The Condition Factor, Feeding and Reproductive Biology of *Oreochromis niloticus* Linn. (Pisces: Cichlidae) in Lake Chamo, Ethiopia

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In partial fulfillment of the requirement for the degree of Master of Science in Biology

By Yirgaw Teferi
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TABLE OF CONTENTS

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LIST OF TABLES PAGE

LIST OF FIGURES

PAGE

ABSTRACT

The length-weight relationship, condition factor, feeding and reproduction of *O. niloticus* from Lake Chamo, Ethiopia were studied from March 1996 to March 1997. The length-weight relationship of 1473 fish ranging in size from 125 to 610 mm Total Length (TL) and in weight from 42.5 to 4800 g Total Weight (TW) was computed. The relationship between total length and total weight for the total sample was curvilinear, and described by: $TW = 0.0258TL^{2.942}$. The regression equation for the females was $TW = 0.069TL^{2.68}$ and for the males it was $TW = 0.022TL^{2.99}$. Fulton's and relative condition factor was calculated for both sexes separately. There was a significant variation in the mean monthly condition factor of both sexes (ANOVA, $P < 0.05$). The mean ± SE Fulton's condition factor of *O. niloticus* in Lake Chamo ranged from 2.10 ± 0.03 to 2.35 ± 0.10 for the males, from 1.96 ± 0.03 to 2.1 ± 0.04 for the females. The food of *O. niloticus* in Lake Chamo was studied from the stomach contents of 449 fish measuring 290-570 mm TL. In addition, a total of 145 juvenile *O. niloticus*, ranging from 61 to 115 mm caught during three sampling occasions were also examined for diet composition analysis. The diet of adult fish consists of 10 genera of blue greens, 8 genera of green algae and more than 8 genera of diatoms. Blue greens as a group contributed the bulk of the diet. The most frequently encountered species from the blue greens were *Anabaena* (96-100), *Microcystis* (82-100) and *Oscillatoria* (41-100). In terms of percentage composition by number, the blue greens contributed over 60% of the total food ingested. Of these, more than 50% was contributed by *Anabaena*, *Microcystis* and *Oscillatoria*. When the food items were expressed as percentage volume, the blue greens made up 32.2% whereas the green algae and the diatoms contributed about 32.3 and 35.2%, respectively. The mean percentage dry weight of the green algae, diatoms and blue greens was 53.8, 28.2 and 17.7%, respectively. Among the green algae, *Cosmarium* alone contributed more than 40% to the total dry weight. Zooplankters occurred on rare occasions in the stomach contents of adult *O. niloticus* whereas these were relatively more frequent (1.8%) in the diet of the juveniles. The feeding pattern of *O. niloticus* was observed to have a diel rhythm. *O. niloticus* in Lake Chamo is a continuous feeder during the day. Daily ingestion of phytoplankton was estimated to be about 3.75% of its body weight per day at an average water temperature of 26 °C. Gonads from a total of 1349 *O. niloticus* were examined in this study. The mean monthly gonado-somatic index (GSI) of the males ranged from 0.21 to 0.51 whereas that of females ranged from 0.51 to 1.56. Higher values for the females were observed between March and June, and for the males between March and May, 1996. The pattern of gonad development for both sexes was more or less similar. Ripe males occurred at high frequencies (ranged:39-60%) in March, April and May, 1996. The percentage of ripe females ranged from 47 to 53 with seasonally highest frequencies occurring from March to June, 1996. Thus, it was concluded that *O. niloticus* in Lake Chamo spawns throughout the year with peak breeding activity in March, April, May and June. The smallest sexually mature female was 385 mm TL, whereas the male was 395 mm TL. However, the 50% maturity length was415 mm TL for females while 425 mm TL for males. *O. niloticus* were all mature above 500 mm TL. The average fecundity of *O. niloticus* ranging in Length from 390 to 560 mm TL, and in weight from 1300 to 3900 g was 2493 ± 300 (N=209). The smallest count was 1047 (fish length=470 mm TL) whereas the largest was 4590 (fish length=510 mmTL). In general, fecundity of *O. niloticus* in Lake Chamo was linearly related to total length, total weight and gonad weight.

1. INTRODUCTION

Tilapia (Family Cichlidae) are mainly indigenous to Africa, but various species in the group are now found in most tropical and sub-tropical areas of the world. They are naturally distributed throughout Africa, Central America and parts of Asia (Philipart & Ruwet, 1982). Among Tilapia, *Oreochromis niloticus* is more widely distributed in Africa than in any other tropical region (Balarin and Hatton, 1979). It is the most abundant species in Lakes Victoria, Edward, Albert and Rudolf (Fryer and Iles, 1972). In addition, *O. niloticus* is one of the most cultured species in many countries. The distribution of this species in Ethiopia is quite similar to that of other African countries. It is one of the most important species in the ecology and fisheries of almost all Ethiopian inland waters (Shibru Tedla, 1973). *O. niloticus* has also been introduced or stocked into many reservoirs and ponds of the country (FAO, 1995).

Generally, Tilapia have a diversified diet that is composed of both vegetation and animal components. The vegetation component is usually dominant, and consists of phytoplankton, epilithic algae, epiphytic algae, vegetation debris and sediment rich in diatoms and bacteria (Balarin and Hatton, 1979). The animal component in the diet of Tilapia consists of zooplankton, and benthic animals such as insect larvae, crustaceans and molluscs (Balarin and Hatton, 1979). Fryer and Iles (1972) reported that most members of the group are essentially macrophagous herbivores whereas some species, like *Sarotherodon mossambicus*, *S. andersonii*, *S. niloticus* and *Tilapia sparrmanii*, usually feed only on phytoplankton. However, as is the case in several fish species (Lowe-McConnell, 1987), the food habit of Tilapia is extremely variable within a water body depending on the size/age of the fish, the habitat occupied and the time of the year (Philipart and Ruwet, 1982). Thus, species like *O. niloticus*, *S. esculentus* and *S. alcalicus* feed mainly on phytoplankton as adult, and zooplankton and benthic animals as young (Greenwood, 1953; Welcomme, 1967; Fryer and Iles, 1972).

Studies on the food of *O. niloticus* in Ethiopia (e.g., Getachew Teferra, 1987, 1993; Zenebe Tadesse, 1988; Tudorancea *et al.*, 1988) showed that the fish is omnivorous when young, but it consumes a large quantity of various species of phytoplankton at later stages. In addition to some species of phytoplankton, juvenile *O. niloticus* (<6 cm total length, TL) feed also on chironomid larvae, copepods and rotifers in Lake Zwai (Zenebe Tadesse, 1988) whereas on nematodes and zooplankton in Lake Awassa (Tudorancea *et al.*, 1988). This is consistent with the finding of Moriarty (1973) in that the fish feed progressively more phytoplankton as they grow older and upon reaching 6 cm TL, phytoplankton forms almost the entire diet.

Getachew Teferra (1987) identified more than 20 genera of phytoplankton (belonging to 4 families) from the stomach contents of *O. niloticus* in Lake Awassa. He also reported that the fish feeds mainly on blue greens such as *Chroococcus*, *Oscillatoria* and *Microcystis*, and on the green alga *Botryococcus braunii*. Zenebe Tadesse (1988), who identified 34 genera of phytoplankton (belonging to 3 families) in adult *O. niloticus*, found that blue green algae (mainly *Lyngbya* sp and *Chroococcus* sp) form the dominant component of the diet of the fish in Lake Zwai. A total of 21 genera of phytoplankton belonging to 3 families comprise the diet of adult *O. niloticus* in Lake Chamo (Getachew Teferra, 1993). However, Getachew Teferra's (1993) study was based on samples taken only in July, 1988. Thus, a more frequent sampling regime may show a better picture. This is so, because the composition of the diet of *O. niloticus* varied seasonally, and depended on the composition of the phytoplankton both in Lake Awassa (Getachew Teferra, 1987) as well as in Lake Zwai (Zenebe Tadesse, 1988).

Tilapia in general possess special mechanisms and behavioural skills for the exploitation of primary food resources (plant components) (Bowen, 1983). Digestion of plant matter by the fish is usually hindered by the plant cell wall which acts as a barrier to digestive enzymes. But Tilapia, particularly *O. niloticus*, lyses algal cell wall with gastric acid secreted to produce a stomach pH as low as 1.00 (Moriarty, 1973; Bowen, 1976). In addition, the extended length of the intestine facilitates the digestion of plant materials by allowing extensive exposure to the digestive and absorptive mucosae.

The degree of digestion and absorption depends on the type of food item ingested. Thus, the presence of a food item in the stomach of a fish does not necessarily show that the food is digested and assimilated. It is essential to have an adequate measure of food quality, total organic matter and assimilation efficiency. Food quality can be determined by measuring the various nutritional components of the food whereas total organic matter (ash free dry weight, AFDW) can be determined by igniting a known weight of the food sample, and the weight loss after ignition gives the weight of the total organic matter in the sample (Bagenal and Tesch, 1978). Assimilation efficiency (also called digestive efficiency) is the ratio of absorption to ingestion, and measures the ability of an animal to digest and absorb nutrients from its food (Buddington, 1979).

The nutrient composition of the stomach contents of *O. niloticus* (Getachew Teferra, 1987, 1993; Zenebe Tadesse, 1988) from some Ethiopian lakes has been studied. In Lake Awassa, for instance, Getachew Teferra (1987) found that protein, lipid and carbohydrate made up 9.1, 27.8 and 47.6%, respectively, of the AFDW. In Lake Zwai, these nutrients contributed 11.6, 9.7 and 39%, respectively (Eyualem Abebe and Getachew Teferra, 1992). The remaining portion of the AFDW in each case was believed to have been contributed by other organic materials, mainly detritus, and also nucleic acids, hormones, pigments and vitamins (Getachew Teferra, 1987; Zenebe Tadesse, 1988).

Assimilation efficiency(%) of *O. niloticus* varies depending on the type of nutrient. Generally, protein is the most assimilated whereas lipid is the least assimilated nutrient by the fish in Lakes Awassa, Zwai and Chamo (Getachew Teferra, 1987; 1993). Based on assimilation efficiency and food quality, the seasonally dominant alga, *Botryococcus braunii*, in Lake Awassa (Elizabeth Kebede, 1987) is found to be least nutritious to the fish (Getachew Teferra, 1987). However, blue greens are believed to be more nutritious than others in Lake Zwai (Zenebe Tadesse, 1988). In contrast, diatoms (*Navicula* and *Melosira*) are more nutritious than others to *O. niloticus* in Lake Chamo (Getachew Teferra, 1993).

Tilapia in general tend to show a diel feeding periodicity. Some species are active during the day while others are nocturnal feeders. *O. niloticus*, for example, feeds mainly during the day time in Lakes Awassa (Getachew Teferra, 1987), Zwai (Zenebe Tadesse, 1988) and

Chamo (Getachew Teferra, 1993). Feeding periodicity studies based on rate of gastric evacuation showed that the fish ingests about 11.5, 7.6, and 4.4% of its body weight per day in Lakes Awassa, Zwai and Chamo, respectively (Getachew Teferra, 1987, 1993). Day time feeding appears to be triggered by factors such as temperature and availability of oxygen. For instance, *O. niloticus* stops feeding when the level of oxygen drops below 1.5 mg/l (Balarin and Hatton, 1979). Feeding activity of Tilapia may be temporarily interrupted if the fish are engaged in spawning activity (Getachew Teferra, 1987; Demeke Admassu, 1989). *O. niloticus* is a maternal mouth brooder and the males are also engaged in building and guarding their nests (Fryer and Iles, 1972). Thus, it is probable that the fish may not feed actively when engaged in breeding activities.

Based on reproductive behaviour, Tilapia are grouped as substratum spawners and mouth brooders (Lowe-McConnell, 1982). *O. niloticus*, a maternal mouth brooder, pick up the eggs immediately after they are laid; in many cases the eggs are fertilized in the mouth (Lowe-McConnell, 1987). Then, they move to special brooding grounds, eventually leaving the young in nursery areas, near shores. In Lake Awassa, *O. niloticus* incubates embryos and larvae in the mouth for 10-15 days, and the larvae reach a size of 9-10 mm before they are released (Yosef Tekle-Giorgis, 1990). Similarly, the release of the young in Lake Haiq does not take place before the larvae are 10 mm long and two weeks old (Kebede Alemu, 1995). The juveniles live first in waters less than 50 cm deep, along the shore, and as they grow larger they move into vegetation zones and the open water (Tudorancea *et al.*, 1988).

The length of sexual maturity of Tilapia is extremely variable, and depends on the species, growth rate and environment. Species in small ponds and in cultures mature at a much younger age and smaller size than the same species living in lakes (Fryer and Iles, 1972; Lowe-McConnell, 1987). In addition, in species like *O. niloticus* individuals which are in poor body condition start to breed at a smaller size than those in good condition (Balarin and Hatton, 1979). Furthermore, size of sexual maturity may also be different for the sexes of the same species. In *O. niloticus* in Lakes Zwai and Awassa, for instance, females were found to be mature at a smaller size than males (Zenebe Tadesse, 1988; Demeke Admassu, 1994). The same has been reported by Babiker and Ibrahim (1979) for *O. niloticus* in White Nile. However, both sexes may become sexually mature at approximately the same age (Lowe-McConnell, 1987; Demeke Admassu, 1994).

