplankton					
Microcystis	2860	36.4	2315	53.32	-0.19
Nitzschia	1027	13.07	1247	28.72	-0.37
Phormidia	7	0.09	22	0.51	-0.70
Navicula	3	0.04	100	2.30	-0.97
Melosira	52	0.66	2	0.05	+0.87
Synedra	25	0.32	0	0.00	+1.00
Pediastrum	2	0.03	0	0.00	+1.00
Chlorella	27	0.34	75	1.73	-0.67
Scenedesmus	7	0.09	0	0.00	+1.00
Oscillatoria	104	1.32	3	0.07	+0.90
Synecocystis	92	1.17	300	6.91	-0.71
Nostoc	1	0.01	0	0.00	+1.00
Anabaena	7	0.09	14	0.32	-0.57
Microspora	32	0.41	2	0.05	+0.80
Synedra	26	0.12	0	0.00	+1.00
Ankistrodesmus	0	0.00	2	0.01	-1.00
Aphanocapsa	0	0.00	1	0.02	-1.00
Others					
Detritus material	1335	16.99	0.00	0.00	+1.00
Insect remains	228	2.90	0.00	0.00	+1.00
Higher plant remains	1145	14.57	0.00	0.00	+1.00

possible food items were preferred. Zooplanktons were preferred, with electivity ranging from +0.05 for *Asplachna sp.* to +0.8 for *Filina sp.* Most of the phytoplankton were rejected. Although *Microcystis* and *Nitzschia sp.* were plentiful in the pelagic zone, i.e. 53.3 and 28.7% of the total, respectively, the fish did not prefer them.

The composition of the food organisms in the gut and the items in the benthos showed that there was no commonality. All the items in the benthos except insect remains were not contributing to the fish diet. Therefore, the fish at the Mukutan site were getting the food from the pelagic zone.

4.5.3 Molo site

Keratella sp. contributed the highest proportion of the zooplankton in the fish gut (Table 12) in comparison with the other zooplankton. *Diaptomus sp.* contributed the lowest percentage (0.01%) among the zooplankton eaten by the fish.

Microcystis and *Nitzschia sp.* were the most abundant phytoplankton eaten by fish contributing 33.5 and 14.7%, respectively (Table 13). Other phytoplankton species contributing substantial proportions included

Oscillatoria sp. (1.0%), *Synecocystis sp.* (0.7%) and *Mesocyclops sp.* (0.8%).

Table 12: Summary of statistics for selected food items in the gut of *Oreochromis niloticus baringoensis* at the Molo site in Lake Baringo. (±Standard error), N=58.

Food item	Mean number/fish	Range
Zooplankton		
Keratella	8.7 ±1.8	0-79
Brachionus	1.8±0.6	0-23
Filina	2. 8±1.4	0-66
Daphnia	0.3±0.1	0-4
Diaptomus	0.02±0.02	0-1
Nauplius	0.3±0.1	0-5
Mesocyclops	0.2±0.1	0-2
Eubranchibus	0.1±0.04	0-1
Phytoplankton		
Microcystis	45.8±6.5	0-200
Nitzschia	20.1±4.7	0-120
Navicula	0.5±0.2	0-9
Melosira	1.1±0.4	0-17
Synedra	0.02±0.02	0-1
Scenedesmus	0.1±0.04	0-1
Chlorella	0.2±0.1	0-7
Oscillatoria	1.4±0.7	0-38
Synecocystis	1.02±0.9	0-50
Closterium	0.02±0.02	0-1
Anabaena	0.1±0.04	0-2
Microspora	0.5±0.2	0-11
Others		
Detritus material	31.7±4.0	0-90
Insect remains	2.9±0.5	0-15
Higher plant remains	17.2±3.7	0-150

Other phytoplankton species contributed negligible proportions (<5%). Detritus material contributed a significant proportion to food items in the gut (23.2%). Higher plant remains contributed 12.6% and insect remains 2.1%.

The electivity index values (Table 13) indicate that there was variation in the food preference by *Oreochromis niloticus baringoensis*. There was high rejection of most of the food items, i.e. 71% of the possible food items were rejected. Zooplanktons were highly rejected in this site with only three species selected, *Keratella, Filina* and *Daphnia sp.* Their electivity indices were +0.61, +0.90 and +0.69, respectively. About 81% of all phytoplankton were also highly rejected. It is important to note that although *Microcystis* and *Nitzschia sp.* were plentiful in the pelagic environment, i.e. 50.0 and 24.0% of the total, respectively, the fish did not fully utilize them as food (- E).

Table 13: Analysis of diet of *Oreochromis niloticus baringoensis* at the Molo site in Lake Baringo using Electivity Index (E), N = 58

Gut contents			Pelagic organisms		
Food items	**Total**	**%**	**Total**	**%**	**Electivity index (E)**
Zooplankton					
Keratella	506	6.38	43	1.53	+ 0.61
Brachionus	102	1.29	56	2.00	-0.22
Filina	161	2.03	3	0.11	+0.90
Daphnia	17	0.21	1	0.04	+0.69
Diaptomus	1	0.01	6	0.21	-0.89
Nauplius	16	0.20	18	0.64	-0.52
Mesocyclops	9	0.11	102	3.64	-0.94
Eubranchibus	6	0.08	5	0.18	-0.41
Phytoplankton					
Microcystis	2654	33.48	1403	50.04	-0.20
Nitzschia	1168	14.73	674	24.04	-0.24
Phormidia	0	0.00	22	0.78	-1.00
Navicula	27	0.34	12	0.43	-0.12
Melosira	63	0.79	8	0.29	+0.47
Pediastrum	0	0.00	1	0.04	-1.00
Synedra	1	0.01	0	0.00	+1.00
Chlorella	14	0.18	60	2.14	-0.85
Scenedesmus	5	0.06	2	0.07	-0.05
Oscillatoria	79	1.00	5	0.18	+0.69
Synecocystis	59	0.74	300	10.7	-0.87
Cladophora	0	0.00	10	0.36	-1.00
Closterium	1	0.01	7	0.25	-0.90
Anabaena	4	0.05	6	0.21	-0.61
Microspora	26	0.33	0	0.00	+1.00
Oocystis	0	0.00	4	0.14	-1.00
Ankistrodesmus	0	0.00	1	0.04	-1.00
Spirulina	0	0.00	1	0.04	-1.00
Protococcus	0	0.00	47	1.68	-1.00
Spirogyra	0	0.00	2	0.07	-1.00
Others					
Detritus material	1840	23.21	0.00	0.00	+1.00
Insect remains	170	2.14	0.00	0.00	+1.00
Higher plant remains	999	12.6	0.00	0.00	+1.00

Composition of the food items in the gut and in the benthos showed that there was no commonality. All the items in the benthos except insect remains were not at all contributing to the fish diet. Therefore, the fish at the Molo site was getting its food solely from the pelagic zone.

It was difficult to test hypotheses H_{03} and H_{04} but from tables 4-12, they clearly show that there were differences in the gut contents and also on the gut and diet items in the pelagic and benthos in the various turbidity-stressed sites.

4.6 Summary for habitat and biometrical characteristics, feeding habits and food preferences of *Oreochromis niloticus baringoensis* in Lake Baringo Ecosystem

4.6.1 Physical and chemical variables

Details of the physical and chemical variables in Lake Baringo are given in Table 14. Turbidity and conductivity show high ranges.

Table 14: Summary of statistics for physico-chemical variables in Lake Baringo Ecosystem. (±Standard error)

Variable	Mean ± se	Range
Total dissolved solids (mg/l)	798.2±27.1	95-1132
Water temperature (^{0}C)	26.5±2.0	21.2-33.3
Secchi depth (cm)	6.1±0.5	2.2-32.0
Turbidity (NTU)	645.0±24.6	58-1327.9
Dissolved oxygen concentration (mg/l)	5.8±0.1	2.2-10.8
Dissolved oxygen saturation (%)	93.3±1.8	45-145
Conductivity (µS/cm)	1722.6±72.7	221-5920
PH	8.4±0.1	6.11-9.9

4.6.2 Biometrical characteristics of *Oreochromis niloticus baringoensis* population

4.6.2.1 Quantitative characters

The mean standard length of the fish was 15.1±0.2 and ranged from 9.5-25.0 cm. The mean total length was 18.5±0.3 cm and ranged from 12.0-30 cm whilst the mean peduncle length was 1.6 ±0.03 and 10.6% of the standard length. Other details of the quantitative characteristics are presented in Table 15.

