ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

The Condition factor, Feeding and Reproductive Biology of *Oreochromis niloticus* L. (Pisces: Cichlidae) in Lake Beseka (Metehara), Ethiopia.

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June, 2005

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A thesis presented to the School of Graduate Studies,

Addis Ababa University

In partial fulfillment of the requirement for the degree of

Master of Science in Biology

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June, 2005

Acknowledgments

It gives me great pleasure to acknowledge my research supervisor Dr. Demeke Admassu, for suggesting the research area, unreserved advice and critical comments during the course of my study. Without his generous help and support it would have been impossible to complete my study.

I would like to express my sincere appreciation to Drs. Abebe Getahun and Seyoum Mengistou for their constant encouragement and providing me with relevant literature. I would also like to express my deep gratitude and appreciation to Dr. Tenalein Ayenew (from Geology Department of AAU) for providing me with the map of Lake Beseka and other valuable information about the lake.

I would like to express my deep appreciation to the School of Graduate Studies, A.A.U. for the financial support to this study. I am also deeply indebted to Dr. Demeke Kifle for the financial support especially for the last two field trips from his project and for his generous help in providing me with relevant literature, and I am thankful to Addis Ababa Administration Education Bureau for sponsoring my study. The Department of Biology, AAU, is also gratefully appreciated for giving me such an opportunity to study at the department and providing me vehicle, field equipment and other materials for the field work.

A special thanks to Oromiya Agricultural Development Bureau, in particular to Fishery Department of Biology Fentale Woreda Rural Development Office, particularly Alemu Diribi, for his valuable support in my study by providing me with some field equipment.

I wish to thank my colleagues in Fisheries and Aquatic Science Stream especially Wassie Anteneh, Getachew Beneberu and Tadesse Fetahi for their constructive advice and provoking discussion related to my study.

I am extremely grateful to all member of my family, especially to my father Ato Beyene Haile, for his encouragement support and precious love to accomplish my thesis work successfully.

Finally and most importantly I would like to thank my field assistants and fishermen like Alemayehu Wolde, Tamirat Terefe and Azimach Wolde at Lake Beseka for their unforgettable help during the field work.

Above all, I praise My LORD.

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Abstract

The condition factor, feeding and reproductive biology of *O. niloticus* from L. Beseka, Ethiopia, were studied from samples taken during November 2003 to November 2004. The length- weight relationship of 1028 fish ranging in size from 4 cm to 24 cm TL and from 6 g to 140 g TW was computed. The relationship was curvilinear, and described by $TW = 0.0546 \text{ X } TL^{2.g}$! the regression equation for females was $TW = 0.1005 \text{ X } TL^{2.3}$ and that of males was $TW = 0.0742 \text{ X } TL^{2.7}$. Fulton's condition factor (FCF) was calculated for the total sample as well as for both sexes separately. The mean monthly FCF was highly significantly different between sampling months and sexes and the sex by month interaction was insignificant. The mean . i SE ranged from 1.2 ± 0.06 to 2.0 ± 0.04 for females whereas from 1.3 ± 0.01 to 2.6 ± 0.04 for males. The stomach contents of 690 fish (200 males and 490 females) were examined. The stomach contents were found to be composed of diverse items. A total of 22 algal genera belonging to three families! *Cyanophyceae* (blue greens), *Chlorophyceae* (green algae), *Bacillariophyceae* (diatoms), were identified. Among the diatoms *Navicula*, *Cyclotella*, *Cymbella* and *Thallasiossira*, from the blue greens *Microcysts*, *Osciiiatoria* and *Anabena* and from the green algae *Cosmarium*, *Botryococcus* and *Scendsmus* were the most frequently encountered algal genera in the stomach of the fish. In addition, foods of animal origin, zooplankton, macrophytes, sand grains and detritus were found in the stomach of the fish.