Brood size of *O. niloticus* is related to the total length of the fish (Fryer and Iles, 1972). Brooding efficiency(%), which is equal to brood size divided by fecundity, varies considerably from species to species among the cichlids. The difference might be due to variation in egg size, buccal cavity (mouth size) and fecundity of the brooding fish. Brooding efficiency of a species varies also with the length of the fish. In Lake Awassa, for instance, it is maximum for 23 cm *O. niloticus*, but progressively decreases for those smaller and larger than 23 cm (Demeke Admassu, 1994).

Tilapia in equatorial waters tend to breed almost throughout the year, but those in lakes distant from the equator tend to have well defined breeding seasons (Lowe-McConnell, 1982). Seasonally breeding Tilapia can have a unimodal or multimodal peak breeding activities in a year (Lowe-McConnell, 1982; Demeke Admassu, 1996). Nevertheless, some individuals in breeding condition can be caught at any time of the year even in seasonally breeding Tilapia (Lowe-McConnell, 1982; Demeke Admassu. 1996). *O. niloticus* in Ethiopian lakes, for instance, may breed throughout the year, but breeding activity is intensive during the periods from December to March in Lake Zwai (Zenebe Tadesse, 1988), January to April and July to September in Lake Awassa (Demeke Admassu, 1996) and in Lake Haiq (Kebede Alemu, 1995). In lake Tana, unlike in the rift valley lakes, *O. niloticus* seems to have a long spawning season lasting from March to August (Zenebe Tadesse, 1997).

The main breeding activity of fish species in the tropics has been variously associated with light intensity, temperature, rainfall and water level or seasonal flooding (Fryer and Iles, 1972; Lowe-McConnell, 1982). Abundance of food has also been considered as an important factor in timing of breeding in some species at low latitudes (Mckaye, 1977). Demeke Admassu (1996) found that intensive breeding activity by *O. niloticus* in lake Awassa coincides with increase in phytoplankton biomass. He, therefore, argued that the increase in phytoplankton biomass may be one of the factors stimulating spawning in *O. niloticus* whereas some other environmental factors (e.g., rainfall, light intensity) may have secondary or indirect effect through their role in modifying phytoplankton biomass.

With the ever-increasing need for cheap source of protein world-wide, more and more attention has to be given to exploit natural fish resources. The problem of food shortage is acute in countries like Ethiopia. However, Ethiopia is endowed with 7400 sq. km. of fresh water (i.e., lakes) which can provide about 20,000 tonnes of fish per year (LFDP, 1996). But, the current level of fish exploitation from the major lakes in the country amounts to

8,474 tonnes per year. The overall fish production that is recommended per year from all water bodies of the country (including rivers) ranges from 40,000 to 50,000 tonnes (LFDP, 1996). The resource undoubtedly can offer one of the solutions to the problem of food shortage in the country. Nevertheless, the yield that can be obtained from the resource will be sustained only if the exploitation is well managed. Proper management of fish resources, however, requires detailed knowledge on the fisheries as well as on the biology of the fish (Lackey and Nielsen, 1980). Such detailed knowledge is not available for the *O. niloticus* stock in Ethiopia, and this has hindered proper management of the fisheries. The present study was, therefore, conducted to contribute to the knowledge on *O. niloticus* in Lake Chamo, where the fish is one of the most exploited species.

The specific objectives of the study were:

(i) To determine the food and feeding habit of the fish, and to investigate if these vary seasonally and with fish length.

(ii) To determine breeding season, maturation, fecundity and sex-ratio of *O. niloticus*.

(iii) To assess length-weight relationship and seasonal variation in the condition of *O. niloticus* in Lake Chamo.

The outcome of the study can, hopefully, be used as base-line information, on the base of which management decisions can be made to sustain the *O. niloticus* yield from Ethiopian waters in general and from Lake Chamo in particular. In addition, the study may also provide useful information for future development of culture fisheries in the country.

2. DESCRIPTION OF THE STUDY AREA

The Ethiopian Rift Valley is part of the Great African Rift Valley which extends from Mozambique in the south up to the Red Sea coast in the north. The rift valley in Ethiopia runs from south towards the north-east dividing the country almost into two halves. Most of the lakes in Ethiopia are located within the southern half of this valley, and are grouped into three distinct basins (Von Damm and Edmond, 1984): the Zwai-shalla, the Shallo-Awassa, and the Abaya-Chamo basins (Fig. 1). The Zwai-Shalla basin occupies the northern part, and contains Lakes Zwai, Langano, Abijata and Shalla. The artificial Lake Koka is also located in this basin. The Shallo-Awassa basin is to the south of the Zwai-Shalla basin, and contains Lake Awassa and the swampy lake - Lake Shallo. The Abaya-Chamo basin is the southernmost in the valley, and in addition to containing Lakes Abaya and Chamo, it is also believed to be part of a much larger drainage basin which extends further south up to Lakes Chew Bahir and Turkana (Von Domm and Edmond, 1984). Discontinuous river flows have in the past linked Lakes Abaya, Chamo and Chew Bahir to Lake Turkana and the later to the White Nile (Grove *et al.*,1975; Wood and Talling, 1988).

Lake Chamo (Lat.: 5^0 42'- 5^0 48' N; Long:36^0 30'- 38^0 30' E) is located at an altitude of 1108 m, and about 518 km south of Addis Ababa (Makin *et al.*, 1975; Amha Belay and Wood, 1984) (Table 1). The lake covers an area of 551 km^2 and is the second largest among the rift valley lakes and the third in the country. According to earlier records (Amha Belay and Wood, 1982) Lake Chamo had a maximum depth of 20 m, but Elizabeth Kebede (1996) reported a maximum depth of 13 m. However, measurements done at the time of sampling in the present study did not exceed 9 m. The mean depth of the lake might have also changed, because the lake has receded by about half a kilometre in the last two decades, which also reduce the surface area. Beadle (1981) suggested that irregular overflow of Lake Chamo via the Sagan River to Lake Chew Bahir has occurred in the last century. At present, however, the water level of the lake is lower than that of the outlet channel. Indeed, Lake Chamo has no obvious surface outlet currently, but it is fed principally by Kulfo River from the north and by two rivers of less importance, Sile and Sego, from the west (Fig. 2).

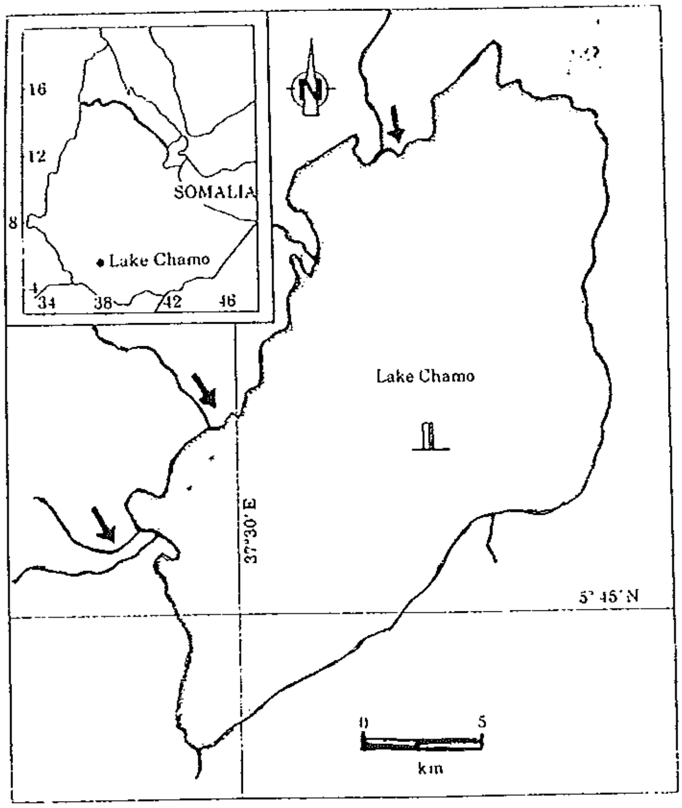


Fig. 2. Map of Lake Chamo. (Source: Getachew Teferra,1993).

The climate of the Lake Chamo region is characterized by warm and sub-humid conditions, consisting of one dry and one rainy season per year (Daniel Gemechu, 1977). Data on rainfall during the present study, and for 1995 provided in Hailu Anja (1996), both obtained from the Agro-meteorological Station of the North Omo Agricultural Development Enterprise, indicate that the rainy season extends from March to October, the peak being in April and May (Fig. 3). December is the driest month. During the period from 1990 to 1996, the minimum air temperature ranged from 15.0 to 21.5 °C whereas the maximum air temperature ranged from 25.8 to 34.4 ° C (Fig. 4). The absolute difference between maximum and minimum air temperature was largest in December and lowest in July (Fig, 4). Apparently, mean daily air temperature was higher in 1996 than the previous six years. Water temperature of Lake Chamo, measured at the time of sampling by a concurrently conducted study (Demeke Admassu and Zenebe Tadesse, unpublished manuscript) showed that high water temperature ranged from 23 to 29 ° C. Getachew Teferra (1993) has also reported that an average surface water temperature of Lake Chamo is about 25 ° C all year round.

Lake Chamo is chemically similar to most other East African Rift Valley lakes in that sodium, carbonate and bicarbonate are the dominant ions (Talling and Talling, 1965) (Table 2). Alkalinity of the lake is 6.2 meq/l according to Amha Belay and Wood (1982), but 12 meq/l according to Elizabeth Kebede (1996). The lake has a pH of 8.9 (Elizabeth Kebede, 1996). Elizabeth Kebede (1996) reported that the salinity of the lake has changed two fold in the last four decades. Salinity measurements taken during the present study ranged from 1 g/l to 1.2 g/l (Demeke Admassu and Zenebe Tadesse pers. comm.). As compared to 0.6

g/l that was measured by Loffredo and Maldura (1941), it is evident that the water has become more concentrated, which might be attributed to the high evaporation.

According to Elizabeth Kebede (1996), Lake Chamo had nitrate, phosphate and silica concentrations of 30, 135 and <100 μg/l, respectively. According to Amha Belay and Wood, 1982 chlorophyll a concentration in Lake Chamo was generally high (56-238 μg/l), indicating the lake's high primary productivity. An algal bloom mainly due to *Microcystis* sp has been reported from Lake Chamo (Amha Belay and Wood, 1982) which resulted in a mass fish kill and death of wildlife. The other dominant algae in the lake include *Anabaena*, *Chroococcus* and *Navicula* sp. Zooplankton community of Lake Chamo is composed of *Mesocyclops aequatorialis*, *Thermocyclops decipiens, Moina micrura, Ceriodaphnia cornuta, Daphnia magna* and *Brachionus angularis* (Defaye, 1988; Green and Seyoum Mengistou, 1991; Seyoum Mengistou pers. comm.). The major benthic animals in Lake Chamo are oligochoetes, gastropods, ostracods, chironomids and hemipterans such as corixids (Tudorancea *et al.*, 1988).

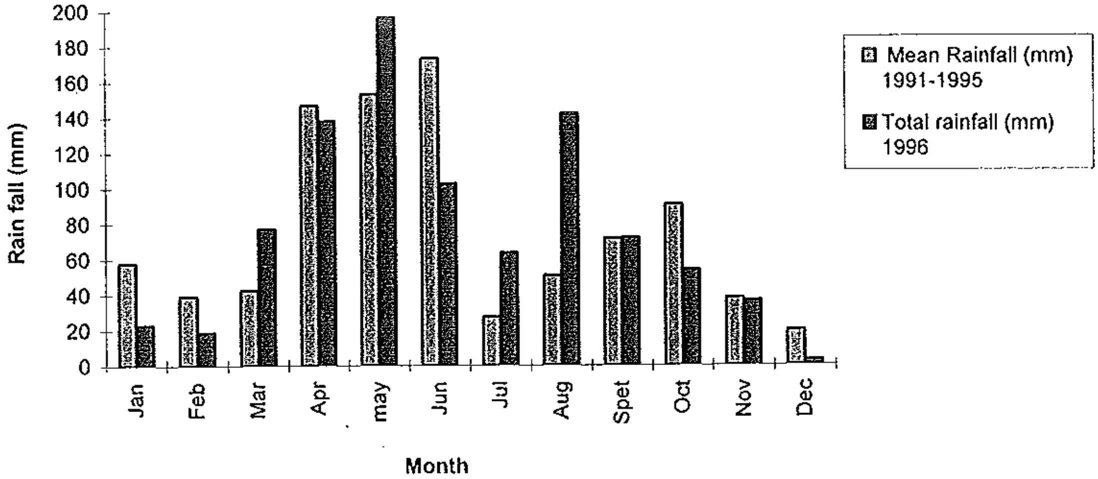


Fig.3. Seasonal variation in rainfall (mm) for the Lake Chamo region. Mean monthly rainfall from 1990-1995 and the total monthly rainfall for 1996 are indicated separately