Table 15: Quantitative characteristics of *Oreochromis niloticus baringoensis* in Lake Baringo Ecosystem (±Standard error)

Character	Mean ±se	Range
Standard length (cm)	15.1±0.1	9.5-25.0
Caudal peduncle length (cm)	1.6±0.03	0.6-3.0
Total length (cm)	18.5±0.3	12.0-30.0
Head length (cm)	4.9±0.1	2.5-7.5
Head width (cm)	2.3±0.1	1.3-5.0
Snout length (cm)	1.5±0.03	0.8-3.0
Eye diameter (cm)	1.1±0.02	0.7-1.8
Upper jaw length (cm)	1.2±0.03	0.5-2.4

4.6.2.2 Meristic characteristics

The meristic characteristics are shown in Table 16. The fish weights ranged from 34.0-516.1 g with a mean weight of 139.1±7.2 g. Further, the fish condition factor ranged from 1.33-2.70. The mean number of dorsal spines was 16±0.1 and dorsal rays 12±0.1. The dorsal fin formula was therefore, D.XVI, 12. This signifies 16 spines in the dorsal fin followed by 12 soft rays both in the hard and soft dorsal, respectively. The mean number of anal spines was 3±0.02 and the soft rays 9±0.1, hence the formula A.III, 9. The mean number of total pectoral rays was 12±0.1 and ranged between 9-14.

Table 16: Meristic characteristics of *Oreochromis niloticus baringoensis* in Lake Baringo. (±Standard error)

Character	Mean ±se	Range
Fish weight (g)	139.1±7.2	34.0-516.1
Gonad weight (g)	0.8±0.1	0.001-4.3
Condition factor (K)	1.96±0.02	1.33-2.70
Maturity factor (M)	0.6±0.1	0.001-4.0
Dorsal spines	16±0.1	14-18
Dorsal soft rays	12±0.1	10-13
Anal spines	3±0.02	3-4
Anal soft rays	9±0.1	8-11
Total pectoral rays	12±0.1	9-14

The factors that were found to have effect on the condition of fish are summarized in Table 17. *Nitzschia sp* had the highest effect on the condition of the fish. The effects of the other food items and variables were insignificant (P>0.05).

Table 17: Bivariate regression results for food and variables with the condition (K) of *Oreochromis niloticus baringoensis* in Lake Baringo.Significance levels: *P<0.05, **P<0.01

Food/ variable	t	p
Nitzschia	3.11	0.002**
Anabaena	2.77	0.007**
Detritus material	3.15	0.002**
pH	2.50	0.014*
Turbidity	2.03	0.045*
Dissolved oxygen	2.60	0.011*

Computation of length-weight relationship for Lake Baringo fish population gave the equation; **Log Weight= 3.12 (Log Length)–1.87**, where weight is in grams and length in cm (Fig.15).

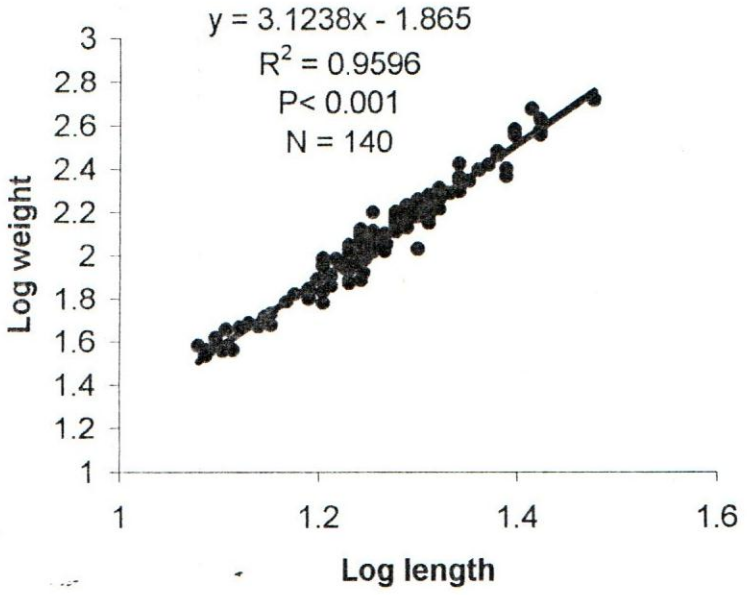


Fig. 15: Fish length-weight relationship of the fish in Lake Baringo.

4.6.3 Composition of zooplankton and phytoplankton in the pelagic zone and benthos in Lake Baringo

The dominant dietary items in the pelagic zone were the zooplankton (3.6%) and the phytoplankton (96.3%) (Table 18a). It was therefore evident that the phytoplanktons were more abundant in the pelagic zone of the lake than the zooplankton. *Mesocyclops sp.* contributed (1.3%), *Keratella sp* (1.0%), *Nauplius sp.* (0.5%) and *Brachionus sp.*, 0.5%.

Of the phytoplankton in the pelagic zone, *Microcystis sp.* and *Nitzschia sp.* contributed 41.3 and 35.5%, respectively. Other phytoplankton, which contributed appreciable proportions, were *Spirulina sp.* (4.9%), *Synecocystis sp.* (8.1%), *Chlorella sp.* (1.1%) and *Phormidia sp.* (1.1%). Other phytoplankton contributed negligible proportions, <1.0%.

Table 18a: Summary of statistics for organisms in the pelagic zone in Lake Baringo. (±Standard error) N = 140

Pelagic organisms	Mean number	Range	Total	%
Zooplankton				
Keratella	3.1±0.6	0-18	166	0.96
Brachionus	1.7±0.5	0-17	94	0.54
Filina	0.2±0.1	0-6	12	0.06
Diaptomus	0.02±0.02	0-1	7	0.04
Daphnia	0.2±0.6	0-3	14	0.08
Nauplius	1.6±0.4	0-16	89	0.52
Mesocyclops	4.4±1.0	0-41	235	1.34
Eubranchibus	0.1±0.1	0-5	8	0.05
Asplachna	0.02±0.02	0-1	1	0.01
Ceriodaphnia	0.02±0.01	0-1	1	0.01
Phytoplankton				
Microcystis	136.7±21.7	0-600	7384	41.31
Nitzschia	119.1±22.0	0-700	6431	35.50
Phormidia	3.6±1.3	0-50	192	1.08
Navicula	8.2±4.1	0-160	442	2.56
Melosira	2.4±1.9	0-100	129	0.75
Pseudoanabaena	0.1±0.1	0-4	4	0.02
Chlorella	3.5±1.5	0-50	189	1.1
Scenedesmus	0.04±0.03	0-1	2	0.01
Oscillatoria	0.1±0.1	0-4	8	0.05
Synecocystis	26.5±10.1	0-500	1399	8.1
Closterium	0.2±0.1	0-7	9	0.05
Nostoc	0.02±0.02	0-1	1	0.01
Anabaena	2.4±1.9	0-100	132	0.76
Microspora	0.04±0.04	0-2	5	0.03
Spyrogyra	0.04±0.04	0-2	2	0.01
Spirulina	0.04±0.03	0-2	847	4.9
Cladophora	0.3±0.2	0-10	14	0.01

The benthos had a totally different invertebrate structure and composition (Table 18b) from that of the pelagic environment.

Table 18b: Summary of statistics for organisms in the benthos in Lake Baringo. (±Standard error)

Sediment organisms	Mean number	Range	Total	%
Diptera	0.2±0.1	0-5	10	0.97
Hirudinea	0.04±0.03	0-1	2	0.20
Mollusca	15.3±5.4	0-225	826	80.35
Hemiptera	3.4±1.4	0-53	181	17.60
Plecoptera	0.2±0.1	0-3	9	0.090

4.6.4 Gut contents, food selectivity and preferences by *Oreochromis niloticus baringoensis*

Keratella sp. contributed about 6% of the zooplankton items in the fish gut (Table 19). In comparison to the other zooplankton, it contributed the highest number of the eaten items, with a mean (±se) of 9.4 ±1.2 per fish and a range of 0 to 91. *Asplachna sp.* contributed the lowest percentage (0.01%) among the zooplankton eaten by the fish. *Microcystis* and *Nitzschia sp.* were the most abundant phytoplankton eaten by fish contributing 34.2 and 12.3%, respectively.

Other phytoplankton species contributing substantial proportions included *Synecocystis sp.* (3.2%) and *Oscillatoria sp.* (2.7%). The rest of the phytoplankton species contributed negligible proportions. Detritus material contributed a significant proportion to the gut contents (22.1%).

Table 19: Summary of statistics for some selected food items in the gut of *Oreochromis niloticus baringoensis* in Lake Baringo. (±Standard error) N = 140

Food item	Mean number/fish	Range
Zooplankton		
Keratella	9.4±1.2	0-91
Brachionus	3.0±0.5	0-30
Filina	1.2±0.6	0-66
Daphnia	0.3±0.7	0-4
Nauplius	0.3±0.1	0-6
Mesocyclops	0.1±0.03	0-3
Eubranchibus	0.1±0.02	0-2
Asplachna	0.02±0.1	0-1
Phytoplankton		
Microcystis	54.1±5.3	0-260
Nitzschia	19.4±3.1	0-207
Navicula	0.6±0.4	0-50
Melosira	1.3±0.5	0-60
Synedra	0.2±0.1	0-8
Chlorella	0.3±0.1	0-11
Scenedesmus	0.1±0.03	0-2
Oscillatoria	4.2±2.0	0-200
Synecosystis	5.1±1.8	0-148
Nostoc	0.04±0.02	0-3
Anabaena	0.1±0.03	0-3
Microspora	0.5±0.1	0-11
Others		
Detrital material	34.8±2.5	0-90
Insect remains	3.2±0.5	0-50
Higher plant remains	19.4±3.5	0-240

Higher plant remains contributed a similar percentage as the *Nitzschia sp.* (12.3%). Insect remains contributed 2.1% to the food items. The components of the gut contents of *Oreochromis niloticus baringoensis* in Lake Baringo were therefore zooplankton (9.2%), phytoplankton (54.4%)

and others, i.e. detritus material, insect remains and higher plant remains, contributed (36.4%).