Generally, diatoms and blue greens as a group contributed the bulk of the diet. Considering the average importance of algal genera, *Microcysts* and *Navicula* are the most important in the diet of the fish in L. Beseka. The smallest sexually mature female was 6 cm TL whereas the male was 10 cm TL. However, the 50% maturity length (L_{50}) was 12cm TL for females and 14cm TL for males, and all fish above 20cm TL were sexually mature. The average ± SE fecundity of *O, niloticus* ranging in length from 10 to 23cm TL and in weight from 14 to 81g TW was 154 ± 2.8. The smallest count was 110 eggs and the largest was 235 eggs. In general, fecundity of *O. niloticus* in L. Beseka was linearly related to total length, total weight and gonad weight. The mean monthly gonadosomatic index (GSI) of females ranged from 0.7 to 3.5 and that of males from 0.6 to 2.1. There was biannual cycle in which GSI increased from February peaking in April and from August peaking in September. Ripe females and males also occurred at high frequencies in April and September. Hence, it was found that the fish in L. Beseka spawned throughout the year, with a peak of activity between March and April and also between August and September.

Key words/ phrases: Breeding season, fecundity, Fulton's condition factor, L. Beseka, *Oreochromis niloticus*, stomach contents.

1. Introduction

The group of fishes commonly known as Tilapia (family: Cichliclae) are mainly indigenous to Africa (Balarin and Hatton, 1979), but many species are now found in most tropical and subtropical waters of Africa, South America and Asia (Fryer and lies, 1972). Tilapias are generally grouped into four genera, *Tilapia, Sarotherodon, Danakilia and Oreochromis* (Trewavas, 1983).

Oreochromis niloticus, a member of the group, is a broadly distributed tilapiine in Ethiopia (Trewavas, 1983). It is found in almost all lakes and rivers of Ethiopia (Shibru Tedla, 1973). According to LFDP (1995) it accounts for about 60% of the annual commercial fishery of the country. Therefore, it is one of the most important species biologically and in the fisheries of Ethiopia.

Although, tilapiine fishes in general are herbivores (Fryer and lies, 1972), they have diversified diet composed of both vegetation and animal components. The vegetation component is usually dominant and consists 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 mollusks (Balarin and Hatton, 1979). According to Philipart and

Ruwet (1982), members of the genus *Tilapia, T. rendalli, T. sparrmani, T. zilli*, and *T. thollinii* are chiefly macrophyte feeders and adults feed preferentially on filamentous algae, macrophytes and vegetable matter of terrestrial origin.

The genus *Sarotherodon* usually feeds on the blue green algae, epilithic algae, insect larvae, crustacean and mollusks (Harbot, 1975; Sparatu and Zorn, 1978). *O. niloticus* feeds on phytoplankton mostly blue green, green algae and diatoms. Rotifers, crustaceans and aquatic insects are also common food for the fish (Fryer and lies, 1972). Harbott (1975) reported that this fish also feeds on small particles probably including bacteria, aided by mucus produced in the bucal cavity. However, as it is the case in several fish species, the food habit of *O. niloticus* is extremely variable within a water body depending on the size and age of the fish, the habitat occupied and the time of the year (Phlipart and Ruwet, 1982). Thus, the fish species feeds mainly on phytoplankton as adult. The fry and early juvenile are omnivores. They actively pursue rotifers, copepods, benthic animals such as insect larvae and chironomid larvae. These fish tend to eat progressively more phytoplankton as they grow older and upon reaching 6 cm total length, phytoplankton forms almost the entire diet (Moriarity, 1973).

The food and feeding habits of *O. niloticus* have been studied in most lakes of Ethiopia. For instance, from Lake Awassa (Tudorancea et ah, 1988; Getachew

Teferra and Fernando, 1989), Lake Ziway (Zenebe Tadesse, 1988), Lake Chamo (Yirgaw Teferi, 1997; Yirgaw Teferi et al, 2000). From these and other studies it has been known that the fish is omnivorous at early developmental stage but herbivorous at the later developmental stage. Because of its herbivorous feeding habit it plays an important role in transferring energy from the base of the food chain to the top consumers (Zenebe Tadesse, 1999).