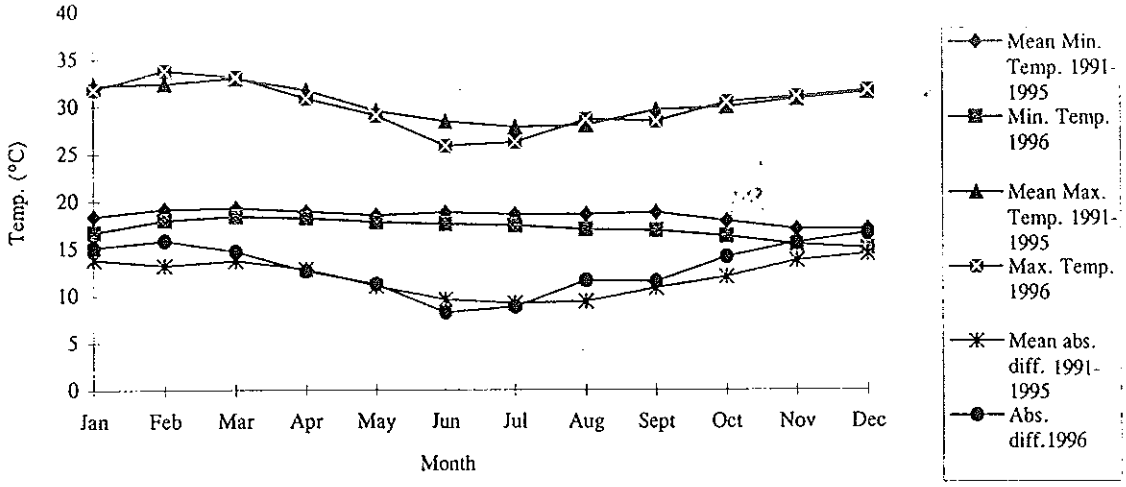


Fig. 4. Seasonal variation in the maximum and minimum air temperature (° C) of the Lake Chamo region. The mean monthly maximum and minimum, and absolute difference between maximum and minimum air temperature for the period between 1991-1995 and the average maximum and minimum, and absolute difference between maximum and minimum air temperature for 1996 are indicated separately

The shore line of Lake Chamo is fringed by various form of macrophytes which includes *Typha* sp, *Phragmites* sp and *Juncus* sp as well as water-side grasses such as *Loudetia phragmitodes* and *Sebestian* sp (FAO, 1992). *Aeschynomene elaphroxylon* (local name: "Sokie") is found in the south-western riverine shore; fishermen construct their fishing rafts from this woody plant. At high water level, the lake water floods terrestrial grasses and other plants (pers. obs.), and these provide feeding ground and shelter for juvenile fish.

The fish fauna of Lake Chamo, and that of Lake Abaya, is Soudanian species (Beadle, 1981). This is believed to be due to a free passage of the Nile fauna up into Lake Abaya and Chamo as a result of previous inter-connection of Lakes Abaya, Chamo, Chew Bahir and Turkana, and the later with the Nile system. As a result, the fish fauna in Lakes Chamo and Abaya is the most diversified in the rift valley lakes, and is composed of more than 20 species of which 12 are listed in Table 3. From these, *Lates niloticus*, *O. niloticus*, *Labeo horii*, *Bagrus docmac*, *Clarias gariepinus* and *Barbus* sp are of great economic importance to the fishery of Lake Chamo (FAO, 1995). The estimated sustainable yield from Lake Chamo is 4500 t/yr but the estimated total landing in 1995 was 1814 t. This is composed of 39% *L. niloticus*, 35% *O. niloticus* and 26% other species such as *L. horii*, *B. docmac* and *C. gariepinus* (LFDP, 1995). Currently, *O. niloticus* comprises by far the bulk of the catch due to the decline in the catch of *L. niloticus*.

The decline in the catch of *L. niloticus* is believed to be due to the introduction of a type of cotton gillnet (locally called "Gancho") (LFDP, 1995). This net is made from a multifilament cotton twine (size 210/24 or above), and its stretched mesh size ranges from popular at Lake Chamo. Hook and line gears are also used to catch mainly *L. niloticus*, *C. gariepinus* and *B. docmac*. The major catch of *L. horii* is supplied for the crocodile farm located at the shore of Lake Abaya.

Crocodile (*Crocodylus niloticus*) are found in great number at Lake Chamo. In addition to several fish eating birds such as white pelican (*Pelicanus onocrotalus*), pink - backed pelican (*P. rufescens*), cormorants (*Phalacrocorax africanus*), darters (*Anhinga rufa*) and storks, the fish of Lake Chamo supports a large population of crocodiles and nile monitors (*Varanus niloticus*).

Table 1. Some morphometric features of Lake Chamo

Characteristics	Values
Latitude	5°50'N (c)
Longitude	37° 35'E (c)
Altitude	1233 m (a)
Surface area	551 km^2 (a)
Catchment area	2210 km^2 (a)
Length	36 km (b)
Width	23 km (b)
Perimeter	118 km (b)
Max. depth	13 m (a)
Secchi depth	65 cm (a)

Sources: (a) Elizabeth Kebede (1996)
(b) FAO (1992)
(c) Makin *et al.* (1975)

Table 2. The chemical composition of Lake Cham

Chemical features	Mean values
pH	8.9 (a)
Chlorophyll a	44 $\mu g\ l^{-1}$ (b)
Salinity	1.0 $g\ l^{-1}$ (c)
Conductivity (k_{20})	1320 $\mu S\ cm^{-1}$ (b)
Calcium (Ca^{2+})	0.35 meq l^{-1} (b)
Magnesium (Mg^{2+})	0.70 meq l^{-1} (b)
Sodium (Na^{+})	12.61 meq l^{-1} (b)
Potassium (K^{+})	0.78 meq l^{-1} (b)
Chloride (Cl^{-1})	2.02 meq l^{-1} (b)
Sulfate	1.10 meq l^{-1} (b)
Carbonate-bicarbonate	
(Co_3-HCo_3)	12.25 meq l^{-1} (b)
Total cations	11.9 meq l^{-1} (a)
Total anions	11.7 meq l^{-1} (a)

Sources: (a) Amha Belay and Wood (1982)
(b) Elizabeth Kebede (1996)
(c) Wood and Talling (1988)

Table 3. List of major fish species found in Lake Chamo

Family	Species	Common name
Cyprinodontidae	*Aplocheilchthys* sp	Minnow
Mormyridae	*Mormyrus caschive*	Elephant snout fish
Characidae	*Hydrocynus forskalii*	Tiger fish
Cyprinidae	*Barbus bynni*	Barbus
	Barbus sp	Barbus
	Labeo horii	Labeo
	Labeo niloticus	Labeo
Bagridae	*Bagrus docmac*	Catfish
Clariidae	*Clarias gariepinus*	"
Mochokidae	*Synodontis schall*	"
Centropomidae	*Lates niloticus*	Nile perch
Cichlidae	*Oreochromis niloticus*	Tilapia

lowest taxa possible and then analysed using numerical and volumetric methods (Windell and Bowen, 1978).

3.2.2 Composition of stomach contents of adult *O. niloticus*

The natural food of adult *O. niloticus* in Lake Chamo was studied from the stomach contents of 449 fish measuring 290-570 mm TL. Of these 216 were males and 233 were females. Sex ratio (females to males) in the total sample was 1:1.08.

The stomach contents preserved in 5% formaldehyde solution were examined at magnification between 100x and 400x. Food items were identified to the lowest taxa possible using description in various literature sources (for example, Mammaril and Fernando, 1978; Blomqvist, 1981; etc.). The relative importance of the different food items found in the stomach were determined using numerical, volumetric and gravimetric methods (Windell and Bowen, 1978).

(i) Numerical analysis

The various food types identified were analysed in two ways.

(a) Percentage frequency of occurrence - the proportion of the fish that contained one or more of a given food type (undiluted samples) were calculated as the frequency of occurrence for the food type.

(b) Percentage composition by number - samples were diluted to obtain a count of 50-300 food items along a transect (Getachew Teferra, 1987). Ten μl was then taken from the diluted sample and placed on a microscope slide and covered with a 22 mm cover slip. Counting was made along five transects under high power objective (400x). The total number of algal unit per slide (10 µl) was calculated as total number of algal unit per transect multiplied by all transects per slide (48). The percent abundance of each food item was calculated by taking the total number of individuals of each algal type / 5 transect as percentage of the total number of all algae / 5 transect. This value, therefore, gave the percentage composition by number of each algal type.

(ii) Volumetric analysis

The dimensions of the different algal units ware measured using an inverted microscope, calibrated with a stage micrometer. Then, the volume of each algal unit was calculated using simple geometric figures (Windell and Bowen, 1978; Rott, 1981). For the colonial forms such as *Microcystis*, about 10-21 algal units were measured and the average volume was then estimated. The total volume of algal unit in 10 ml sample was calculated as follows:

Total volume of algal unit per slide (10 µl) was calculated by the total volume of algae per transect multiplied by all transects per slide (48). Thus, total volume of algal unit in 10 ml sample is equal to total volume of algae unit per slide multiplied by the volume of the sample (10 ml) divided by the volume taken for the counting. The percent volume of each food item was then calculated by taking the total volume of individuals of each type and expressing it as a percentage of the total volume of all algae in all fish.

(iii) Gravimetric analysis

Food items of the stomach contents were divided into taxonomic categories and the dry weight of the group specimens in each category were indirectly estimated using volume - dry weight conversion factor as 1 mm^3 = 0.1 mg (Bowen, 1983; Getachew Teferra and Fernando, 1989). The dry weight of each food category were then expressed as percentage of the total dry weight of stomach contents.

3.2.3 Diurnal feeding rhythm

A total of 202 specimens of *O. niloticus* were collected at intervals of four hours during a 24 hours period using gillnets of 180 and 220 mm stretched mesh. Total length and total weight were measured to the nearest 0.1 cm and 0.5 gm, respectively. The stomach was isolated and weighed. The pH of the stomach contents was measured using a pH meter with glass electrodes. The stomach was then washed off its contents and weighed. The difference in weight between the full and washed stomach gave the wet weight of the stomach contents. The number of empty stomachs was also recorded for each time interval. Percent stomach fullness(%SF) [(Wt. of stomach content multiplied by 100 and divided by the body weight)] was plotted against time of capture. Similarly, the proportion of empty stomach was plotted against time of capture to determine the feeding pattern of the fish.

Rate of gastric evacuation was also determined using two parameters: percent stomach fullness index and time of the day. Then, a regression relationship was estimated between percent stomach fullness values and time of capture, starting the time when the highest percent stomach fullness was observed. The slope of this regression relationship was used to express rate of gastric evacuation (Lauzanne, 1978).

3.3 Determination of breeding season, sexual maturity and fecundity

A total of 1349 gonads of *O. niloticus* were examined in this study. Of these 658 were males and 691 were females ranging in size from 130 to 610 mm TL and from 125 to 580 mm TL, respectively.

Breeding season of *O. niloticus* was determined based on the level of gonad maturation and gonadosomatic index (GSI). A six stage gonad maturation scale was used to describe the stage of maturation of the fish (Babiker and Ibrahim, 1979). The proportion of the different gonad stages was estimated at different seasons. GSI was calculated as gonad weight as a percentage of total body weight (including the gonads). The percentage frequency of breeding fish and GSI were then plotted by month. The time of the year when the frequency and GSI were high was considered as the peak breeding season of the fish.

Average size at first sexual maturity (the size at which 50% of the fish are mature) was also determined according to Bagenal and Tesch (1978). Size of 50% maturity of both sexes was estimated from the maturity index, indicating the proportion of mature female and male *O. niloticus* of 5 cm TL interval.

Ripe ovaries which were kept in Gilson's fluid were used for fecundity estimates. Oocytes were separated by repeated washing, and fecundity was determined by counting all eggs. Least square regression was then used to find the relationship between mean fecundity and fish of the same size (TL, TW) and gonad weight (Gow) (Sokal and Rohlf, 1981).

3.4 Determination of length - weight relationship and condition factor

Length-weight relationship was calculated using least squares regression analysis (Bagenal and Tesch, 1978): Log TW = Log a +b Log TL, where, Log a is the intercept and b is the slope of the regression line. Length composition of the sample used in this study was determined after classifying the data into six TL groups of 10 cm width. Condition factor of the fish was determined by calculating both Fulton's and Relative Condition Factor (R.C.F.) for each sampling occasion (Bagenal and Tesch, 1978) as followsin: Fulton's condition factor $=TL/TW^3$ X 100, Relative Condition Factor = TL/aTW^b, where a and b are intercept and slope of the length-weight regression equation, respectively.

Sex-ratio (female to male) was also determined for various size classes of fish. Chi-square test was done to determine the significance of differences in sex-ratio.

4. RESULTS

4.1 Food and feeding habits

4.1.1 Composition of stomach contents of juvenile *O. niloticus*

Blue green algae, green algae and diatoms constituted the bulk of the diet of the juveniles. Animal foods, mainly copepods and rotifers were also observed in the stomach contents of the fish. Unidentified nematodes and chironomid larvae were observed on rare occasions in the diet of juvenile *O. niloticus*. About 24 algal genera were identified in the stomach contents of the juveniles. Of these, blue greens constituted 10 genera and the most frequently encountered species were *Anabaena* (92-100%), *Microcystis* (83-96%) and *Oscillatoria* (51-97%). Green algae and diatoms each constituted 7 genera of the phytoplankton diet of the juveniles; the dominant species being *Cosmarium* (93-100%) and *Navicula* (90-100%), respectively (Table 4).