There was variation in the food preference by *Oreochromis niloticus baringoensis.* There was rejection of most of the food items, i.e. 66% of the possible food items were rejected. The highly preferred food items were mostly the large-sized plant and animal materials (Table 20). However, zooplanktons were also preferred with electivity ranging from +0.15 for *Asplachna sp.* to +0.86 for *Filina sp.* All the items, which were highly rejected, were missing in the gut and only found in the pelagic zone. They were mostly phytoplankton. It is important to note that although *Microcystis* and *Nitzschia sp.* were plentiful in the pelagic zone, i.e. 41.3 and 35.5% of the total, respectively, the fish did not prefer them. Composition of the food items in the gut and the benthos showed that there was no commonality. All the items in the benthos except insect remains were not at all contributing to the fish diet. Therefore, the fish was getting its food from the pelagic zone. The origin of the plant diet component is the materials brought by the inflowing rivers and fragments from the littoral papyrus stands.

Table 20: Analysis of diet of *Oreochromis niloticus baringoensis* in Lake Baringo using Electivity index (E), N = 140

Gut contents			Pelagic organisms		
Food items	**Total**	**%**	**Totals**	**%**	**Electivity index (E)**
Zooplankton					
Keratella	1322	5.98	166	0.96	+ 0.72
Brachionus	420	1.90	94	0.54	+0.56
Filina	179	0.81	11	0.06	+0.86
Daphnia	35	0.16	14	0.08	+0.33
Diaptomus	1	0.00	7	0.04	-0.80
Nauplius	45	0.20	89	0.52	-0.44
Mesocyclops	17	0.08	232	1.34	-0.89
Eubranchibus	9	0.04	8	0.05	-0.10
Asplachna	3	0.01	1	0.01	+0.15
Ceriodaphnia	0	0.00	1	0.01	-1.00
Phytoplankton					
Microcystis	7568	34.24	7134	41.31	-0.09
Nitzschia	2716	12.29	6131	35.50	-0.49
Phormidia	12	0.05	187	1.08	-0.90
Navicula	90	0.81	442	2.56	-0.52
Melosira	178	0.41	129	0.75	-0.30
Pediastrum	3	0.01	4	0.02	-0.19
Chlorella	42	0.19	189	1.09	-0.70
Scenedesmus	12	0.05	2	0.01	+0.69
Oscillatoria	586	2.65	8	0.05	+0.96
Synecosystis	715	3.23	1399	8.1	-0.43
Closterium	4	0.02	9	0.05	-0.47
Nostoc	6	0.03	1	0.01	+0.46
Anabaena	11	0.05	132	0.76	-0.88
Microspora	64	0.29	5	0.03	+0.81
Synedra	26	0.12	0	0.00	+1.00
Pseudoanabaena	0	0.00	4	0.02	-1.00
Oocystis	0	0.00	2	0.01	-1.00
Ankistrodesmus	0	0.00	2	0.01	-1.00
Aphanocapsa	0	0.00	2	0.01	-1.00
Spirulina	0	0.00	847	4.90	-1.00
Protococcus	0	0.00	14	0.08	-1.00
Cladophora	0	0.00	1	0.01	-1.00
Others					
Detritus material	4875	22.05	0.00	0.00	+1.00
Insect remains	453	2.05	0.00	0.00	+1.00
Higher plant remains	2713	12.27	0.00	0.00	+1.00

CHAPTER 5.0

DISCUSSION

Water temperatures were strongly influenced by the intensity of radiation as well as the afternoon winds that blow across the lake. It was observed that time of the day played an important role. Temperature readings in the afternoon were high as the solar radiation was strong at the time compared to the records made in the morning. The high radiations cause the heating of water surface leading to a warmer layer that overlies the cool water resulting in stratification.

The high concentration of total dissolved solids enhances surface heating of the water as they aid in absorption of heat. Wetzel (1983) observed that the presence of dissolved materials in water increases solar energy absorption. Graeme and Kiplagat (1995) noted that the low transparency in Lake Baringo due to dissolved and suspended materials enhances surface heating hence the high surface temperatures ranging from 21.2-33.3^0 C. The high temperatures recorded at the KMFRI site may probably be due to the higher levels of total dissolved solids as compared to the other sites. Molo site, which normally receives inputs of freshwater from the rivers especially the Molo River, coupled with the low levels of total dissolved solids, explains the low temperatures recorded at the site.

A conductivity of about 1723 μS/cm was recorded for this lake over the study period and this was higher than the value recorded for the same lake of 1200 μS/cm by Omondi (2000) and 790 μS/cm by Kiplagat (1989). Graeme and Kiplagat (1995) found that the levels of conductivity fluctuate with inputs or inflows of water. The inflowing water causes the dilution of the various ions hence the low conductivity. Payne (1975) noted that conductivity was lowest during and after the rains and highest during the dry season. This was due to reduced water flow, which allowed more time for salts from rocks and soil to dissolve in water. Mukutan site had the highest conductivity among the three study sites. This could be explained partly by the presence of the hot springs that release saline water (conductivity of about 5900 μS cm/cm) to the lake at this site. As observed by Shivoga (2000), leachates and seepage from highly saline sediments and springs enhances the conductivity gradients at the mouths of springs flowing into Lake Nakuru. Low conductivity was observed at the Molo site and this could probably be due to the inflows of fresh water from the Molo River. The dilution of the ions might also have led to the trend in pH values observed in the current study. Omondi (2000) observed that inflows of fresh water dilutes the various ions hence the decrease in pH.

The temporal trend observed for conductivity typically corresponds well with the water levels and the inflows from the rivers. During the month of

March, water levels were lowest and the conductivity was highest whilst in the months of April and May, the water level was high hence the low conductivity. This observation can be explained by the fact that the higher the levels of water the higher the dilution of the various ions resulting in low conductivity. When the water levels are low there is little dilution and thus the high conductivity recorded.

The frequent mixing of the Lake Baringo water on a daily basis due to the strong winds in the afternoon brings about resuspension of silt. The shallowness of the lake further contributes to this phenomenon. Tilahun (1988) and Mihret-AB (1988) (cit. in Abebe and Getachew 1992) found that shallowness and constant mixing coupled with catchment's erosion also led to the high turbidity in Lake Ziway in Ethiopia. The strong winds blowing in the northeasterly direction across the lake ensure that the Lake Baringo is uniformly mixed, a trend also observed by Kallqvist (1987). This might explain the observed temporal trend in turbidity.

In this study, low turbidity was recorded at the Molo site though it receives sediments and other allochthonous materials from the rivers. From the observation made, the macrophytes in the wetland trapped materials destined for the open water and this made Molo site to have relatively low turbidity in comparison with the other sites. The shallowness at the

Mukutan site explains the high turbidity recorded because of the quantity of the suspended materials that are moved into the water column due to the wave action. When the lake is shallow, the bottom is exposed to the action of waves, which stir up the sediments hence the high turbidity (Omondi, 2000).

Dissolved oxygen is important both in the aquatic and terrestrial life. In the aquatic systems it is the most influential factor that determines the distribution of individual species. All aquatic organisms rely on dissolved oxygen in the water to support their metabolism and the waters ability to take oxygen depends on the water temperature and the levels of dissolved solids. Lake Baringo's dissolved oxygen concentration of 5.8 mg/l and percent saturation of 93.3% showed that the lake is well aerated. This could be due to the constant mixing and strong winds that always blow in the afternoon. However, KMFRI site recorded high oxygen concentration and saturation whereas Molo site recorded the lowest. This could partly be attributed to the low abundance of photosynthesising plants in the Molo site, particularly the phytoplankton. Further, bacterial decomposition of the allochthonous materials brought in by rivers and streams may consume most of the oxygen. Molo site is a kind of shallow estuary and as explained by Bussmann *et al.*, (2000), sediments of such estuaries contain large amounts of organic materials and can rapidly become anoxic.

In this study, the blue-green algae particularly the *Microcystis sp.* and *Synecocystis sp.* were the most abundant in the different sites and over the sampling dates, but in varying proportions. When the water is calm, rafts of *Microcystis sp.* could be seen forming on the surface. They are able to regulate their buoyancy with the help of gas vesicles, which are permeable to the atmospheric gases, and not to water (Ganf, 1972; Moss, 1988). They were therefore in a position to out-compete the other phytoplankton by remaining in the photic zone and thus utilize the limited light in the turbid lake. Another factor that may favour the survival of blue-green algae in this harsh environment is their ability to form masses of floating colonies thus they are able to maintain buoyancy as opposed to single cells.