Studies on the stomach content of adult *O. niloticus* shows that the common composition of the group of phytoplankton mainly includes the blue green algae, green algae, diatoms, macrophyte and amorphous detritus (Tudorancea et al., 1988; Zenebe Tadesse, 1988; Getachew Teferra and Fernando, 1989; Kebede Alemu, 1995; Yirgaw Teferi, 1997; Yirgaw Teferi et al, 2000). Feeding activity of tilapia in general, according to many researchers, varies seasonally based on various factors such as temperature, the time of the day and reproduction. Although seasonal changes in day length and temperature are small in the tropics, seasonal changes in wind and rainfall regimes do cause some seasonality in most tropical ecosystems (Lowe-McConnell, 1987). Therefore, qualitative and quantitative changes in the available food of the fish could result from wind pattern and rainfall regimes in tropical lakes (Lowe-McConnell, 1987).

Tilapias have many similarities with other cichlids in their reproductive habit. They actually exhibit a high degree of parental care, and in this respect, they are clearly divided into substrate spawners and mouth brooders (Lowe-McConnell, 1959). The reproductive biology of *O .niloticus*, a maternal mouth brooder, in the Ethiopian lakes has been studied by Zenebe Tadesse (1988; 1997), Demeke Admassu (1994; 1996), and Yirgaw Teferi et al. (2001). The fish breeds continuously throughout the year in the Ethiopian lakes, but the breeding activity is intensive during the periods from December to March in Lake Ziway (Zenebe Tadesse, 1988), January to April and July to September in Lake Awassa (Demeke Admassu, 1994; 1996), April to August (peaking in June and July) in Lake Tana (Zenebe Tadesse, 1997) and from March to June in Lake Chamo (Yirgaw Teferi, (1997). Stewart (1988) also reported that the species in Lake Turkana breeds continuously throughout the year but peak breeding occurs during March to July. The peak breeding activity of the fish in Lakes Awassa and Ziway, according to Zenebe Tadesse (1988) and Demeke Admassu (1989), respectively, appear to be correlated with rainfall, peak in phytoplankton biomass and other associated factors.

The main breeding activity of the fish species in the tropics in general has been associated with light intensity, temperature, water level and seasonal flooding

(Low-McConnell, 1982). Abundance of food has also been considered as an important factor in timing of breeding in some species (McBaye, 1977). According to Demeke Admassu (1996) the peak breeding of *O. niloticus* in Lake Awassa coincides with increase in phytoplankton biomass.

The length of sexual maturity of tilapia is extremely variable depending on the species, growth rate and the environment (Balarin and Hatton, 1979). For instance, the species in small water bodies and riverine habitats mature at a much younger age and smaller size than the same species living in lakes (Lowe-McConnell, 1987). *O. niloticus* individuals that are in poor body condition start to breed at smaller size than those in good condition (Balarin and Hatton, 1979). Additionally, size of sexual maturity may also be different for the sexes of the same species. For instance, in Lakes Ziway and Awassa *O. niloticus* females mature at smaller size than males (Zenebe Tadesse, 1988; Demeke Admassu, 1994). Variations in condition and growth of the fish in different water bodies are attributable to differences in the quantity and quality of food available (Demeke Admassu, 1989; 1998). This is also reflected in body condition factor, which is derivative of the length-weight relationship (Demeke Admassu, 1990).

Fecundity, the number of oocytes per ripe female, depends on body size. It is related to total length, body weight and gonad weight of the fish (Fryer and Iles, 1972). Zenebe Tadesse (1988) in L. Ziway and Demeke Admassu (1994) in L. Awassa observed curvilinear relationship between fecundity and total length of *O. niloticus*. However, Babiker and Ibrahim (1979) in White Nile, and Yirgaw Teferi (1997) in L. Chamo observed linear relationship between fecundity and fish size of the same species.

Cheap source of protein is urgently required to support an ever increasing human population. Fishery resources definitely can offer one of the solutions to the problem of food shortage in a country like Ethiopia. Moreover, *O. niloticus* is the most preferred fish in Ethiopia for human consumption and the demand has increased rapidly over the last two decades (Zenebe Tadesse, 1999).