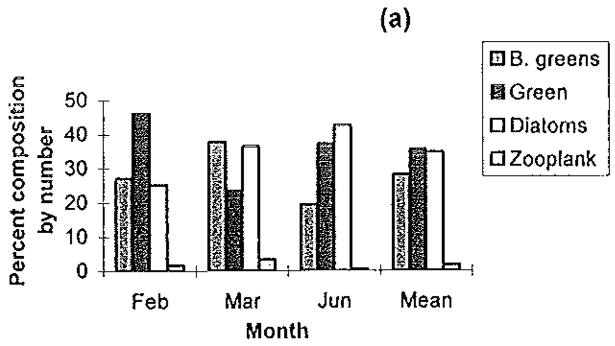
In terms of percentage composition by number, blue greens contributed 28.2% whereas green algae and diatoms contributed 35.6 and 34.8%, respectively, of the total food ingested by the fish (Fig. 5-a). Zooplankters occurred (1.8%) in the stomach contents of the juveniles (Fig. 5-a).

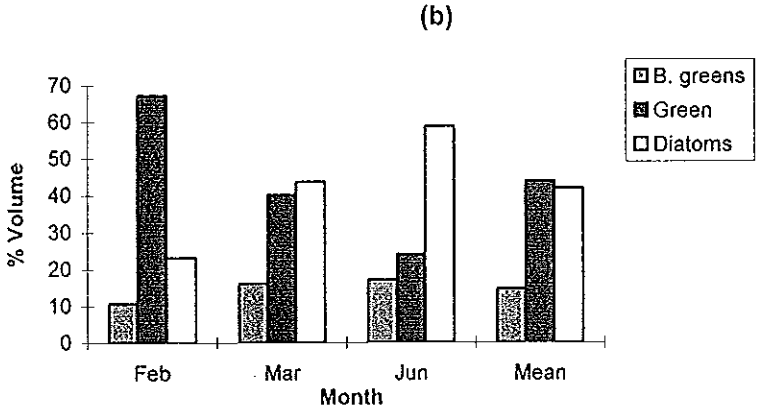
In terms of percent composition by volume green algae contributed the major portion (43.8%) of the food volume whereas diatoms and blue greens constituted 41.9 and 14.7% of the total food volume of the juveniles, respectively (Fig. 5-b).

Table 4. Percentage of occurrence of algae and zooplankton present in the food of adult and juvenile *O. niloticus* in Lake Chamo.

	Adults	Juveniles
	%occur. (Range)	%occur.(Range)
I. Phytoplankton		
Cynophyta (B.greens)		
Anabaena	96-100	92-100
Microystis	82-100	83-96
Oscillatoria	41-100	51-97
Lyngbya	85-100	20-70
Merismopedia	42-85	0-70
Chroococcus	42-100	20-70
Raphidiopsis	12-97	20-35
Aphanizomenon	12-86	0-35
Anabaenopsis	15-23	0-25
Spirulina	8-23	0-10
Chlorophyta (Green algae)		
Cosmarium	79-100	93-100
Scenedesmus	42-82	73-90
Chlorella	8-85	25-100
Tetraedron	18-59	0-67
Oocystis	6-55	20-55
Coelastrum	10-41	7-35
Pediastrum	6-26	0-30
Ankistrodesmus	0-25	-----
Bacillarophyta (Diatoms)		
Navicula	82-100	90-100
Nitzschia	25-61	0-30
Cyclotella	10-62	40-87
Pinnularia	6-35	53-80
Melosira	6-27	0-20
Cymbella	0-36	-----
Surirella	0-29	10-15
Rhopalodia	0-15	15-20
II. Zooplankton		
Copepoda	0-10	7-45
Rotifera	0-19	0-30
III. Others		
Nematode	-----	7-20
Chir. larvae	-----	0-35
Macrophytes	Abundant	rare

Fig. 5. Relative importance of various food items in the diet of juvenile *O. niloticus* in Lake Chamo as determined using the numerical (a) and volumetric (b) methods.


(a)
B. greens
Green
Diatoms
Zooplank
Percent composition by number
50
40
30
20
10
0
Feb
Mar
Jun
Mean
Month


(b)
B. greens
Green
Diatoms
% Volume
70
60
50
40
30
20
10
0
Feb
Mar
Jun
Mean
Month

4.1.2 Composition of stomach contents of adult *O. niloticus*

Blue green algae, green algae and diatoms were abundant in the food of adult fish whereas animal foods were observed on rare occasions and these were mainly copepods and rotifers. Macrophytes were also found in large quantities in the stomach contents of adult fish (Table 4).

More than 26 algal genera were identified in the stomach contents of adult *O. niloticus*. Blue greens as a group constituted the bulk of the diet. Blue greens constituted 10 genera whereas green algae and diatoms each constituted 8 genera of the phytoplankton diet of the adult fish. The most frequently encountered species from the blue greens were *Anabaena* (96 - 100%) and *Microcystis* (82-100%), followed by *Chroococcus* (42 - 100%), *Oscillatoria* (41 - 100%) and *Merismopedia* (42 - 85%). Among the diatoms, *Navicula* (82 - 100%) and *Nitschia* (25 - 61%) were abundant in the diet of the adult fish. The green algae of the genera *Cosmarium* (79 - 100%), *Scenedesmus* (42 - 82%) and *Tetraedron* (18 - 59%) were also among the dominant species (Table 4).

In terms of percentage composition by number, the blue greens contributed over 60% of the total food ingested. Of this more than 50% was contributed by *Anabaena, Oscillatoria* and *Microcystis*. The diatoms which constituted 24.0% of the total diet, were dominated by *Navicula* which made up 19.5% of the total food item. The remaining 16% of the food item was due to green algae which included *Cosmarium* and *Scenedesmus* that accounted for 10.3 and 3.1%, respectively, of the total food ingested (Fig. 6-a). Zooplankters (copepods and rotifers) contributed 0.18% of the diet of adult *O. niloticus* (Table 4).

When the food items were expressed as percentage volume, the blue greens made up 32.3% whereas the green algae and the diatoms contributed 32.3 and 35.2%, respectively (Fig.6-b).

The relative contribution of the major algal groups to the total dry weight is shown in Fig.6-c. When the importance of each food item was considered as percentage dry weight, the green algae contributed the major portion in the diet of the adult fish. The mean percentage dry weight of the green algae, diatoms and blue greens was 53.8, 28.2 and 17.7%, respectively. Among the green algae, *Cosmarium* alone contributed more than 40% to the total dry weight.

Blue greens were observed in large quantity (above 40%) in almost all sampling occasions whereas green algae were found with high frequencies in the stomach contents of the fish caught during March, April and May, 1996 (Fig. 6-a). Diatoms were abundant in the diet of the fish caught between March and May, and during November and December. Zooplankters occurred abundantly in the stomach samples collected between May and August, 1996. No zooplankters were observed in the stomach contents of the fish caught in January and February.

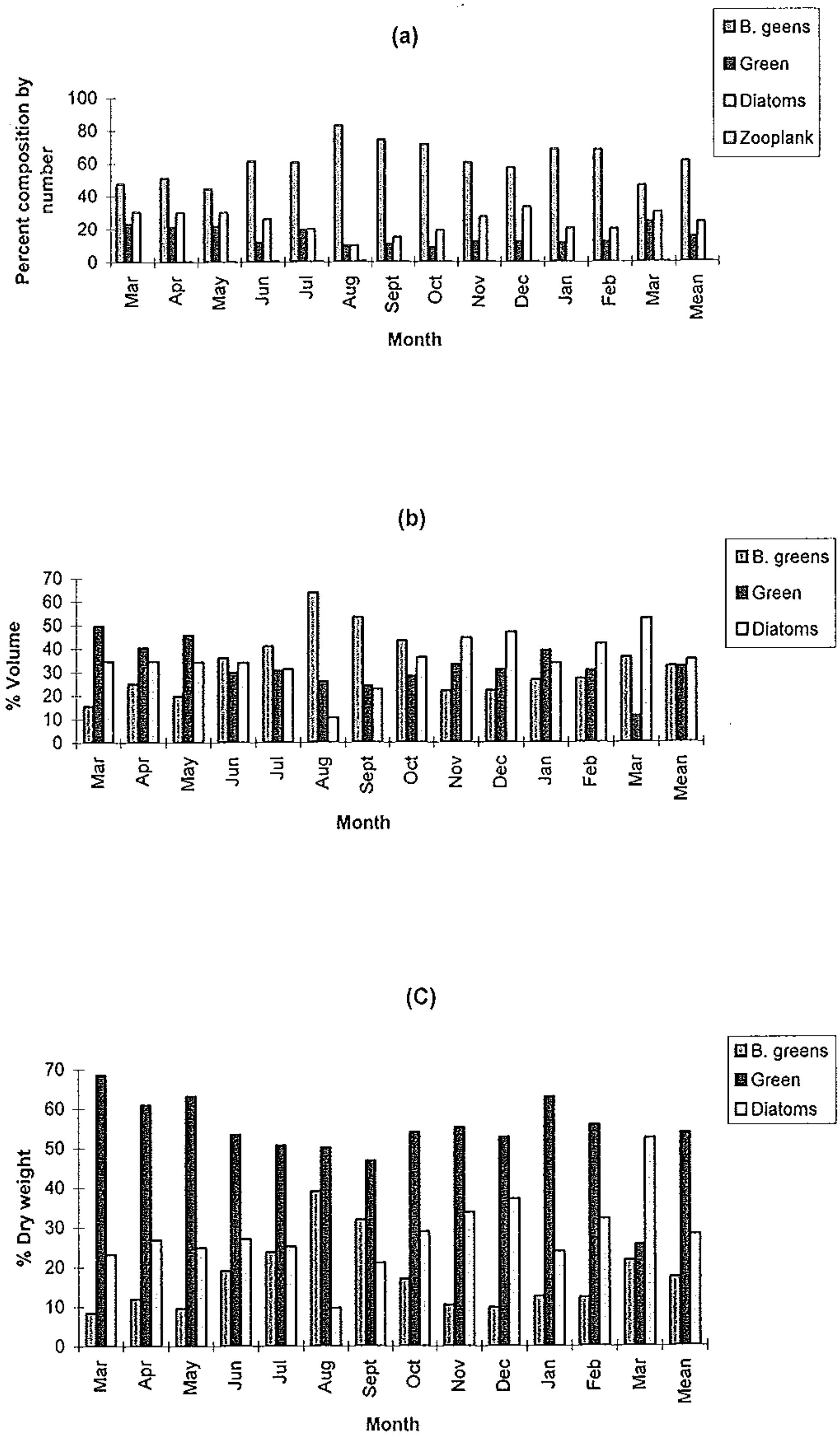
Green algae constituted the bulk of the food volume in the stomach contents of the fish collected between March and May, and during January. Blue greens made the major portion of the food volume in the stomach contents of the fish caught between June and September whereas diatoms constituted a high proportion of the food volume in the stomach samples taken between October and December and during February (Fig. 6-b).

In terms of percentage dry weight, green algae constituted the major portion of the diet in all sampling occasions except in March, 1997. The percentage dry weight of the blue greens was higher in the samples collected during July, August and September, and that of diatoms during November, December, February and March (Fig. 6-c).

4.1.3 Comparison of stomach contents of juvenile and adult *O. niloticus*

The diet of the juvenile *O. niloticus* is dominated by blue greens, green algae and diatoms, as in the case of the adults. However, animal foods, mainly copepods and rotifers were more abundant (1.8%) in the diet of the juveniles than in that of the adult fish (0.18%). Furthermore, plankters were observed in the stomach contents of the juveniles caught during January but not in the stomach contents of the adult fish. Macrophytes (unidentified) were abundant in the diet of the adults whereas chironomid larvae were observed in the diet of the juvenile *O. niloticus* in all sampling periods. Nematodes (unidentified) were also observed in the stomach contents of the juvenile fish.

Fig. 6. Relative importance of various food items in the diet of adult *O. niloticus* in Lake Chamo determined using the numerical (a), volumetric (b) and gravimetric (c) methods.


(a)
Percent composition by number
100
80
60
40
20
0
Mar
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec
Jan
Feb
Mar
Mean
Month
B. geens
Green
Diatoms
Zooplank
(b)
% Volume
70
60
50
40
30
20
10
0
Mar
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec
Jan
Feb
Mar
Mean
Month
B. greens
Green
Diatoms
(C)
% Dry weight
70
60
50
40
30
20
10
0
Mar
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec
Jan
Feb
Mar
Mean
Month
B. greens
Green
Diatoms

4.1.4 Diurnal feeding rhythm

Percent stomach fullness index values were observed to have a diel rhythm (Fig. 7-a). Stomach fullness increased progressively from 8 hr to a peak at 16 hr, and then decreased from 20 hr, and stayed lower up to 4 hr. With an increase in the stomach fullness, the pH of the stomach declined (Fig. 7-a). The pH values were higher during the sample periods when the stomach fullness was low. The pH of the stomach started to drop at 8 hr and remained lower up to 20 hr and then increased when the stomach fullness started to decrease. A pH value as low as 1.4 was measured when the stomach was full.