The dominance of diatoms in the lake could be attributed to the daily mixing process which serves to redistribute cells which are closer to the surface and resuspension of some from the lower depths particularly the *Melosira sp.* (Talling and Talling, 1965; Payne, 1986). The ability of *Nitzschia sp.* to associate with colonial *Microcystis sp.* as observed in this study helps them to survive in the upper depths. Similar observation was reported by Kiplagat (1989). The phytoplankton that have no floatation devices survive in the lower levels until they are stirred up by the wind thus bringing them up into the light water where they can photosynthesise.

The most abundant zooplankton was the copepod- *Mesocyclops sp.* Its ability to survive in this environment could well be due to its nature of feeding. Whereas *Thermocyclops sp.* is a herbivore surviving on the blue-green and/ or detritus as reported by Kamanya *et al.*, (1996, 97) in Lake George, Uganda, *Mesocyclops sp.* is a predator in nature and tends to predate on other zooplankton (Payne, 1986).

Payne (op. cit.) reported that zooplankton are generally less diverse in the tropics and apart from the *Ceriodaphnia*, *Diaptomus, Asplachna,* and *Filina sp.* it was noted that there are other few cosmopolitan species including *Keratella* and *Brachionus sp.* among the rotifers and *Daphnia* and *Ceriodaphnia* among the cladocerans. It was noted that these species are adapted to the tropical conditions.

In aquatic ecosystems, there is a net movement of matter and energy upwards through the biomass spectrum from small to larger producers through a succession of trophic linkages (Thebaux and Dickie, 1983). This succession of trophic linkages is partly portrayed by the consumption of zooplankton and phytoplankton by fish as observed in this study. In the wild fish must decide where to feed and what type of prey to feed on and thus the individual making the most correct decisions will feed more efficiently and therefore have better fitness and condition than other

members of the population (Dill, 1983). *Oreochromis sp.* has been found to feed during the day (shortly before dawn until dusk (Moriarty and Moriarty 1973; Getachew, 1993). In Lake Baringo, *Oreochromis niloticus baringoensis* obtains most of its food from the pelagic zone. The factors, which may favour daytime feeding, include temperature and oxygen (Akintude, 1982). When temperature is high, photosynthetic activity and production of oxygen are at maximum (Akintude op.cit). This will finally allow for high respiratory activity as well as high swimming and feeding activity of the fish. Further, since this species is a visual predator, it is important that it feeds during the day hence the reason why it is affected by the high turbidity. Hetcht and Van der Lingen (1992) suggested that the level of turbidity does not affect those species that are not visual pelagic predators but it has a lot of effect on the visual pelagic predators. Most studies report that phytoplankton and zooplankton dominate the diet of *Oreochromis niloticus* (Poll, 1939 cit. in Kamanya *et al.*, 1996/7; Lowe-McConnell, 1958; Ganf, 1972; Moriarty and Moriarty, 1973, Getabu, 1994) and this is in accord with the results of the current study. In addition, some studies have reported bottom deposits, insects and protozoan in the diet of fish (Fish 1955; Welcomme 1967; Harbott, 1975; Balirwa, 1990, 1998).

Results of the present study indicate that the feeding of *Oreochromis niloticus baringoensis* supports the fact that the intensity of predation of a

particular food item is not in proportion to the item's availability in the fish eco-areas. This was clearly shown by *Microcystis* and *Nitzschia sp.*, which were more prominent in the water column and yet were not utilized exhaustively as food. The fish fed more on zooplankton, *Brachionus* and *Keratella sp.,* and others though they were not so abundant in the water column. The plausible reason attributed to this observation could be that the food items were not preferred by the fish hence the rejection. This phenomenon concurs with that of Mathooko (1993) and Kamanya *et al.,* (1996/7) who observed this phenomenon in the Naro Moru River and Lake George, Uganda, respectively.

The variation in foods in the different study sites is more on the availability and rejection of the different food items. Zooplanktons that were highly preferred included *Brachionus* and *Keratella sp.* although the fish in Molo site rejected the former. Further, *Asplachna sp.*, which seemed to have been highly preferred by the fish, was absent in Mukutan and Molo sites. In addition, the fish in the Mukutan and Molo sites preferred *Filina sp.,* which was rejected by the fish in KMFRI site, respectively. Whereas the fish in the KMFRI site fed mainly on *Oscillatoria, Nostoc* and *Microspora sp.* In addition to the above, fish from Mukutan site fed on *Synedra, Pediastrum* and *Scenedesmus sp.* which were not available in the KMFRI site. Fish from Molo rejected *Pediastrum sp.* Generally, the Mukutan fish

had higher variety of food items from its water column than those of the other sites. They were able to select from a wide range of food items.

Oreochromis niloticus baringoensis has previously been thought to be a herbivorous fish (Moriarty and Moriarty, 1973). However, Balirwa (1990, 98) found that *Oreochromis niloticus* in Lake Victoria had expanded its diet. The study reported that the food items in the diet of *Oreochromis niloticus* included detritus, invertebrates, adult insect and higher plant remains. The abundance of phytoplankton in the pelagic zone of Lake Baringo and the corresponding percent in the gut of fish suggests that the phytoplankton are still readily available to the fish in the lake. The high percent of other materials apart from phytoplankton clearly indicates that the diet of *Oreochromis niloticus baringoensis* could be changing; confirming it as an omnivore. These results compare well with those of Balirwa (1990, 98) in Lake Victoria, Kamanya *et al.,* (1996, 97) in Lakes Edward, George, and Kazinga channel in Uganda and Harbott (1975) in the *Oreochromis* of Lake Turkana.

There was no commonality between the diet items and the benthos according to the results of this study. A possible explanation for this could be that most of the benthic organisms did not form important food sources for *Oreochromis niloticus baringoensis*. This explains the importance of the

pelagic zone for the provision of food for the fish and also for the management of the lake and its catchment.

The nutritional value of the diet for supporting fish growth is affected by the physical processes in the environment that determine the abundance of phytoplankton, detritus and other food items. Lake Baringo mixes on a daily basis and this helps to bring about the resuspension of silt thus changing frequently the fish environment. During feeding the fish could filter the silt plus the food items and this reduces the level of energy in the food (Abebe and Getachew, 1992). This phenomenon might explain the low production and condition of fish, particularly *Oreochromis niloticus baringoensis* (Omondi, 2000). Further, the low production could also be due to the mixing of organic nutrients with mineral laden water that originates from the rivers which helps to dilute the nutritionally valuable components thus making them less accessible to fish (Abebe and Getachew, 1992).

Condition of fish can be affected by a number of factors such as food quality and quantity, the environment and rate of feeding, parasitization and reproductive activity (Le Cren, 1951; Bowen, 1979 cit. in Abebe and Getachew, 1992; Getachew, 1987). The physico-chemical variables that negatively affected condition of fish in this were turbidity, dissolved oxygen

and pH. Food items included *Nitzschia* and *Anabaena sp.* and detritus material. Welcomme (1985) and Teshima *et al.*, (1987) have shown that the condition and/ or growth of *Oreochromis niloticus* is markedly affected by its feeding rate and hence the availability of the food as well as the physical processes within the fish's environment.

The condition of *Oreochromis niloticus baringoensis* in Lake Baringo (K < 2.5) does not compare favourably to that of *Tilapia zilli* of K>4.1 all the year round (Daget, 1956) but compares to that of *Oreochromis niloticus* in Lakes Ziway (K=1.89) and Awasi (K=2.03), both in Ethiopia which were noted by Abebe and Getachew (1992) as having very poor condition due to turbidity and food problems. The poor condition could therefore be attributed to poor rate of feeding resulting from poor visibility caused by the high turbidity and consequently high energy consumption in searching for food. Waters (1995) observed that the effect of high-suspended sediments on fish includes the loss of visual capability leading to reduced feeding and depressed growth rate. This fact coupled with the presence of parasites in most of the species explains the poor production in the lake. The same problem could also be compounded by poor food quality, especially when it is ingested with the silt. The changes in quality of the diet as noted by Getachew *et al.*, (2000), reflect the changes in condition of the fish. The high condition recorded in January 2001 shows that the fish fed on a diet

of high nutritional value probably of phytoplankton. Bowen *et al.*, (1995) reported that phytoplankton have a high nutritional value. This also coincided with the period of high water levels, which might have favoured the growth of phytoplankton as the lake water was at the time enriched by nutrients brought in by the rivers. The increase in condition, however, lags about 1 or 2 months behind the changes in diet quality (Getachew *et al.*, 2000) showing that there was an abundance of food in the month of November 2000 or early December 2000.