Potential yield from Ethiopian water bodies is not accurately estimated. However, according to LFDP (1996), major waters can provide about 60,000 tones of fish per year, but the current exploitation is only about 20,000 tones per year (LFDP, 1996). Compared with the potential the current fishing rate offered as low as 33 percent. Furthermore, the methods used for fishing are still primitive and some stocks show signs of over-fishing (LFDP, 1996). Therefore, the resource calls for proper management, to protect stocks, and also to further develop the fishery on the under exploited stocks, however, requires detailed knowledge on the fisheries as well as on the biology of the fish (Lackey and

Nielson, 1980). The feeding and reproductive biology of *O. niloticus* in several lakes of Ethiopia has been well studied. Such knowledge is not available for the species in Lake Metehara (Beseka) and this has hindered proper management of the fishery.

The present study was, therefore, conducted with a general objective of providing base line biological data useful for rational exploitation and management of *O. niloticus* stock in Lake Beseka.

The specific objectives of the study were:

i) To study the food and feeding habit of *O. niloticus* in L. Beseka.

ii) To study breeding season, maturation, fecundity and sex ratio of *O. niloticus* in L. Beseka.

iii) To assess length-weight relationship and condition factor of *O. niloticus* in L. Beseka.

The results from this study possibly will provide basic information upon which rational exploitation and management of *O. niloticus* fishery can be made. The study may also provide useful information for further development of fisheries in Ethiopia in general and that of L. Beseka in particular. It could also provide base-line information for future aquaculture development in the country.

2. Study Area

L. Beseka (latitude 39^0 51'-31^0 53'N and longitude 8^0 52'-8^0 54'E) is located in the northern half of the Ethiopian Rift valley, about 200 kilometers east of Addis Ababa (Figs.1 and 2). The lava-dam lake covers an area of 40 km^2 with a mean depth of 6m (Tenalem Ayenew, 2004) (Table 1). According to Tenalem Ayenew (2004), the area of the lake increased from 3 km^2 to 40 Km^2 between 1964 and 1997. This shows approximately a 13 fold increase in area over a period of thirty years. This change in the water balance of L. Beseka comes from a ground water input, which is related to the recent increase in recharge from the irrigation fields and the rise in the level of the River Awash after the construction of the Koka Dam, which is located some 152 km upstream (Tenalem Ayenew, 2004). As it was reported previously by Elizabeth Kebede and Willen (1998), the conductivity and ionic concentrations of the lake has decreased by 10 fold during about the same period. This dilution, according to the authors, is due to a 10 fold increase in the area of the lake because of subterranean seepage from the basin and spillage from the River Awash during periods of high water level.