The frequency of fish with empty stomach varied throughout the 24 hr sampling periods (Fig. 7-b). The frequency was low between 12 and 20 hr and it increased at 24 hr and then decreased after 8 hr to a lower value at 20 hr. No empty stomach was recorded at 16 hr. The present study, therefore, suggests that *O. niloticus* in Lake Chamo actively feed during the day time (Fig. 7).

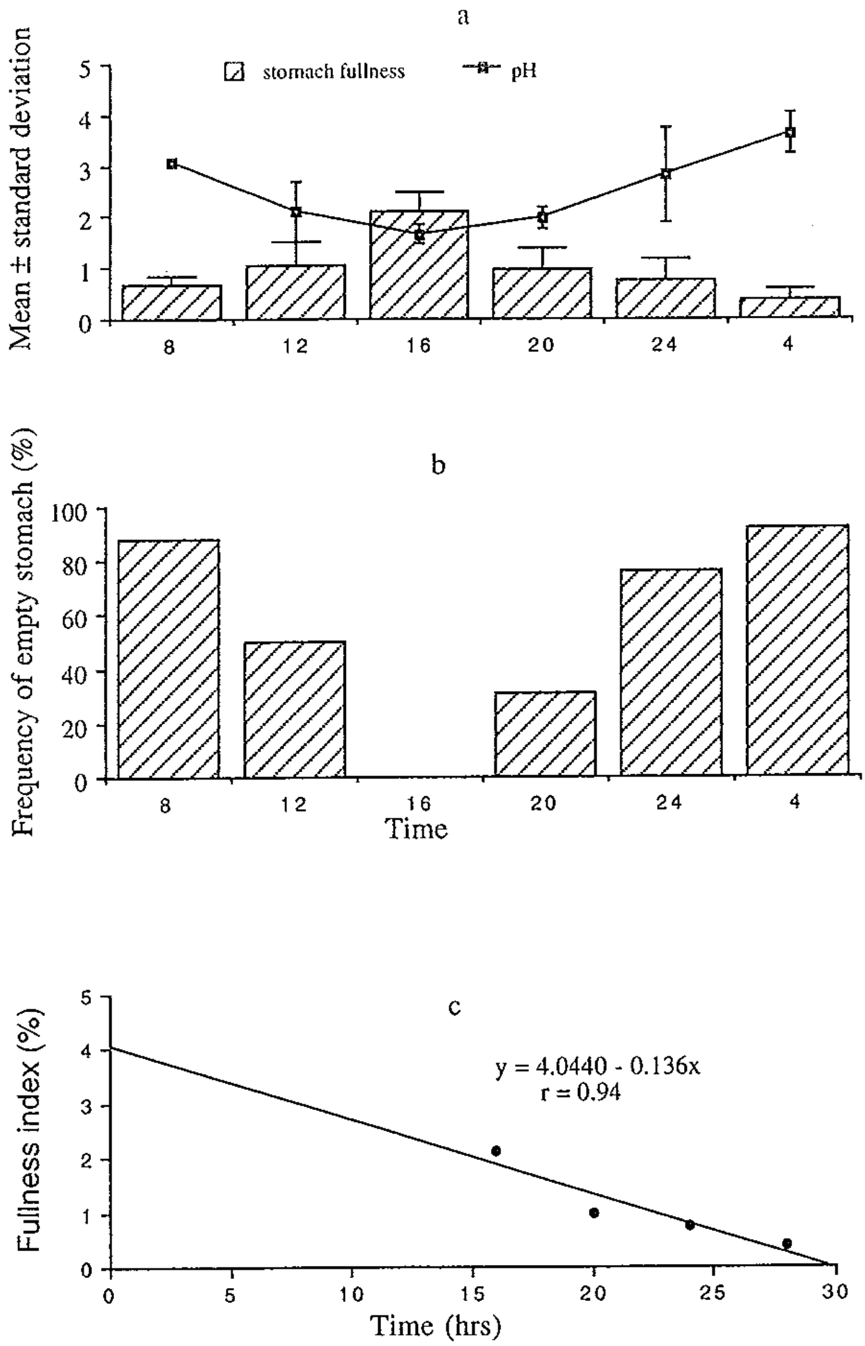
The rate of gastric evacuation at an average water temperature of 26 $^{\circ}$C was estimated to be 2.12% at 16 hr and 0.39%at 4 hr or 0.136%/hr (Fig. 7-c). The relationship between the decrease in stomach contents and time of the day is expressed by the following linear regression.

$$Y = 4.0440 - 0.136X, \quad r = 0.94$$

Where Y= %stomach fullness, X= hours of the day

From 8 hr to 20 hr (12 hrs) when the fish were assumed to be eating at the same rate (0.136%/hr) the amount of food evacuated to the intestine is estimated to be 1.63% (0.136x12 hr). As a whole 3.75% (2.12+1.63) is ingested per day. This indicated that the fish ingested 3.75% of its body weight per day at an average water temperature of 26 °C.

Fig. 7. Diel changes in percent stomach fullness and stomach pH (mean ± s.d.) (a), percent empty stomach (b) and rate of gastric evacuation (c) in *O. niloticus* in Lake Chamo.


a
Mean ± standard deviation
stomach fullness
pH
5
4
3
2
1
0
8
12
16
20
24
4
b
Frequency of empty stomach (%)
100
80
60
40
20
0
8
12
16
20
24
4
Time
c
Fullness index (%)
y = 4.0440 - 0.136x
r = 0.94
5
4
3
2
1
0
0
5
10
15
20
25
30
Time (hrs)

4.2 Reproductive biology

4.2.1 Breeding season

Seasonal variation in GSI of both sexes was quite evident (Fig. 8). The mean monthly GSI of males ranged from 0.21 to 0.71 whereas that of females ranged from 0.75 to 1.71. GSI varied significantly between months both for females (ANOVA, $F=7.025$, $P<0.0001$) as well as males (ANOVA, $F=8.091$, $P<0.0001$). The seasonal pattern of gonad development of both sexes was more or less similar (Fig. 8). Higher GSI values were measured between March and June for both sexes. The GSI value of the females dropped rapidly after June, and lower values were recorded between September and October. GSI value of males dropped in June and July, and lower values were measured between October and November. *O. niloticus* were also caught at various stages of gonad development and reproduction in almost all months. However, their frequency varied with the month of capture. The pattern of gonad development for both sexes was almost similar. Ripe males occurred at high frequencies (ranged 39-60%) in March, April and May whereas females occurred in March, April, May and June (range 47-53%) (Fig 9-a). Low frequency of ripe fish of both sexes was recorded in November, December and January. Ripe fish of both sexes were not caught in October. But, 3% of the males and 8% of the females were spawning during this month. The percentage of spawning females ranged from 8-43% and of the males from 3-60% with highest seasonal values in June for both sexes and lowest in October for the males and in February for the females (Fig. 9-b). Large numbers of brooding females were also observed in April and June (pers. obs.). From the above observations it is evident that *O. niloticus* in Lake Chamo spawns throughout the year with peak breeding activity in March, April, May and June.

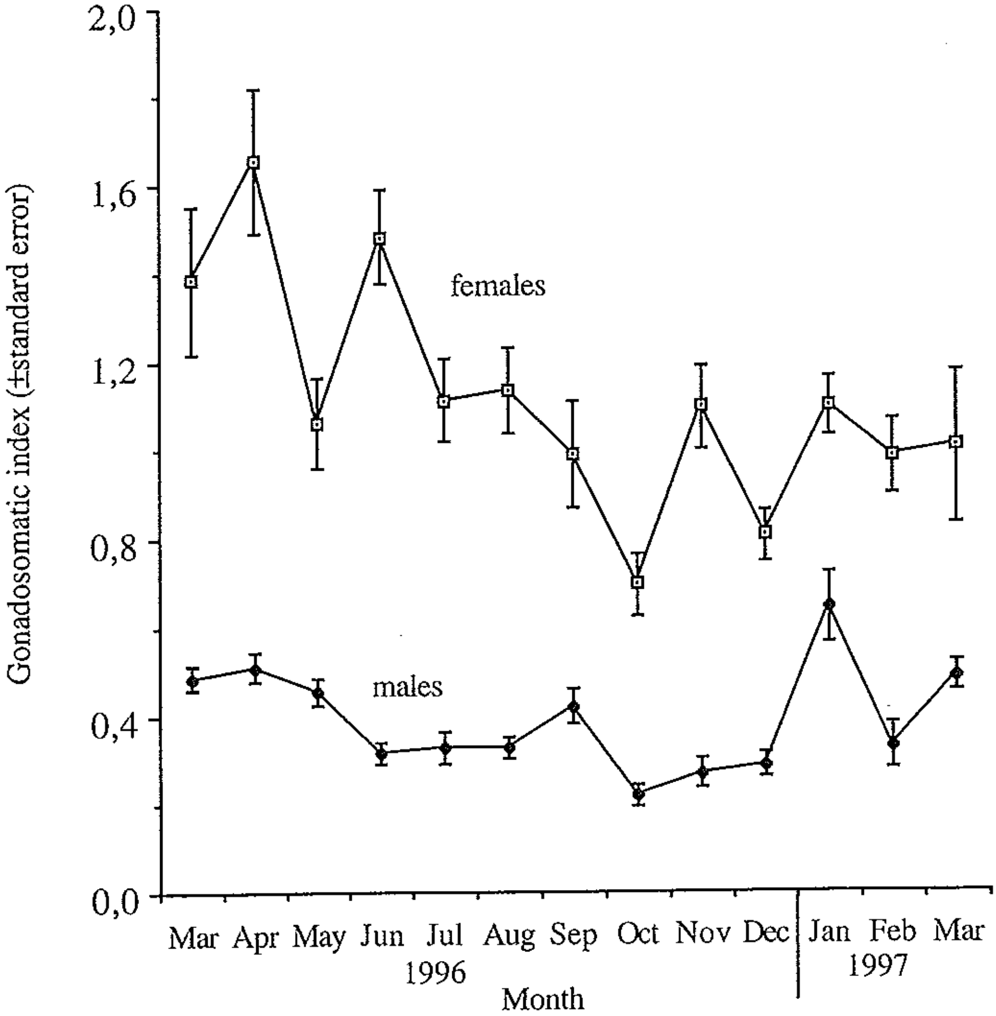
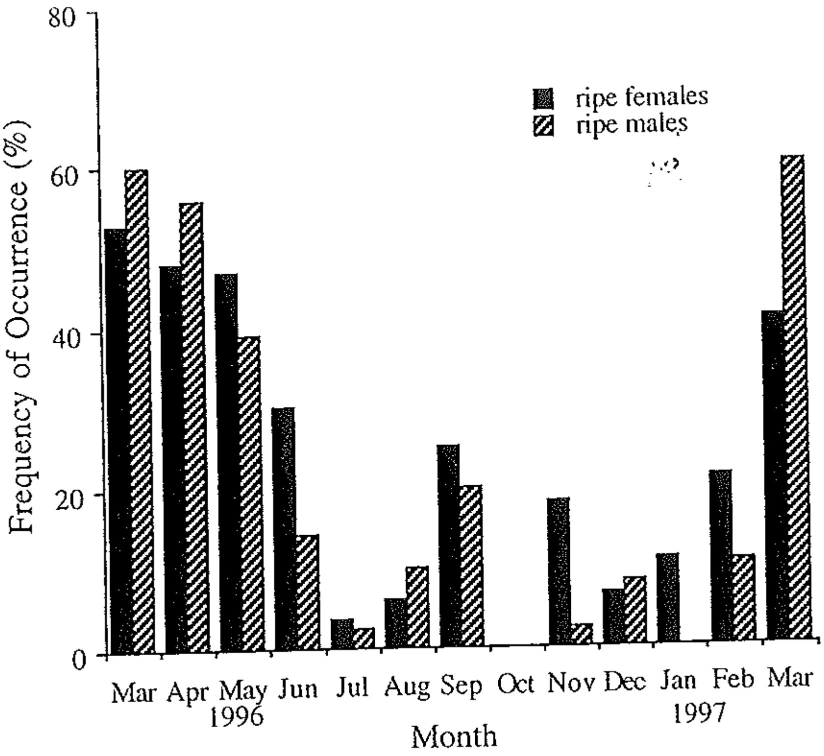


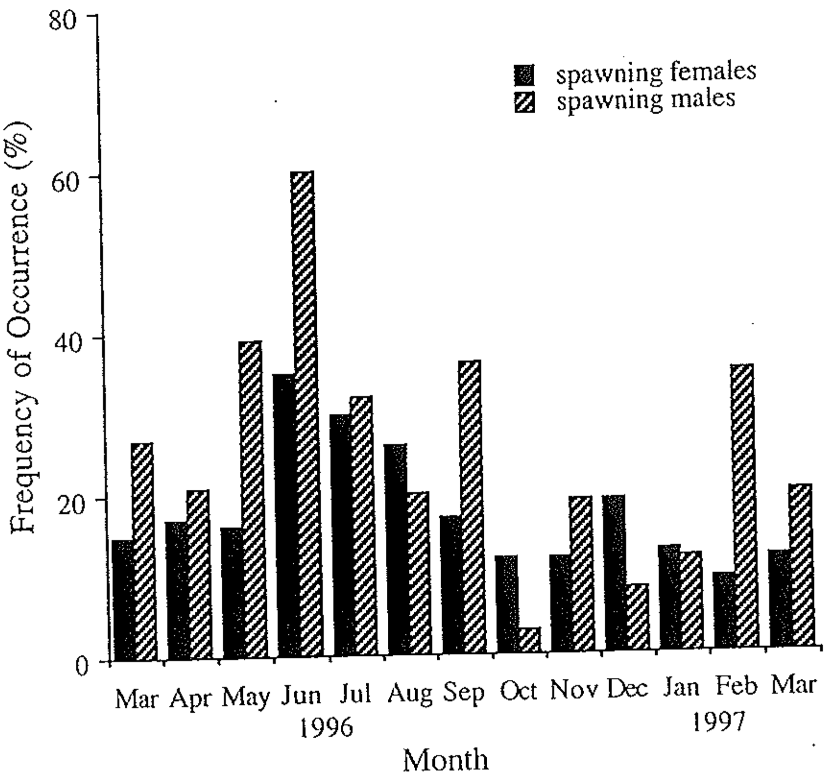
Fig. 8. Seasonal variation in gonadosomatic index (GSI, mean ± SE) of *O. niloticus* in Lake Chamo determined for both sexes separately.