The low condition (K=1.85) recorded in the Molo site compared to the other sites could probably be due to the high rejection of the food items (71%) as well as the dilution of organic nutrients from the inflowing rivers making them unavailable to the fish. The relatively high condition (K=2.02) in Mukutan site could be due to an abundance of food as shown by the numerous types of phytoplankton that were available in this site. Whereas Mukutan site had the highest turbidity, it also had fish with the highest condition. This could be due to the fact that there was enough food in this site and therefore even though the turbidity was high the fish preferred to feed here. The differences in the sizes of fish are a direct reflection of the condition as the condition is derived from the weight and length of fish. It therefore follows that where the condition was high the sizes were large, respectively. Generally, the Lake Baringo fish mature early (length, 12.5

cm and weight, 40g) whereas the Lake Turkana *Oreochromis*, mature at length of 39 cm and Lake George's of 28 cm. This then calls for more investigations on the factors that make the fish mature early unlike the species in the other East African lakes

CHAPTER 6.0

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The present study has brought into focus several aspects of the tropical lakes particularly those that are faced with problems of siltation and turbidity. Turbidity has been shown as one of the main problems, which further translates into other limnological problems. Other physico-chemical inconveniences include the high levels of pH, total dissolved solids, temperature and conductivity, which are all intertwined to the levels of turbidity.

Zooplankton and phytoplankton in the pelagic zone are also affected by the physico-chemical variables. Zooplankton, e.g. *Mesocyclops sp.*, dominance is due to its feeding strategy whilst the blue green algae were dominant because they have adapted to this environment because of their ability to regulate their position by gas vesicles hence utilize areas with light and nutrients.

The general highlights of the feeding habits of *Oreochromis niloticus baringoensis* are that it is a fish that can utilize a wide range of food types, probably whatever happens to be available, it is dependant on the phytoplankton and zooplankton as well as the detritus material, the fish

does not seem to experience acute shortage of food although out of the 140 fish stomachs examined, 18 were found to be empty, i.e. 13%. This species is therefore not a specialized feeder, a common attribute that has of late gained prominence and led to the conclusion that it is not a herbivore but an omnivore. For this particular lake the benthic environment does not provide food for this fish.

The availability of food or feeding activity together with the development of gonads affects the condition of fish. When the feeding activity is reduced the condition is also likely to reduce whereas during reproductive activity more energy reserves are channelled towards the development of gonads hence poor condition.

6.2 Recommendations

This investigation has not exhausted areas of research in this lake. The following recommendations were found to be of importance if the lake and its biodiversity are to be conserved:

1. That further fieldwork needs to be conducted to provide information on species distribution, reproductive strategies and migrations of this fish within the lake.
2. The results from this study indicates that the one way of increasing the fish production would be by reducing turbidity of the water which

would in turn increase primary production. Efforts should therefore be made to seek positive mitigation options including reafforestation of the highland areas through which the rivers flow. Establishing reserve areas or buffer zones adjacent to the lake will be a welcome management measure.

3. Efforts should be put in place to curb over fishing by developing regulatory strategies, which will discourage over fishing by involving the fishermen and ultimately to inculcate a sense of local ownership of this lake and the resources therein.
4. Damming and diversion of rivers have been evident in the recent past. There is need therefore to control damming and the diversions of these rivers so as to maintain the levels of water in the lake.

REFERENCES

Abebe, E. and T. Getachew (1992). Seasonal changes in the nutritional status of *Oreochromis niloticus* LINN. (Pisces: Cichlidae) in Lake Ziway, Ethiopia. *Arch. Hydrobiol.* **124**: 109-122.

Akintude, E.A. (1982). Feeding rhythm in relation to changing patterns of pH in the gut of *Sarortherodon galilaeus* (Artedi) of Lake Kainj, Nigeria. *Hydrobiologia* **97**: 179-184.

Alexander, G. R. and E A. Hansen (1986). Sand bed load in a brook trout stream. *North America Journal of Fisheries Management* **6**: 9-23.

Alin, S. R., A. S. Cohen, R. Bills, M. M. Gashagaza, E. Michel, J. Tiercelin, K. Martens, P. Coveliers, S. K. Mboko, K. West, M. Soreghan, S. Kimbadi and G. Ntakimazi (1999). Effects of landscape disturbance on animal communities in Lake Tanganyika, East Africa. *Conservation Biology* **13**: 1017-1033.

Balirwa, J. S. (1990). The effect of ecological changes in Lake Victoria on present trophic characteristic of *Oreochromis niloticus* in relation to species role as a stabilising factor of biomanipulation. *Societes international limnologie*. (SIL), IAC Occasional paper no. **3**: 58-66.

Balirwa, J. S. (1998). Lake Victoria wetlands and the ecology of Nile Tilapia, *Oreochromis niloticus*, PhD dissertation, Wageningen University, The Netherlands.

Beadle, L. G. (1932). Scientific results of the Expedition to the East African lakes, 1930-1. The waters of some East African lakes in relation to their fauna and flora. *J. Linn. Soc. (Zool)* **38**:157-211.

Berg, L. and T. G. Northcote (1985). Changes in territorial, gill-flaring, and feeding behaviour in juvenile coho salmon (*Oncorhynchus kisutch*) following short pulses of suspended sediment. *Canadian Journal of Fisheries and Aquatic Sciences* **42**:1410-1417

Berkman, H. E. and C. F. Rabeni (1987). Effects of siltation on stream fish communities. *Environmental Biology of Fishes* **18**: 285-294.

Bowen, S. H. (1979). A nutritional constraint in detritivory by fishes: the stunted population of *Sarotherodon mossambicus* in Lake Sibaya, South Africa. *Ecol. Monogr.* **49**:17-31.

Bowen, S. H., E.V. Lutz and M. O. Alhgren (1995). Dietary protein and energy as determinants of food quality: Trophic strategies compared. *Ecology* **76**:899-907

Brusven, M. A. and S. T. Rose (1981). Influence of substrate composition and suspended sediment on insect predation by the torrent Sculpin, *Cottus rhotheus*. *Canadian Journal of Fisheries and Aquatic Sciences* **38**: 1444-1448.

Bruton, M. N. (1985). The effects of suspensoids on the fish. *Hydrobiologia* **125**: 221-241.

Bussmann, I., J. Hughes and S. Wainright (2000). Sediment resuspension and its effects on the turnover of methane, oxygen and carbon dioxide. *Verh. Internat. Verein. Limnol.* **27**:1428-1431.

Cleary, R. E. (1956). Observations of factors affecting small mouth bass production in Iowa. *Journal of Wildlife Management* **20**:353-359.

Cohen, A. S., R. Bills, C. Z. Cocquyt and A. G. Caljon (1993). The Impact of Sediment Pollution on Biodiversity in Lake Tanganyika. *Conservation Biology* **7**: 667-677.

Cordone, A. J. and D. W. Kelly. (1961). The influence of inorganic sediment on the aquatic life of streams. *California Fish and Game* **47**:189-228.

Daget, J. (1956). Memoires sur la biologie des poisons du Niger moyen. 2. Recherches sur Tilapia zillii (Gerv.) *Bull. Inst. Fr. Afr. Noire*, **36:** 391p.

De Groot, P., A. Field-Juma and D. O. Hall (1992). Taking Root: Revegetation in Semi-arid Kenya. Africa Centre for Technology Studies (ACTS) Press, Nairobi, Kenya.

Dill, L. M. (1983). Adaptive flexibility in the foraging behaviour of fishes. *Can. J. Fish. Aquat. Sci.* **40**:398-408.

Fish, G. R. (1955). The food of Tilapia in East Africa. *Uganda J.* **19**:85-89.

Ganf, G. G. (1972). The regulation of primary net production in lake George Uganda. In: Proceedings of IBP-UNESCO *Symposium on*

Productivity Problems of freshwaters. Kazimierz Dolny Poland. May 1970, Kajak,Z. and Hillbricht LIKowaska, A. (Eds). Polish Scientific Publishers, Warsaw, Poland.

Getabu, A. (1994). A comparative study of feeding habits of *Oreochromis niloticus* (Linnaeus) in Nyanza gulf, Lake Victoria and sewage ponds 93 – 103. In Okemwa, E., E. Wakwabi and A. Getabu (Eds). Recent trends of research on Lake Victoria fisheries. ICIPE Sciences Press, Nairobi, Kenya 198p.

Getachew, T. (1987). A study of an herbivorous fish, *Oreochromis niloticus* L., diet and its quality in two Ethiopian Rift Valley Lakes, Awasi and Zwai. *J. Fish.Biol.* **30**: 439-449.

Getachew, T. (1993). The composition and nutritional status of the diet of *Oreochromis niloticus* in Lake Chamo, Ethiopia. *J Fish Biol.* **42**:865-874.

Getachew, T., S.H. Bowen, E. Abebe and Z. Tadasse (2000). Seasonal variations determine diet quality for *Oreochromis niloticus* L. (Pisces: Cichlidae) in Lake Tana, Ethiopia. *Ethiop. J. Sci.*, **23**: 13-23.

Graeme P. and Kiplagat, K. W. (1995). The influence of the diel climatic cycle on the depth-time distribution of phytoplankton and photosynthesis in a shallow equatorial lake (Lake Baringo, Kenya). *Hydrobiologia* **304**:1-8.

Harbott, B. J. (1975). Preliminary observations of the feeding of *Tilapia nilotica* Linn. in Lake Rudolf. *Afr. J. Trop. Hydrobiol. Fish.* **4**:27-37.