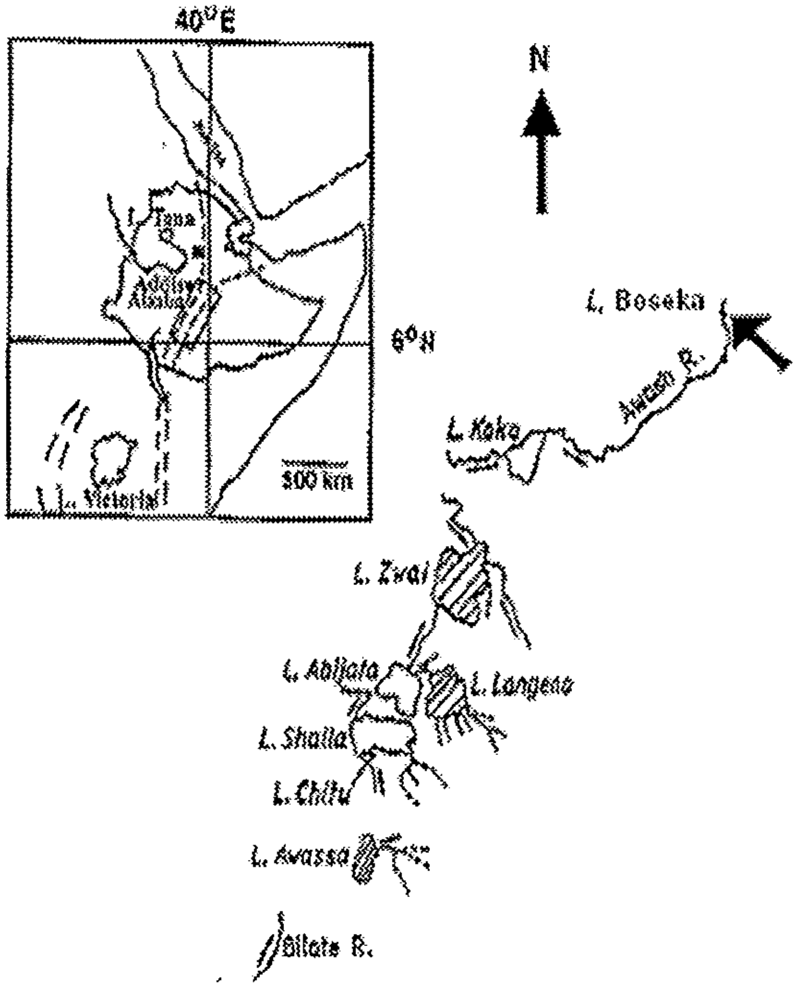

Fig. 1. Map of Ethiopia (inset) and the Rift Valley Lakes with their drainage basin pattern. The arrow indicates L. Beseka (Modified after Elizabeth Kebede et al., 1994 and Demeke Admassu, 1998).

Table 1. Some physical and chemical characteristics of L. Beseka (Unless indicated otherwise, data are from the present study)

Characteristics	*Value*
Altitude	1200m [a]
Surface area	>40km^{2} [b]
Mean depth	6m [b]
Secchi depth	44cm
Salinity	3.1gl^{-1}
Alkalinity	46.5meql^{-1} [a]
Conductivity	7441µS cm^{-1} [a]
pH	9.4 [a]
Chl-a	19.1µgl^{-1}
Nitrate (NO_3^{-3}-N)	0.4µgl^{-1}
Phosphate (PO_4^{-3})	1.62µgl^{-1}
Sulfate (SO_4^{-2})	> 70µgl^{-1}

Source:

[a] Elizabeth Kebede and Willen (1998)

[b] Tenalem Ayenew (2004).