Fig. 9. Seasonal frequency(%) of female and male *O. niloticus* at ripe (a) and spawning (b) stages in Lake Chamo.

a


80
60
40
20
0
Frequency of Occurrence (%)
ripe females
ripe males
Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar
1996
1997
Month

b


80
60
40
20
0
Frequency of Occurrence (%)
spawning females
spawning males
Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar
1996
1997
Month

4.2.2. Length at maturity

The smallest sexually mature female that was caught in this study was 385 mm TL, whereas the male was 395 mm TL. However, the 50% maturity length was found to be 415 mm TL for females (Fig. 10-a) and 425 mm TL for males (Fig. 10-b). *O. niloticus* were all sexually mature above 500 mm TL.

4.2.3 Fecundity

The diameter of ripe ova of *O. niloticus* in Lake Chamo was found to be between 1.4 mm and 3.0 mm (Table 5). The mean ova diameter was 2.1 mm (± 0.11). The smallest egg count was 1047 (fish length = 470 mm) and the largest was 4590 (fish length = 510 mm). Average fecundity of *O. niloticus* ranging in length from 390 to 560 mm TL and in weight from 1300 to 3900 g was 2493 ± 300 (N = 209). In general, fecundity was linearly related to total length, total weight as well as to gonad weight (Fig. 11- a, b and c). The lines fitted to the relationships, respectively, were:

$\text{Log } F = -3222.3 + 127.4\ TL$, ($r=0.89$, $P<0.001$)

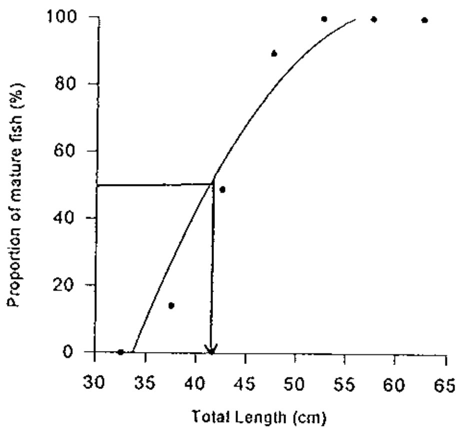
$\text{Log } F = 291.0 + 1.099\ TW$, ($r=0.98$, $P<0.001$)

$\text{Log } F = 920.9 + 41.1 GoW$, ($r=0.94$, $P<0.001$),

where, F = fecundity, TL = total length(mm), TW = total weight(g) and GoW = gonad weight(g).

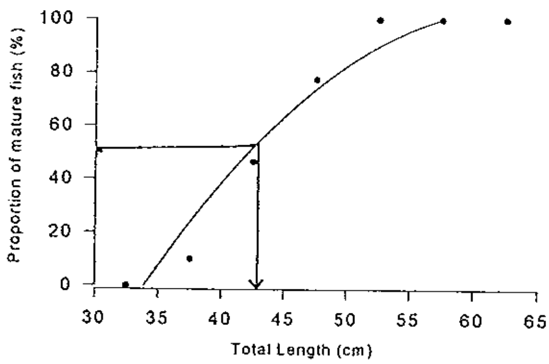
Fig. 10. The proportion of mature female (a) and male (b) *O. niloticus* out of the total fish caught in 5 cm length interval. The arrows shows the TL of 50% maturity.

(a)



100
80
60
40
20
0
Proportion of mature fish (%)
30
35
40
45
50
55
60
65
Total Length (cm)

(b)



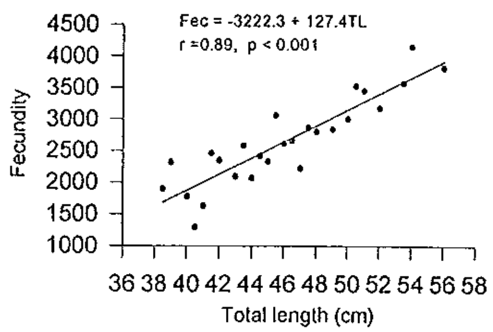
100
80
60
40
20
0
Proportion of mature fish (%)
30
35
40
45
50
55
60
65
Total Length (cm)

Table 5. Frequency of the diameter (mm) of ripe ova of *O. niloticus* in Lake Chamo

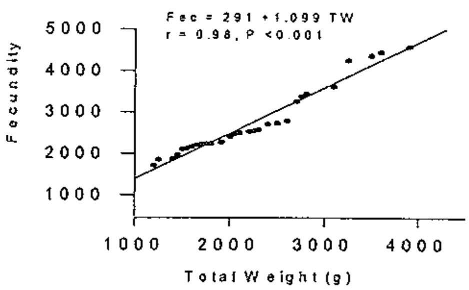
Diameter (mm)	Frequency
1.1-1.5	16
1.6-2.0	81
2.1-25	41
2.6-3.0	2

Fig. 11. Fecundity (F) of *O. niloticus* in Lake Chamo in relation to: (a) total length (TL), (b)total weight (TW), and (c) Gonad weight (GoW) of the fish

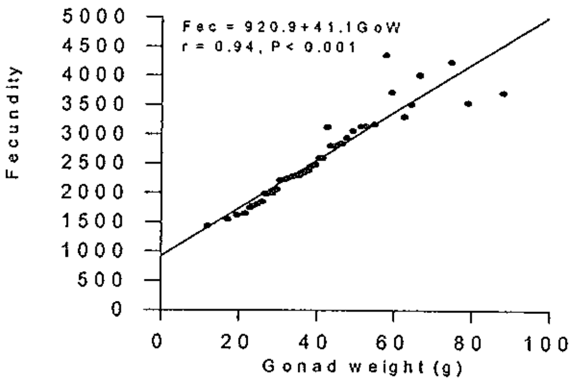
(a)


Fec = -3222.3 + 127.4TL
r =0.89, p < 0.001
Fecundity
4500
4000
3500
3000
2500
2000
1500
1000
36 38 40 42 44 46 48 50 52 54 56 58
Total length (cm)

(b)


Fec = 291 +1.099 TW
r = 0.98, P <0.001
Fecundity
5000
4000
3000
2000
1000
1000
2000
3000
4000
Total Weight (g)

(c)


Fec = 920.9+41.1GoW
r = 0.94, P< 0.001
Fecundity
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
20
40
60
80
100
Gonad weight (g)

4.3 Length - weight relationship and condition factor

The size of the fish ranged from 125 to 610 mm TL and from 42.5 to 4800 g TW. The length frequency composition and sample size of the fish grouped into 10 mm TL is indicated in Table 6. The relationship between total length and total weight was curvilinear (Fig. 12) and statistically significant ($r^2 = 0.982$, $P < 0.05$). The line fitted to the data was described by the following regression equation: $TW = 0.0259TL^{2.942}$. The length - weight relationship of females (n=733) and males (n=740) was also determined separately. The regression equation for the females was $TW = 0.069TL^{2.68}$, $r = 0.91$ and that for the males was $TW = 0.022TL^{2.99}$, $r = 0.98$. Both equations were statistically significant ($P < 0.05$).

Table 6. Length frequency composition and sample size of *O. niloticus* in Lake Chamo

TL group (mm)	Frequency	
	No	%
100-199	53	3.6
200-299	29	2.0
300-399	77	5.2
400-499	957	65.5
500-599	355	24.0
>600	2	0.1
Total	1473	100

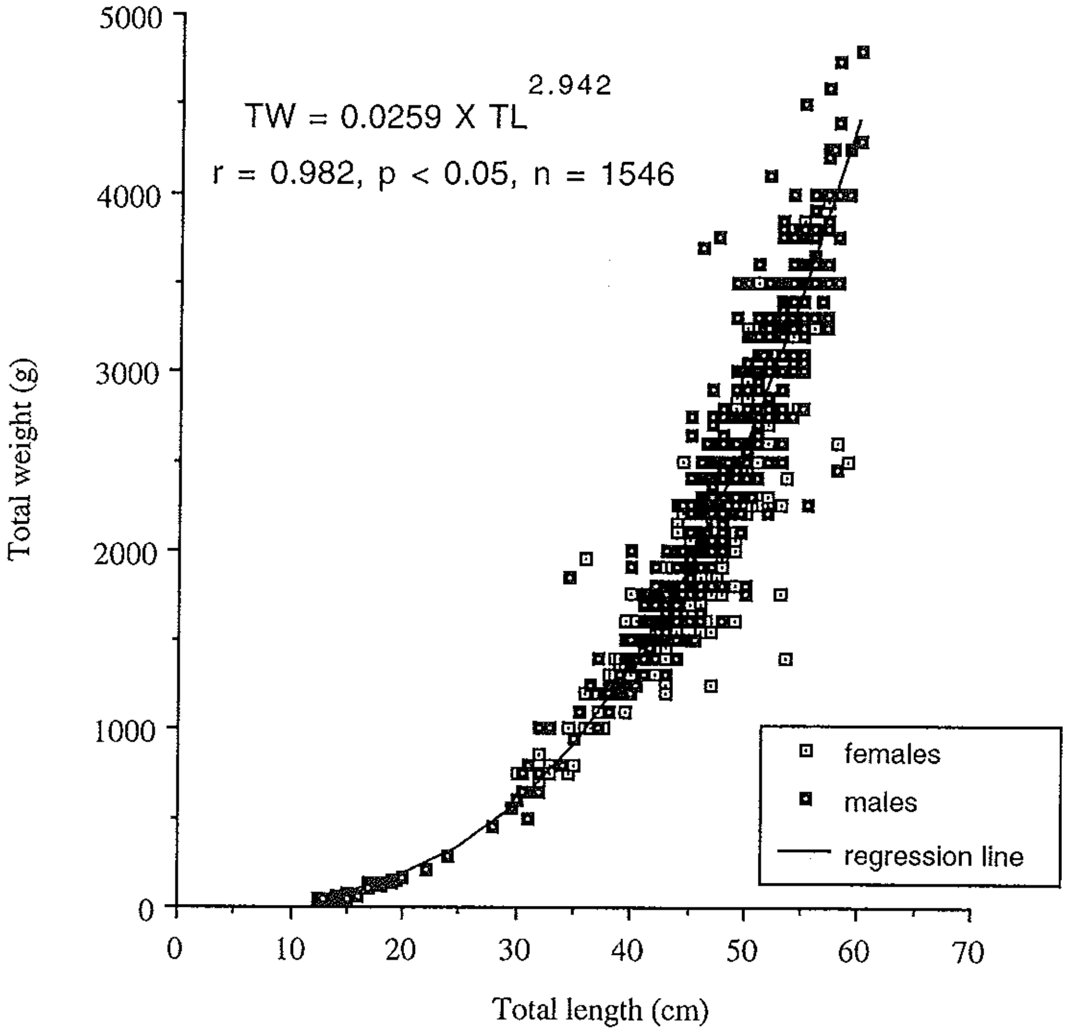
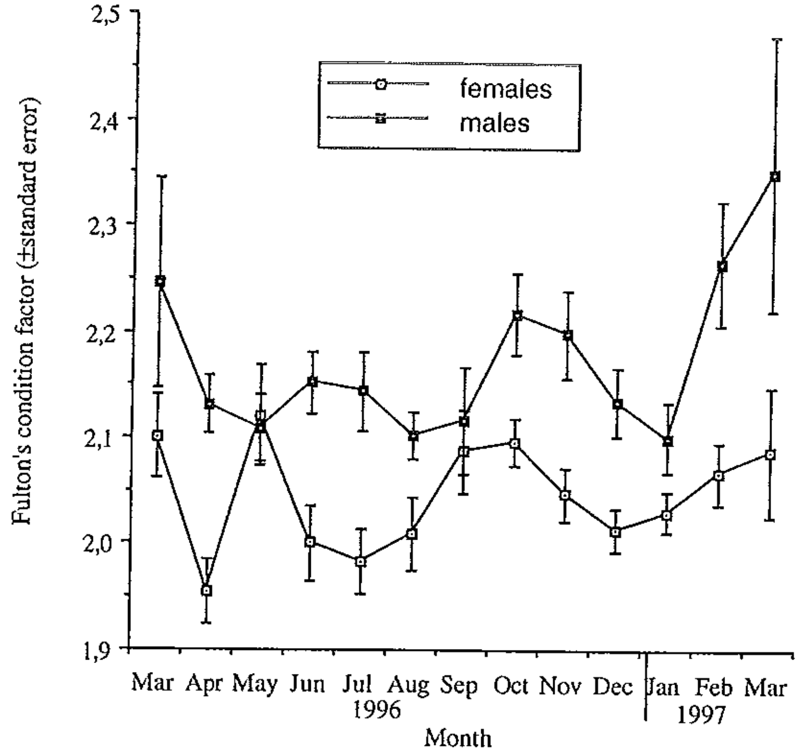


Fig. 12. Length-weight relationship of *O. niloticus* in Lake Chamo.