Hecht, T. and C.D Van der Lingen. (1992). Turbidity-induced changes in feeding strategies of fish in estuaries. *S. Afr. J. Zool.* **27**: 95-107.

Hynes, H.B.N. (1970). The ecology of running waters. Liverpool University Press. 555pp.

Ivlev, V. S. (1961). *Experimental Ecology of the Feeding of Fishes*. Yale University Press, New Haven.

Kallqvist, T. (1987). Primary Production and phytoplankton in Lake Baringo and Lake Naivasha, Kenya. Report No. E-8041905. Norwegian Institute for water Research, Blinder, Oslo.

Kamanya, J., E. Twongo and Olet-ogwang (1996/97). Plankton identified in stomach contents of *Oreochromis niloticus* (Pisces, Cichlidae) and the water system of Lakes Edward, George and Kazinga channel-Uganda. *Afr. J. Trop. Hydrobiol.Fish.* **7**:49-54.

Kiplagat, W. K. (1989). Phytoplankton and Physicochemical dynamics of Lake Baringo. *M.Sc.thesis*. Kenyatta University, Nairobi, Kenya.

Kottelat, M. and T. Whitten (1996). Freshwater Biodiversity in Asia With Special Reference to Fish. World Bank Technical Paper No. 343. The World Bank, Washington D.C.

Larimore, R. W. (1975). Visual and tactile orientation of smallmouth bass fry under flood water conditions. Pages 323-332 in Stroud R. H. and H. Clepper, editors. Black bass biology and management. Sport fishing institute, Washington, DC.

Larimore, R. W. and P. W. Smith (1963). The fishes of Champaign County, Illinois, as affected by 60 years of steam changes. *Illinois Natural History Survey Bulletin* **28**:299-382.

Le Cren, E. D. (1951). The length-weight relationship and the seasonal cycle in gonad weight and condition of perch (*Perca fluviatilis*). *J. Anim. Ecol.* **20**:201-209.

Lowe-McConnell, R. H. (1958). Observations on the biology of *Tilapia nilotica* in East African Waters. *Revue. Zool. Bot. Afri.* **57**:129-170.

Lowe-McConnell, R. H. (1982). *Tilapias* in Fish communities- Pullin, R. S. V. and Lowe-McConnell, R. H (Eds). The Biology and culture of Tilapias. ICLARM (Manila, Philippines): 83-113.

Mann, M. J. (1971). Some taxonomical notes on fish fauna of the Baringo area. *Afr. J. Trop. Fish.* **1**: 25-34.

Mathooko, J. M. (1988). Downstream drift of invertebrates in Naro Moru River, a tropical River in Central Kenya. *M.Sc. thesis,* University of Nairobi, Kenya.

Mathooko, J. M. (1993). Availability and selection of mayfly, *Caenis kungu* Kimm. (Ephemeroptera: Caenidae) as a natural source of food by

rainbow trout, *Oncorhynchus mykiss* Walb., in a tropical river in Kenya. *Afr. J. Ecol.* **31**: 58-65.

Mcleay, D. J., I. K. Birtwell, G. F. Hartman and G. L. Ennis (1987). Response of Arctic grayling (*Thymallus arcticus)* to acute and prolonged exposure to Yukon placer mining sediment. *Canadian Journal of Fisheries and Aquatic Sciences* **44**:658-673.

Mihret-AB, T. (1988). A seasonal study on the species composition and phytoplankton biomass in Lake Ziway, Ethiopia. - Unpubl. M.Sc. thesis. Addis Ababa University, Addis Ababa, 72pp.

Moriarty, C. M. and Moriarty D. J. W. (1973). Quatitative estimation of the daily ingestion of phytoplankton by *Tilapia nilotica* and *Haplochromis nigripinnis* in Lake George , Uganda. *J. Zool.* **171**:15-23.

Moss, B. (1988). Ecology of fresh waters, Man and Medium. Blackwell Scientific Publishers, London, (2nd Ed).

Omondi, S. O. (2000). Diel physico-chemical dynamics, primary production and Algae of Lake Baringo, Kenya. *MSc. thesis*, Institute for infrastructural, Hydraulic and Environmental Engineering (IHE), Delft, The Netherlands.

Payne, A. I. (1975). The reproductive cycle, condition and feeding in *Barbus liberiensis*, a tropical stream-dwelling cyprinid. *J. Zool., Lond.* **176**: 247-269

Payne, A. I. (1986). The ecology of tropical lakes and rivers. John Wiley and Sons, Great Britain.

Poll, M. (1939). Exploration dug Parc Nationale Albert Mission. H. Dans (1935-1936). Fasc. 6. Poissons. Inst. Parcs Nationaux Congo Belge, Bruxuelles: 30-35 and 60-66.

Redding, J. M., C. B. Schreck, and F. H. Everest (1987). Physiological effects on Coho salmon and steelhead of exposures to suspended solids. *Transactions of the American Fisheries Society* **116**:737-744.

Republic of Kenya, (1996). Baringo District Development Plan, 1997-2001, Ministry of Planning and National Development. Government Printer: Nairobi.

Republic of Kenya, (1994). Baringo District Development Plan, 1994-1996, Ministry of Planning and National Development. Government Printer: Nairobi.

Reynolds, J. B., R. C. Simmons, and A. R. Burkholder (1989). Effects of placer mining discharge on health and food of Arctic grayling. Water Resources Bulletin. **25:** 625-635

Shivoga, W.A. (1999). Spatial-temporal variations in physicochemical factors, stream fauna abundance and composition in the zones of transition between Baharaini springbrook, Njoro River and Lake Nakuru, Kenya. *PhD thesis*, Vienna University, Austria.

Shivoga, W. A. (2000). Stream faunal distribution along a steep salinity gradient in Eastern Rift Valley of Kenya. *Vero. Internat. Verein. Limnol.* **27**: 1285-1289.

Smith, O. R. (1940). Placer mining silt and its relation to salmon and trout on the pacific coast. *Transactions of the American Fisheries Society* **69**: 225-230.

SPSS for Windows (1992). Base user's guide. 672pp.

Ssentongo, G. W. (1974). On the fishes and fisheries of Lake Baringo. *African journal of Tropical Hydrobiology* **3:** 95-106.

Ssentongo, G. W. (1971). Yield equations and indices for tropical freshwater fish populations. MSc. thesis, Department of Zoology, University of British Columbia, Vancouver, Canada.

Sumner, F. H., and O. R. Smith (1940). Hydraulic mining and debris dams in relation to fish life in the American and Yuba rivers of California. *California Fish and Game* **26**:2-22

Tadesse, Z. (1988). Studies on some aspects of the biology of *Oreochromis niloticus* (L.) (Pisces: Cichlidae) in Lake Ziway Ethiopia. – Unpubl. M.Sc. thesis. Addis Ababa University, Addis Ababa, 78pp.

Taft, A. C. and L. Shapavalov. (1935). Biological survey of streams and lakes in the Klamath and Shasta national forest on California. U.S. Bureau of Fisheries, Washington DC.

Talling J. F. and I. B. Talling (1965). The chemical composition of African Lake waters. In: Kallqvist, T. (1980). Primary Production and phytoplankton in Lake Baringo and Lake Naivasha, Kenya. Report No. E-8041905. Norwegian Institute for water Research, Blinder, Oslo.

Teshima, S., A. Kanazawa and S. Koshio (1987). Effects of feeding rate, fish size and dietary protein and cellulose levels on the growth of *Tilapia nilotica – Mem. Fac. Fish.* **36**:7-15.

Thebaux, M. L. and L. M. Dickie (1983). Structure of the body-size spectrum of the biomass in aquatic ecosystems: a consequence of allometry in predator-prey interactions. *Can. J. Fish. Aquat. Sci.* **50**: 1308-1317.

Thomas, R., M. Meybeck and A. Beim (1992). Lakes and Reservoirs. In: Chapman, D. (ed). Water Quality Assessments. A guide to the use of biota, sediments and water in environmental monitoring. Chapman and Hall. London.

Tilahun, G. (1988). A seasonal study on the phytoplankton primary production in relation to light and nutrients in Lake Ziway, Ethiopia. - Unpubl. M.Sc. thesis. Addis Ababa University, Addis Ababa, 61pp.

Trautman, M. B. (1981). The fishes of Ohio. 2nd edition. Ohio State University Press, Columbus.

Trewavas, E. (1983). Tilapiine Fishes of the genera *Sarotherodon*, *Oreochromis* and *Danakilia*. British Museums (Natural History), Cromwell Road, London.

Wallen, I. E. (1951). The direct effect of turbidity on fishes. Bulletin of Oklahoma Agricultural Research Station **48**: 1-27.

Waters, T. F. (1995): Sediment in Streams: Sources, Biological Effects, and Control. American Fisheries Society Monograph 7, Bethesda, Maryland.

Welcomme, R. L. (1967). The relation between fecundity and fertility in mouthbrooding cichlid fish (*Tilapia leucosticta*), *J. Zool. Lond.* **151**: 453-468.