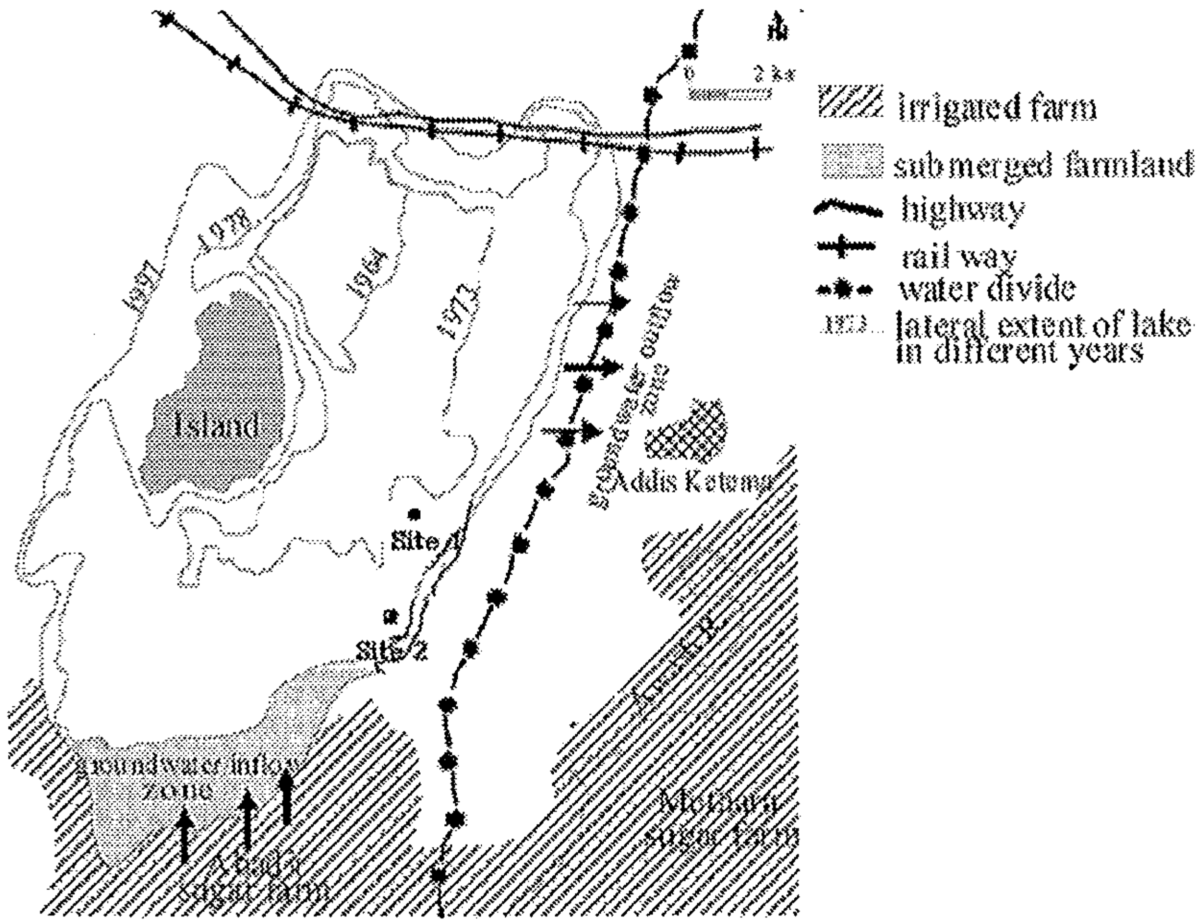

Fig. 2. Map of L. Beseka showing sampling sites and its surrounding areas (Tenalem Ayenew, 2004).

The region is characterized by semi-arid climate. In the study year monthly total rainfall ranged from none in May to only 188 mm in August. The rainy seasons were from July to September (major rain); March to April (minor rains) and from December to February (little rain). Maximum rainfall was recorded in August and September (Fig. 3); with monthly total rainfall below 200 mm and the rest of the months were dry.

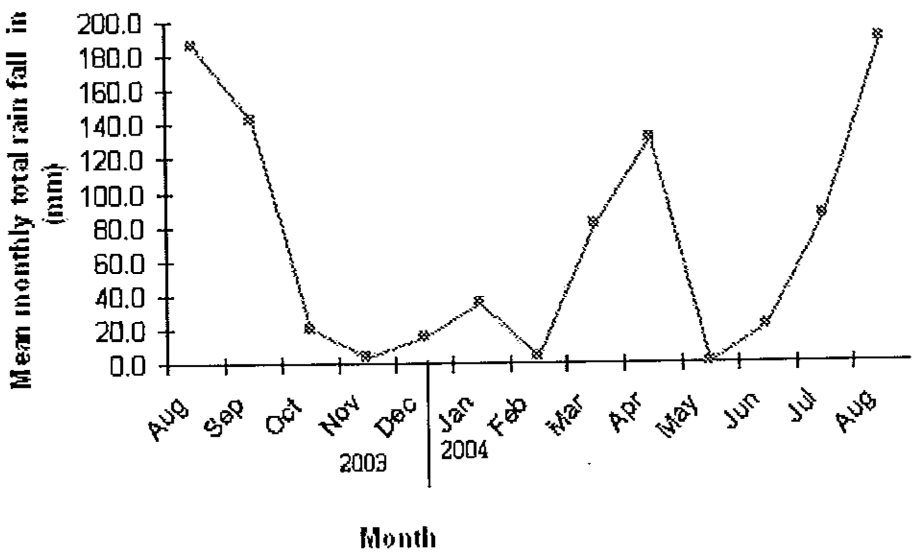

Fig. 3. Rainfall (mm) pattern of L. Beseka area August 2003 and August 2004 (Data from National Meteorological Organization of Ethiopia).