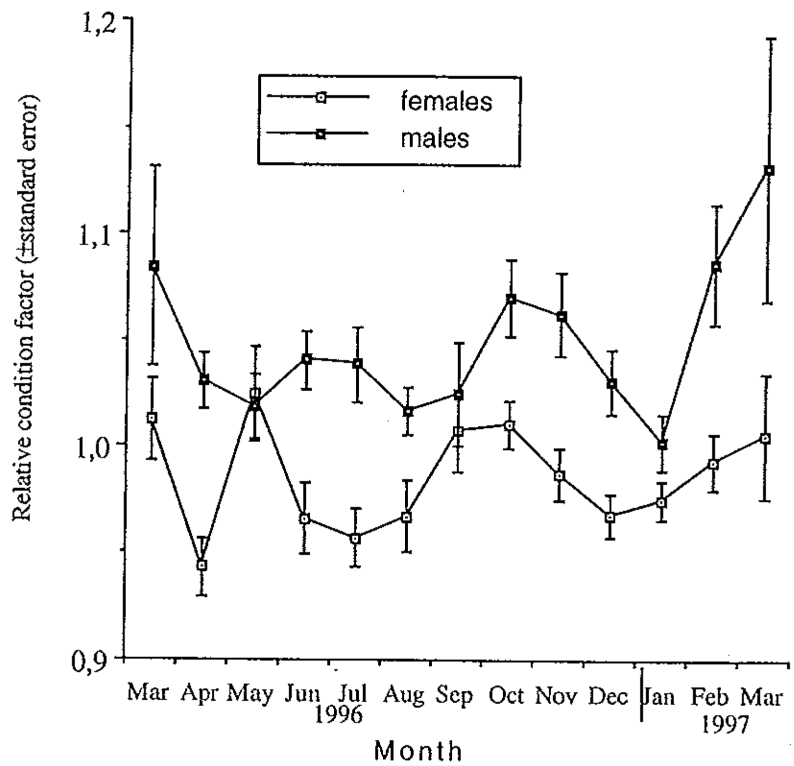
Mean ± SE Fulton's condition factor of females *O. niloticus* in Lake Chamo ranged from 1.96 ± 0.03 to 2.10 ± 0.04 whereas that of males ranged from 2.10 ± 0.03 to 2.35 ± 0.10 (Fig. 13-a). Mean ± SE relative condition factor of females ranged from 0.94 ± 0.01 to 1.01 ± 0.02 whereas that of males ranged from 1.02 ± 0.01 to 1.13 ± 0.06 (Fig. 13-b). There was a significant variation in the mean monthly Fulton's and relative condition factor for both sexes (ANOVA, $P<0.05$). The condition factor of the males showed a decreasing trend from March to May and also from October to January, but a rapid increase was observed from January to March. There was also a gradual increase from May to July (Fig. 13). The condition of the females was lower from May to July and from October to December, but higher between July and October (Fig. 13). Therefore, seasonal variation in the condition factor of the females also followed a pattern, which was similar to that of the males except in June, July and August. The condition factor of the males was higher in these months but not in the females. In addition, it was observed that the males showed a rapid rate of decrease in condition factor from March to April.

Fig. 13. Fluctuation in Fulton's condition factor (a) and relative condition factor (b) of *O. niloticus* in Lake Chamo indicated for both sexes separately.

a


2,5
2,4
2,3
2,2
2,1
2,0
1,9
Fulton's condition factor (±standard error)
females
males
Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar
1996
1997
Month

b


1,2
1,1
1,0
0,9
Relative condition factor (±standard error)
females
males
Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar
1996
1997
Month

Of 1473 individual *O. niloticus* examined, 733 (49.8%) were females and 740 (50.2%) were males. The largest female caught was 580 mm TL and the heaviest was 3950 g (TL = 570 mm). In contrast, the largest male caught was 610 mm TL and the heaviest was 4800 g (TL=600 mm). The total ratio of females to males was 1 : 1.01 (Table 7), which did not deviate significantly from the theoretical ratio of 1 : 1 ($P>0.05$). Females were significantly greater ($P< 0.05$) in number than males in the samples taken during March, April, May, August and September whereas in favour males in samples taken between November and February. However, the sexes were equally frequent in the samples taken in the other months as well as in the total sample. Sex ratio was also calculated after grouping the data into various length classes (Table 8). There was a significant variation in sex ratio only in fish greater than or equal to 400 mm TL.

Table 7. Number of female and male, sex ratio (female: male) of *O. niloticus* caught from Lake Chamo between March 1996 and March 1997

Month	Female	Male	Sex ratio (F:M)	Chi-sq.
March	55	34	1:0.62	5.0
April	101	63	1:0.62	8.8
May	84	55	1:0.65	6.1
June	65	53	1:0.82	1.2 *
July	41	54	1:1.32	1.8 *
August	80	50	1:0.63	6.9
September	50	37	1:0.74	1.9 *
November	33	55	1:1.67	5.5
October	42	70	1:1.67	7.0
December	37	65	1:1.76	7.7
January	57	103	1:1.55	13.2
February	4	80	1:1.67	68.8
March	40	21	1:1.91	5.9
Total	733	740	1:1.01	0.03 *

* = not significant at 5% level, P > 0.05

Table 8. Number of female and male, sex ratio (female: male) of *O. niloticus* of various length group (TL) caught from Lake Chamo during the sampling periods

Length group (mm)	Female	Male	Sex ratio (F:M)
100-199	25	28	1:1.12
200-299	17	12	1:0.71
300-399	37	40	1:1.08
400-499	416	548	1:1.32 *
500-599	236	119	1:1.98 *
>600	2	----	-----
Total	733	740	1:1.01

* = Significant at 5% level, $P<0.05$

5. DISCUSSION

5.1 Feeding Habit of *O. niloticus*

The diet of adult *O. niloticus* in Lake Chamo consists of 10 genera of blue greens, 8 genera of green algae, and 8 genera of diatoms. Although these genera were not equally represented in the diet, the wide choice available to the fish suggests that when one food item is in short supply, others in abundance could be eaten.

The type of food items found in the stomach of *O. niloticus* was quite similar to what has been reported for several other tilapine species. Fish (1955) reported that *T. esculenta* feed mainly on phytoplankton. Fagade (1978) showed that many tilapine cichlids feed on blue greens, green algae and diatoms. Adebisi (1978) reported blue greens to represent the main diet of *S. galilaeus*. Getachew Teferra (1987) reported that *O. niloticus* from Lakes Zwai and Awassa feeds mainly on phytoplankton. Blue greens, green algae and diatoms were also observed in the stomach contents of *O. niloticus* from White Nile by Kallaf and Alne-naen (1987) and from Lake Turkana by Harbott (1975).

Previous studies by Getachew Teferra (1993) and Zenebe Tadesse (1988) have shown that *O. niloticus* feeds on zooplankton when young. Chironomid larvae were also noted in the stomach of this species in Lake Awassa (Tudorancea *et al.*, 1988). The present work also confirms that juvenile *O. niloticus* consumes zooplanktonic and benthic organisms. These are dominated by rotifers, mainly *Branchinous* sp and *Keratella* sp, and copepods while a few chironomid larvae were also represented in the diet. When the animal component of the diet of juvenile *O. niloticus* in Lake Chamo is compared with the plant component, phytoplankton diet constituted the major portion. However, in the report of Tudorancea, *et al.* (1988), the juveniles in Lake Awassa fed mainly on zooplankton. The difference may be because of the size range of the juveniles. The juveniles in the present study ranged from 61-115 mm TL unlike Tudorancea, *et al.*, (1988) who considered very small sized juveniles (<30 mm). Thus, juvenile *O. niloticus* considered in this study may have already shifted to the phytoplankton diet.

Although adult *O. niloticus* feeds mainly on phytoplankton, it is not uncommon to find its stomach full of detritus. Bowen (1980) has shown that *O. niloticus* feeds on abundant amorphous detritus in Lake Valencia, Venezuela. So, this food source is also probably important for *O. niloticus* in Lake Chamo. Moreover, the large number of bacteria and protozoan normally associated with unidentified organic materials and detritus would no doubt be nutritionally beneficial to the species (Bowen, 1980). From the foregoing, it is obvious that *O. niloticus* utilises a combination of plant and animal materials as source of food. The ability to utilise these wide variety of food items available in the habitat may account for the prominence of this species in the lake.

In terms of numerical percentage, the blue greens contributed over 60% of the food ingested by adult *O. niloticus*. Out of this, 20% was *Anabaena* sp and 10% *Oscillatoria* sp. Similarly, blue greens were found in great abundance in the stomach contents of *O. niloticus* in Lakes Awassa (Getachew Teferra, 1987; Tudorancea, *et al.*, 1988) and Zwai (Zenebe Tadesse, 1988). The same results were also reported by Welcomme (1967) in

Lake Victoria, where the blue greens *Lyngbya* sp and *Microcystis* sp contributed about 80% and 40% of the fish diet, respectively. Furthermore, *O. niloticus* in Lake Turkana consumes large quantities of blue green algae, but mainly *Spirulina* and *Anabaenopsis*. Studies in the Nile canal, Egypt, also indicated that *O. niloticus* feeds on large quantities of blue green algae (Kallaf and Alen-naen, 1987).

Blue greens and green algae are nearly equally represented by percent volume in the food of *O. niloticus*. Among the diatoms, *Navicula* sp which constituted above 25% by volume, was found in great abundance in the diet of *O. niloticus*. Food quality depends on the composition of the diet, and also the extent to which the components are digested and assimilated. The rate of digestion is particularly important in herbivorous fish that feed on plants because the structural materials, which may contain cellulose, chitin, and lignin, are not susceptible to digestive enzymes (Moriarty, 1973). However, Bowen (1982) ascertained that acid hydrolysis can break algal cells, releasing the contents. Moriarty and Moriarty (1973) showed that blue greens are digested and assimilated by *O. niloticus*. Getachew Teferra (1987) and Zenebe Tadesse (1988) also reported that blue greens such as *Microcystis* sp are easily digested and nutritionally important components of *O. niloticus*, because the digestion of these items is aided by the acidic gastric secretion.

Diatoms, which are among the dominant food items in the diet of *O. niloticus*, are highly digestible because the pores in the frustules allow entrance of enzymes into the cytoplasm to enhance digestion, or the frustules may open to release their contents into the digestive system (Harbott, 1975; Spataru and Zorn, 1978). The silicon content of diatoms growing in warm water bodies is reported to be low, which makes the wall highly fragile (Paasche, 1980). This could also make the diatoms susceptible to digestion. The high temperature, coupled with the ease of digestion of diatoms which make up the bulk of the diet, may account for the rapid growth and good condition of *O. niloticus* in Lake Chamo.

O. niloticus in Lake Chamo appears to have higher growth and better condition than the same species in the other Ethiopian rift valley lakes. This may be because *O. niloticus* in Lake Chamo is nutritionally in a better condition. Although less digestible, *Botryococcus* contributed the major portion of the food for the fish in Lakes Awassa and Zwai. (Getachew Teferra, 1987).

The relative contribution of algae to AFDW in the stomach shows that the bulk of the food is contributed by green algae mainly *Cosmarium* sp, followed by diatoms and blue greens. It is possible to see that due to their silica cell wall, diatoms contain less organic matter compared with other algae which have cellulose cell wall (Getachew Teferra, 1993). This could explain why %AFDW of the diatoms was not as high as would be expected from their contribution to the diet. The diatoms also tend to increase in the diet of *O. niloticus* during the dry months (October, November and December). Seasonal variation in algal species composition could influence the quality of the food ingested by the fish.