Welcomme, R. L. (1983). River Fisheries, FAO Fisheries Technical Paper 262. Food and Agricultural Organisation of the United Nations, Rome.

Wetzel, R. G. (1983). Limnology. Saunders Coll., Philadelphia. 2nd Ed.

Worthington, E. B. (1932). Scientific results of Cambridge Expedition to the East African Lakes 1930-1. General introduction and station list. *J. Linn. Soc. Zool.* **38**: 99-119.

Worthington, E. B. and C. H. Ricardo (1936). Scientific results to Cambridge Expedition to East African Lakes, 1930-1931, No. 15. The fishes of Lake Rudolf and Baringo. *J. Linn. Soc. Lond. Zool* **39**: 353-389.

Appendix 1: Physico-chemical variables recorded in the Lake Baringo study sites from the December 2000 – May 2001.

December 2000

Sites	T.D.S. (mg/l)	Temperature (^{0}C)	Secchi depth (cm)	Turbidity (NTU)	DO%	DO Conc. (mg/l)	Conductivity (µS/cm)	pH
KMFRI	627	26.4	5.5	853	125	7.5	1747	7.39
	627	26.1	5.5	853	125	7.5	1752	7.42
	627	26.5	4.5	1042	125	7.4	1752	7.45
	627	33.1	4.5	1042	140	8.1	1693	7.89
	627	33.3	4.5	1042	145	8.2	1701	7.9
	627	33.2	4.5	1042	144	8.2	1697	7.89
Mukutan	627	27.8	5	730	127	7.8	1650	7.48
	627	27.8	5	730	127	7.7	1651	7.38
	627	27.9	5	730	125	7.6	1649	7.52
	627	28.9	5	730	119	7.2	1642	7.21
	627	28.6	5	730	121	7.2	1644	7.33
	627	28.2	5	730	122	7.3	1633	7.44
Molo	627	23.7	3	441	66	5.4	1702	7.94
	627	23.4	3	441	70	5.3	1706	7.96
	627	23.5	3	441	80	5.4	1701	7.95
	627	25.3	4	331	95	6.4	1775	7.63
	627	25.3	4	331	94	6.1	1775	7.67
	627	25.4	4	331	94	6.1	1774	7.6

January 2001

Sites	T.D.S. (mg/l)	Temperature (^{0}C)	Secchi depth (cm)	Turbidity (NTU)	DO%	DO Conc. (mg/l)	Conductivity (µS/cm)	pH
KMFRI	833.5	29	5.5	861	88	5.6	1804	7.7
	908.7	29.7	6	789	88	5.6	1723	7.64
	846	29.3	5.5	861	92	5.7	1744	7.64
	858.5	32.4	6	789	85	5.2	1720	7.64
	940	32.8	5.8	816	86	5.1	1736	7.33
	958.8	32	6.4	740	87	5.3	1721	7.35
Mukutan	833.5	26.1	6	920	79	5	1742	7.81
	852.3	26	5	1104	75	4.9	1765	7.69
	840.5	26.2	6.3	876	78	5	1762	7.66
	889.9	25.8	5	1104	98	5.2	1780	7.69
	889.9	26.6	3.5	1577	89	5.2	1779	7.69
	889.9	25.7	4	1380	85	5.2	1780	7.69
Molo	388.5	22.2	4.5	369	52	4.6	1702	8.55
	357.2	21.6	4.3	386	64	5.2	1706	8.47
	369.7	21.2	4.5	369	68	4.9	1701	8.46
	589.1	23.5	4.5	369	95	10.8	1313	8.66
	607.9	22.6	5	332	94	9.4	1300	8.54
	595.3	22.5	4.8	346	95	9.5	1271	8.54

February 2001

Sites	T.D.S. (mg/l)	Temperature (^{0}C)	Secchi depth (cm)	Turbidity (NTU)	DO%	DO Conc. (mg/l)	Conductivity (µS/cm)	pH
KMFRI	910	28.7	3	866	109	6.3	1968	8.4
	933	27.7	3	866	105	6.6	1951	8.4
	943	27.1	3	866	107	6.7	1961	8.4
	1037	26.9	3	866	106	6.6	1935	9.9
	1033	26.6	3	866	103	6.5	1943	9.9
	1026	26.4	3	866	102	6.5	1946	9.9
Mukutan	922	25	2.6	930	98	6.3	1822	9.19
	970	24.9	2.2	1099	99	6.3	1813	9.2
	972	25.2	2.4	1008	97	6.4	1813	9.1
	945	24.7	3.5	691	90	6.3	1994	9.2
	983	24.5	3.8	636	96	6.3	1996	9.2
	1026	24.4	2.7	896	95	6.4	1993	9.1
Molo	903	21.7	2.8	350	62	3.9	1742	8.96
	907	21.6	3.2	306	56	3.8	1734	9.01
	904	21.3	2.6	377	57	3.6	1733	8.97
	936	23.8	3.3	297	86	5.9	1922	9.17
	814	23.5	2.2	445	83	5.6	1832	9.21
	886	23.7	2.6	377	89	5.6	1839	9.17

March 2001

Sites	T.D.S. (mg/l)	Temperature (^{0}C)	Secchi depth (cm)	Turbidity (NTU)	DO%	DO Conc. (mg/l)	Conductivity (µS/cm)	pH
KMFRI	953	28	6	871	96	6	1045	9.54
	1003	27.5	5.5	950	95	5.9	1047	9.43
	1017	27.2	6	871	94	5.8	1046	9.41
	1032	27.3	5.2	1005	100	6	1943	9.66
	1032	27.3	5	1045	99	6	1942	9.54
	1030	28	5.5	950	100	6.2	1940	9.53
Mukutan	1120	27.7	3.5	1313	99	6.1	1927	9.44
	1124	27.8	4	1149	100	6.2	1931	9.37
	1132	28	3.5	1313	100	6.1	1969	9.33
	989	27.9	4	1149	100	6	5920	8.55
	1018	27.4	5	919	104	6.2	4140	8.75
	1017	26.9	4.5	1021	102	6.1	5030	9.12
Molo	1087	26.6	5	355	91	6.2	1850	7.84
	1103	26.5	4	444	93	6.1	1847	7.8
	1114	26.5	6	296	87	6	1846	7.79
	986	25.6	4	444	74	4.7	1997	7.61
	1018	25.2	6	296	76	4.8	1999	7.63
	1038	25.4	4	444	77	4.9	1997	7.65

April 2001

Sites	T.D.S. (mg/l)	Temperature (^{0}C)	Secchi depth (cm)	Turbidity (NTU)	DO%	DO Conc. (mg/l)	Conductivity (µS/cm)	pH
KMFRI	1032	24.2	6	741	107	5.5	1959	9.55
	1025	24.2	6.5	684	102	5.4	1958	9.52
	1019	24.1	6.5	684	100	5.1	1959	9.5
	1020	24.2	6.5	684	96	4.8	1957	9.5
	1029	24.1	6.4	695	100	4.7	1959	9.52
	1024	24.3	6.2	717	97	5.1	1958	9.51
Mukutan	904	27	4.5	770	88	5.4	1757	9.39
	972	27.1	4.3	806	86	5.2	1760	9.4
	973	26.7	4.5	770	87	5.3	1737	9.38
	960	27.1	4.3	806	76	5	1730	9.42
	880	26.9	4.2	825	78	4.9	1752	9.4
	875	27.3	4.7	737	78	5	1764	9.42
Molo	303	31.7	14	290	99	6.3	658	7.19
	307	31.2	12.5	325	110	6.5	643	7.31
	330	30.9	13.5	301	112	6	645	7.18
	126	28.2	19	214	83	4.7	256	8.09
	127	29.3	19	214	81	4.7	256	7.85
	127	29.4	19	214	80	4.7	256	7.82

May 2001

Sites	T.D.S. (mg/l)	Temperature (^{0}C)	Secchi depth (cm)	Turbidity (NTU)	DO%	DO Conc. (mg/l)	Conductivity (µS/cm)	pH
KMFRI	1032	25.4	4	751	92	5.7	1955	8.87
	1030	25.4	3.8	791	87	5.9	1954	8.84
	1029	25.4	3.5	858	86	5.9	1953	8.86
	1045	25.8	4	751	88	5.8	1952	8.86
	1036	25.7	4.3	699	89	5.9	1953	8.84
	1032	25.7	4.8	626	89	5.6	1950	8.85
Mukutan	896	24.3	4	975	101	5.9	1965	9.02
	968	25.4	4.5	867	100	5.8	1964	8.97
	985	26.1	4.8	813	102	5.8	1958	9
	856	27	5	780	106	6.1	1944	9
	932	26.8	5.2	750	102	5.9	1940	8.99
	934	26.9	5	780	100	5.9	1928	8.97
Molo	95	25.6	29	60	59	2.7	223	6.48
	104	25.7	31	59	48	2.2	222	6.24
	109	25.7	32	58	45	3	221	6.11
	161	27.3	13	290	94	4.5	316	8.53
	166	27.5	13	290	81	4.3	321	7.99
	169	27.9	13.2	289	73	4.3	317	7.78

Appendix 2: Data for the fish specimen caught at the KMFRI site during all the sampling dates

Date	Specimen	Total Length	Weight	Sex	Gonad Weight	K	M %
15.12.2000	1	17	88.4	F	2	1.799	2.262
	2	17.5	111.8	F	0.2	2.086	0.179
	3	17.5	76.5	F	0.2	1.427	0.261
31.01.2001	1	17.5	110.4	M	0.1	2.060	0.091
	2	15.5	70.1	F	0.4	1.882	0.571
27.02.2001	1	22	203.8	M	0.2	1.914	0.098
	2	17	85.1	F	0.4	1.732	0.470
	3	19	140	M	0.2	2.041	0.143
	4	21	182.2	M	0.3	1.967	0.165
	5	17	104.6	M	0.3	2.129	0.287
24.03.2001	1	20.5	189.2	M	0.4	2.196	0.154
	2	23.5	259.7	M	0.8	2.001	0.308
21.04.2001	1	26.5	374.8	M	1.4	2.014	0.374
	2	15.5	63.1	M	0.4	1.694	0.634
	3	15.5	68.9	M	0.1	1.850	0.145
	4	17.5	99.1	F	0.7	1.849	0.706
	5	18	103.5	M	1.4	1.775	1.353
	6	17.6	83.1	M	1	1.524	1.203
	7	16	59.5	M	0.3	1.453	0.504
	8	15.5	69.8	F	0.6	1.874	0.860
	9	17	74.2	F	0.3	1.510	0.404
	10	15.5	62.4	F	0.9	1.676	1.442
	11	14	51.2	M	0.1	1.866	0.195
	12	14.7	60.4	F	1.2	1.901	1.987
23.05.2001	1	12	37.8	F	0.1	2.188	0.265
	2	14	49.1	M	0.1	1.789	0.204
	3	12.8	44.8	F	0.1	2.136	0.223
	4	13.8	46.4	M	0.3	1.766	0.647
	5	12.7	36.4	F	0.2	1.777	0.549
	6	12.7	35.9	F	0.1	1.753	0.279
	7	13	36.2	M	0.1	1.648	0.276

Appendix 3: Data for the fish specimen caught at the Mukutan site during all the sampling dates

Date	Specimen	Total Length	Weight	Sex	Gonad Weight	K	M %
15.12.2000	1	16.5	96.2	F	1.6	2.142	1.663
	2	17	101.9	F	0.2	2.074	0.196
	3	17	107.7	M	0.2	2.192	0.186
	4	20.4	163.4	M	0.3	1.925	0.184
	5	16	89.3	M	0.001	2.180	0.001
	6	17.5	131.2	F	2.8	2.448	2.134
	7	17.5	124.3	F	1	2.319	0.805
31.01.2001	1	19.5	170	M	0.2	2.293	0.118
	2	19	158.8	M	0.3	2.315	0.189
	3	20	166	M	0.6	2.075	0.361
	4	19.5	157.9	M	0.2	2.130	0.127
	5	18	126.3	M	0.2	2.166	0.158
	6	21	204.4	M	0.1	2.207	0.049
27.02.2001	1	22	228.4	M	0.5	2.145	0.219
	2	22	197.2	M	0.7	1.852	0.355
	3	21	184.9	F	1.3	1.997	0.703
	4	25	377.4	M	0.2	2.415	0.053
	5	20	150.3	F	0.7	1.879	0.466
	6	21	163.4	F	1	1.764	0.612
	7	20	169.8	F	1.2	2.123	0.707
	8	22	204.2	M	0.1	1.918	0.049
	9	30	516.1	M	2.5	1.911	0.484
	10	21.5	193.9	F	1.5	1.951	0.774
24.03.2001	1	18	114.4	M	0.1	1.962	0.087
	2	20.5	152.4	M	0.6	1.769	0.394
	3	20	153.4	M	0.6	1.918	0.391
	4	18	106	F	0.7	1.818	0.660
	5	19.5	146.6	M	0.2	1.977	0.136
	6	18.5	125.3	F	0.6	1.979	0.479
	7	18.5	121.6	F	1	1.921	0.822
	8	17	112.1	F	0.4	2.282	0.357
	9	17.5	124.7	M	0.4	2.327	0.321
	10	17.7	109.8	F	1.9	1.980	1.730
21.04.2001	1	24.5	230.5	M	1.6	1.567	0.694
	2	25	354.4	M	2	2.268	0.564
	3	22	263.7	M	2.5	2.477	0.948
	4	26.5	358	M	1.3	1.924	0.363
	5	24.5	249.9	F	1.5	1.699	0.600
	6	23	246.8	F	2.2	2.028	0.891
	7	20	180.8	M	0.5	2.260	0.277
	8	22.5	220.5	F	2.3	1.936	1.043
	9	22	223.4	F	0.2	2.098	0.090
	10	23	248.3	M	0.8	2.041	0.322

23.05.2001	1	16.8	87.1	M	0.4	1.837	0.459
	2	14.2	53	M	0.1	1.851	0.189
	3	15.8	77.5	F	0.6	1.965	0.774
	4	17.7	97.3	M	0.6	1.755	0.617
	5	18.2	107.5	M	0.4	1.783	0.372
	6	18.5	117.5	M	0.8	1.856	0.681
	7	16.3	72	M	0.6	1.663	0.833
	8	16.3	80.4	F	2.7	1.856	3.358

Appendix 4: Data for the fish specimen caught at the Molo site in all the sampling dates

Date	Specimen	Total Length	Weight	Sex	Gonad Weight	K	M %
15.12.2000	1	19	129.1	_	0.001	1.882	0.001
	2	20	106.5	F	4.3	1.331	4.038
	3	16	97.3	F	0.4	2.375	0.411
	4	19.5	143.3	M	0.4	1.933	0.279
	5	26.5	420	M	3.5	2.257	0.833
	6	18	129.1	M	0.5	2.214	0.387
31.01.2001	1	21	182.8	M	0.7	1.974	0.383
	2	17	112	F	0.6	2.280	0.536
	3	24	299.4	M	0.7	2.166	0.234
	4	17.5	114.9	F	0.2	2.144	0.174
	5	19	137.9	F	2.5	2.010	1.813
	6	24	288.6	F	1.1	2.088	0.381
	7	18	158.2	M	0.5	2.713	0.316
	8	17	108.7	M	0.1	2.212	0.092
	9	19	142.2	F	1.2	2.073	0.844
	10	18.5	122.1	F	2.7	1.928	2.211
23.02.2001	1	26	470.4	M	0.7	2.676	0.149
	2	19.2	148.9	M	0.2	2.104	0.134
	3	19	142	M	0.1	2.070	0.070
	4	19.5	145.3	M	0.3	1.960	0.206
	5	17.5	118.2	M	0.7	2.205	0.592
	6	_	113.6	M	0.3	_	0.264
24.03.2001	1	17	85.2	M	0.5	1.734	0.587
	2	18	111.9	F	1	1.919	0.894
	3	19	149.1	M	0.4	2.174	0.268
	4	20	167.8	F	0.8	2.098	0.477
	5	18.5	121.9	F	2.9	1.925	2.379
	6	19	139.8	M	0.5	2.038	0.358
	7	22	198.1	M	0.7	1.860	0.353
	8	19	133.2	M	0.6	1.942	0.450
	9	20.5	140.3	M	0.3	1.629	0.214
	10	17	98.5	M	0.3	2.005	0.305
	11	18.5	104.4	M	0.9	1.649	0.862
	12	17	105.6	M	0.4	2.149	0.379
	13	17.5	109.8	M	0.4	2.049	0.364
	14	20.5	163.6	M	0.6	1.899	0.367
	15	17.5	92.2	F	0.8	1.720	0.868
21.04. 2001	1	20.5	165.3	M	1	1.919	0.605
	2	19	140.2	F	2	2.044	1.427
	3	20	162.8	M	0.6	2.035	0.369
	4	17	86.3	M	0.4	1.757	0.463
	5	17	76.8	F	0.5	1.563	0.651
	6	16	68	F	1.5	1.660	2.206
	7	15	65.9	F	0.3	1.953	0.455
	8	13.5	48.1	M	0.5	1.955	1.040
	9	13.5	47.7	F	0.1	1.939	0.210
	11	13.2	45.8	M	0.1	1.991	0.218
	12	12.5	41.2	F	0.6	2.109	1.456
	13	12.2	34	F	0.1	1.872	0.294
	14	12.5	38	F	0.1	1.946	0.263
	15	12.2	36.1	M	0.1	1.988	0.277

23.05.2001	1	20	153.5	F	3.5	1.919	2.280
	2	19.5	134.3	M	0.7	1.811	0.521
	3	19.3	135.8	F	2.3	1.889	1.694
	4	19.8	156.1	M	0.2	2.011	0.128
	5	19	134.5	M	0.2	1.961	0.149
	6	18.6	112.6	M	0.2	1.991	0.218

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