As is the case in Lakes Zwai and Awassa (Getachew Teferra, 1987; Zenebe Tadesse, 1988), *O. niloticus* in Lake Chamo also feeds continuously during the day. It started feeding at about 8 hr and a steady increase in stomach fullness was observed through the day and peaked at 16 hr. The same species in Lake George fed continuously shortly before dawn until about dusk (Moriarty and Moriarty, 1973). Hodgkiss and Man (1977) reported that *S.*

mossambicus feeds during the day. In Lake Chamo, *O. niloticus* appeared not to feed the night. Feeding time might have an impact on fish catch. Catches of *O. niloticus* b overnight-set gill nets were low at Lake Chamo (pers. obs.). This could also be the reason why fishermen of this lake, most of whom fish at night, hit the water to chase the fish towards their gill nets. Since the fish actively feed during the day, and consequently move about actively, the tilapia catch may increase if gill nets are set during the day time. A similar view is also expressed by Akintude (1982) and Zenebe Tadesse (1988) who stated that tilapia that are quiescent at night are less susceptible to gill nets set overnight.

Feeding activity of *O. niloticus* might be affected by temperature and oxygen (Balarin and Hatton, 1979). Getachew Teferra, (1987) and Demeke Admassu (1989) also suggested that *O. niloticus* may not feed actively if engaged in spawning activity.

This study showed that food had an instantaneous effect in the secretion of acid in the stomach, because low stomach pH in *O. niloticus* coincided with large volume of food. Moriarty *et al.* (1973) have also suggested that the presence of food acts as a stimulus for acid secretion. A pH value as low as 1.4 was measured when the stomach was full at 16 hr.

This study indicated that *O. niloticus* in Lake Chamo ingests about 3.8% of its body weight per day (b. w. d^{-1}) at 26 °C. The species in Lakes Awassa and Zwai ingests about 11.5% b. w. d^{-1} at 21.5 °C and 7.6% b. w. d^{-1} at 21.1 °C, respectively (Zenebe Tadesse, 1988). Balarin and Hatton (1979) have also reported that *S. mossambicus* in Lake Victoria ingests 6.5% b. w. d^{-1}. Apparently, *O. niloticus* in Lake Chamo ingests at a lower rate, although the reason for which is not clear.

5.2 Breeding Habit of *O. niloticus*

Tilapia appear to breed more or less throughout the year in equatorial waters, but in lakes distant from the equator they tend to have a relatively short and well defined breeding season (Lowe McConnell, 1982). This study shows that *O. niloticus* breed intensively during March to June with some breeding activity occurring in other months too. The species in Lake Zwai was found to breed throughout the year, but more intensively between December and March (Zenebe Tadesse, 1988), whereas in Lake Awassa it breeds twice a year, i.e., January to March and August to October (Demeke Admassu, 1994). Stewart (1988) reported that *O. niloticus* in Lake Turkana breeds continuously, but has an increased breeding activity during March to July. The principal breeding season for most species of tilapia in Lake Victoria is at high water levels in January to March (Lowe - McConnell, 1987).

Periodicity in fish breeding is believed to result from adaptation to fluctuation in the environmental factors so that offspring are produced during periods of maximum growth and survival (Welcomme, 1972). Temperature and photo-period are the most important factors associated with the timing of fish breeding in waters at higher latitudes (Billard and Breton, 1978). In tropical waters, major breeding activity of most species has been variously associated with light intensity, temperature, rainfall, and water level or seasonal flooding (Fryer and Iles, 1972; Lowe-McConnell, 1982). Abundance of food has also been considered as an important cue for timing of breeding in some fish at low latitudes (McKaye, 1977).

Although environmental factors such as photo-period and temperature do not vary much in Ethiopian lakes, there are annual peaks of reproduction activity for *O. niloticus* in most lakes (Getachew Teferra, 1987; Zenebe Tadesse,1988; Demeke Admassu, 1989; 1994). The main breeding time in most cases corresponds with the onset of the rainy season. In Lake Chamo, reproduction of *O. niloticus* is higher during the rainy season than the rest of the year. It also coincides with the opening of suitable nurseries and feeding grounds by high water level. Furthermore, the macrophyte vegetation grows extensively during this period, providing sufficient cover for *O. niloticus* juveniles. Thus, the present study supports previous suggestions (Welcomme, 1972; Billard and Breton, 1978) that environmental factors act as cues for fish reproduction so that recruitment of juveniles is timed with conditions allowing maximum growth and survival.

Size of maturation of many fish species depends on demographic conditions and is determined both by genes and the environment (Fryer and Iles, 1972; Lowe - McConnell, 1987). Population of fish in poor conditions start to breed at a smaller size than those in good conditions (Lowe-McConnell, 1958). Previous studies suggested that female *O. niloticus* mature at smaller sizes than males (Babiker and Ibrahim, 1979; Zenebe Tadesse, 1988; Demeke Admassu,1994). In Lake Chamo, the smallest size of mature fish for both sexes was 390 mm TL. This was confirmed both by gonado-somatic index and level of maturity. 50% of both males and females were mature at a length class of 400-440 cm TL.

The size at sexual maturity of *O. niloticus* in Lake Chamo is very large when compared with that of the same species in Lakes Awassa and Zwai. This species in Lakes Awassa and Zwai mature at about 180 mm TL (Zenebe Tadesse, 1988; Demeke Admassu, 1994). The larger size at maturity of *O. niloticus* in Lake Chamo could be due to the fact that *O. niloticus* in Lake Chamo lives in a piscivorous environment. In a piscivorous environment Tilapia mature at larger sizes and produce larger number of broods to increase survival at the juvenile stage. This could be the reason for *O. niloticus* in Lake Chamo to mature at a larger size than the same species in Lakes Awassa and Zwai.

Egg diameter of *O. niloticus* ranged from 1.4 mm to 3.0 mm, with a mean of 2.1 mm. Egg diameter of *O. niloticus* varied not only between different individuals but also within an ovary of the same individual. Such variations in the egg diameter have been reported for other mouth brooding Tilapia species (Lowe - McConnell, 1955; Trewavas, 1983). The wide range of ova diameter may indicate the continuous maturation of eggs in the ovary.

Fecundity of *O. niloticus* in Lake Chamo ranged from 1047 to 4590 eggs. For the same species from Lakes Zwai and Awassa, Zenebe Tadesse (1988) and Demeke Admassu (1994) estimated values ranging from 198 to 934 and from 304 to 967 eggs, respectively. This shows that *O. niloticus* in Lake Chamo is more fecund than in Lakes Awassa and Zwai. Because *O. niloticus* in Lake Chamo matures at bigger sizes than in Lakes Awassa and Zwai, they produce larger number of eggs and broods. The maximum number of eggs counted in ripe ovaries of *O. niloticus* from Lake Albert is 3706 (Fryer and Iles , 1972). The fecundity of *O. niloticus* in this study is still comparable to some members of the group. The highest number recorded in the ripe ovaries of mouth brooding *T. aurea* from Lake Tiberias is 4300 (Fryer and Iles, 1972). In *T. galilaea*, females have been found to contain as many as 5010 eggs (Ben - Tuvia, 1960). As was indicated in the result, *O. niloticus* in this study showed high fecundity. Thus, although the number of eggs per brood are not yet studied in Lake Chamo, the high fecundity may enable the fish to reproduce in the lake rapidly.

In contrast to the curvilinear relationship reported by Zenebe Tadesse (1988) and Demeke Admassu (1994), it was found in this study that fecundity and total length have linear relationship. The Linear relationship found in this study might have arisen from the narrower range of size group used for the analysis. Most of the fish used for this analysis were above 400 mm TL. There was linear relationship between fecundity, body weight and gonad weight in *O. niloticus* in Lake Chamo. Similar results have been reported for the same species in Lakes Zwai (Zenebe Tadesse, 1988) and Awassa (Demeke Admassu, 1994) and in the White Nile (Babiker and Ibrahim, 1979), as well as for several other mouth brooding species of Tilapia (Siddiqui, 1977: Harbott and Ogari, 1982).

5.3 Length-Weight Relationship and Condition Factor

There was a curvilinear relationship between total weight and total length in *O. niloticus* in Lake Chamo. The regression coefficient obtained was near the cube value (b=2.94). This finding is in agreement with the theoretical 'cube law' suggested by Allen (1938 cited in Demeke Admassu, 1990). Thus, the fish may grow isometrically; that is, increase in weight at a rate approximately equal to the cube of increase in length. *O. niloticus* from Lakes Zwai and Awassa was found to have a regression coefficient of 3.03 (Zenebe Tadesse, 1988) and 2.90 (Demeke Admassu, 1990), respectively. These values are roughly similar to the coefficient obtained in this study. The regression coefficient of the females (b=2.63) was less than that of the males (b=2.99). The relatively low length - weight coefficient that was obtained in the females, mainly during March to June may be due to a more pronounced breeding - associated reduction in the condition of females than males.

The value of mean Fulton's condition factor of the fish in Lake Chamo (2.2) is larger than that in Lakes Zwai (C.F.= 1.89) and Awassa (C.F. = 2.03) (Eyualem Abebe and Getachew Teferra, 1992). The high water temperature of 25 °C throughout the year in Lake Chamo is conducive for the fish to digest and absorb food more efficiently than fish in other, cooler, lakes (Getachew Teferra, 1993). As the fish in Lake Chamo are also supplied with good quality food (highly digestible), they may grow relatively rapidly.

There was significant seasonal variation (ANOVA, $P<0.01$) in Fulton's and relative condition of *O. niloticus* in Lake Chamo. The pattern of seasonal fluctuation in Fulton's and relative condition factor of both sexes was similar throughout the year except in the months of June and July. The condition of female *O. niloticus* in Lake Chamo was significantly low in June and July (ANOVA, $P< 0.01$). Condition of fish can be affected by factors such as the environment, food supply, food quality, feeding rate, degree of parasitization and reproductive activity (Bowen, 1979; Getachew Teferra, 1987; Teshima *et al.*, 1987). As indicated in the result, *O. niloticus* in Lake Chamo reproduces throughout the year with a peak between March and June. The female GSI also indicated a prolonged peak, extending to June and July. During this period the fish spends most of its energy for reproduction. All maternal brooder, including *O. niloticus*, are also polygamous (Fryer and Iles, 1972). The male fertilizes many females that come to its nest, spends more time on the spawning grounds (Lowe - McConnell, 1959) and feeds less while guarding its nest. In maternal mouth brooders, the females fast during the early stages and probably often throughout the brooding period, which is between 20 and 30 days in several Tilapia (Fryer and Iles, 1972). Starvation during fasting will have a significant effect on the condition of the female fish. Thus, the poor condition of the females in June and July is likely to be a result of high reproduction activity during the preceeding months in which the fish were intensively breeding.

There was significant change in sex-ratio of *O. niloticus* in the samples caught between November and May, and also in August and September. The sex-ratio in samples taken during March and May is influenced by the large number of females caught during the spawning season. Large number of females were also recorded in August and September. But, the sex ratio from November to February is influenced by the large number of males. This may be explained by the segregation of the sexes after spawning (Fryer and Iles, 1972). The males build and guard spawning grounds where they court several females. The females move to this area for fertilization, and then move with their brood to the brooding sites (Lowe - McConnell, 1958). Therefore, males stay longer in the bottom while females are mostly active and stay near the water surface. Hence, during the spawning seasons, females are more likely to be caught in passive gears such as gill nets than males. A similar phenomenon has been suggested by Demeke Admassu (1994) for *O. niloticus* in Lake Awassa.

6. CONCLUSIONS AND RECOMMENDATIONS

The length-weight relationship for *O. niloticus* in Lake Chamo was found to be $TW=0.0259TL^{2.942}$. This relationship can be utilized to compute the condition factor index of the fish and also to convert weight of the fish to its length and vice-versa for fish between 125 mm and 610 mm TL and 42.5 g and 4800 g in TW.

O. niloticus in Lake Chamo is a continuous feeder during the day. This fish ingestes about 3.75% of its body weight per day at an average temperature of 26 °C. The diet of adult *O. niloticus* (290 to 570 mm TL) was dominated by phytoplankton, consisting of 10 genera of blue greens, 8 genera of green algae and 8 genera of diatoms. Whereas animal foods were observed in the diet of the juveniles between 61 and 115 mm TL in addition to algae. In terms of percentage composition by number, blue greens contributed over 60% of the food ingested by *O. niloticus* in Lake Chamo whereas green algae constituted the major portion of the dry weight. Green algae, blue greens and diatoms were nearly equally represented in terms of percentage by volume.

O. niloticus in Lake Chamo breeds almost throughout the year with a peak reproduction activity between March and June. Both sexes were sexually mature at a size of 390 mm TL. 50% of both males and females were mature at a size between 400-440 mm TL.

It is now possible to make preliminary management recommendations based on the knowledge accumulated on the biology of *O. niloticus* in Lake Chamo. There is clearly a need to continue with studies on the biology of the fish in order to further refine the results obtained in this study and ensure that they keep up with changing biological conditions.

The establishment of a permanent system of monitoring the fish resource and production must be given emphasis. Priority should be given to those water bodies like Lake Chamo that have big fisheries potential.

The following regulation, therefore, should be enforced for sustainable use of the Tilapia fisheries resource of Lake Chamo.

Closing area: It is advisable to ban shore fishing of *O. niloticus* during the breeding season. This helps to protect the capture of breeding fish.

Gear specification: Restriction in minimum mesh size is necessary to ensure a minimum escape of mature fish and protect recruitment. That is, the mesh size should be wide enough so as not to catch fish less than 390 mm TL, the smallest size of first sexual maturity.

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