Data from the National Meteorological Organization of Ethiopia show that the mean maximum air temperature was above 30^0C whereas the mean minimum temperature was below 20^0C (Fig. 4). Differences between mean maximum and mean minimum air temperature were small during the rainy season. May and June were the driest and hottest months of the year

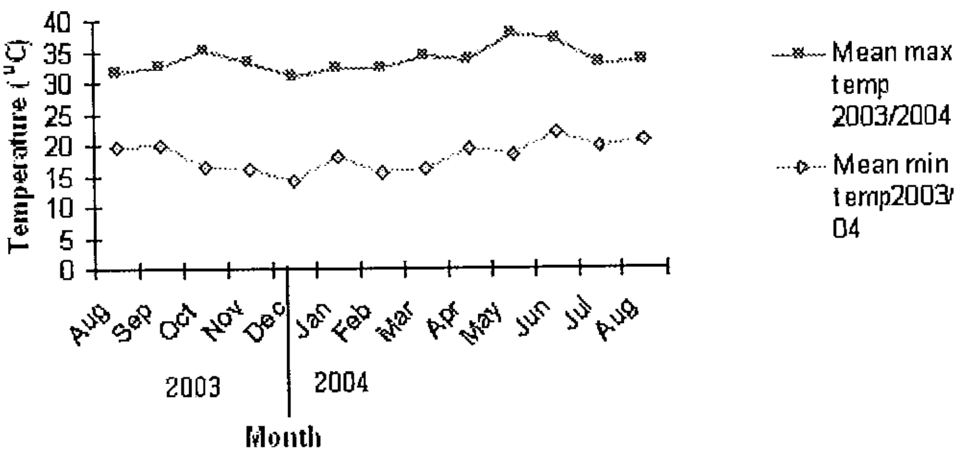

Fig. 4. Seasonal variation in mean maximum and minimum air temperature (^0C) of L. Beseka area from August 2003 to August 2004 (Data from National Meteorological Organization of Ethiopia).

The phytoplankton community of L. Beseka, during the short rains in March-May, 1991 was found to be composed of blue-greens (*Merismopedia glauca)*, greens (3 genera like *Scenedesmus, Tetrastrum*, and *Tetraedron*) and diatoms *(Thalassisira rudolfi, Melosira (Aulacoseria*), *Surirella, Cymbella,* and *Navicula*) (Elizabeth Kebede and Willen, 1998). *Spirulina platensis*, *which* dominated the phytoplankton community in 1961 (Wood and Talling, 1988), was totally absent in 1991 (Elizabeth Kebede and Willen, 1998). Diatoms and green algae, generally, dominate the phytoplankton species of L. Beseka (Elizabeth Kebede and Willen, 1998). *T. rudolfi,* which is the most important and common diatom species, makes up 64% of the phytoplankton biomass of the lake (Elizabeth Kebede and Willen, 1996). However, Wood and Talling (1988) also reported earlier the dominance of *Oscillatoria* and *Anabenopsis*.

Information is lacking about zooplankton community of L. Beseka. However, Seyoum Mengistou and Green (1991) have reported the presence of *Branchionus plicatilis* and *B. dimidiatus* in the lake. In addition, some zooplankton species identified in the present study using the descriptions from Defaye (1988) and Dussart and Fernando (1988) are listed in Table 2.

The fish population of Lake Metahara comprises *O. niloticus* and *Clarias gariepinus* (LFDP, 1995). Cast nets and gill nets are used to catch tilapia;

whereas, hook and line gear is used to catch mainly *C. gariepinus* by local fishermen.

Crocodiles are found in great number in L. Beseka (personal observation). Moreover, more than 460 species of birds have been recorded including the amazing *Abyssinian ground hornbill*, extremely localized endemic *White-tailed swallow*, Kori and Arabian Bustards, *Pygmy flacon*, *Ruppell's vultures* etc. (Van, 2005).

Table 2. List of Zooplankton species identified in net samples taken from L. Beseka.

ROTIFERA	COPEPODA	CLADOCERA
Branchionus plicatilis	*Thermocyclopes* spp.	*Diaphanosoma* spp.
B. leydigi	*Mesocyclopes* spp.	*Moina* spp.
B. dimidiatus	*Nauphlii*	
B. variablis	*Copepodites*	
Keratella americana`		

3. MATERIALS AND METHODS

3.1. Field sampling and measurements

Samples of *O. niloticus* were collected monthly over nine months period, between November, 2003 and November, 2004. A random sample of 1028 fish was taken using beach seine (5 mm and 8 mm stretched mesh) from two sites of the lake. Site one (Sebara Jelba) is 2 m deep and about 10 meters away from the shore. Site two (Wacho) (shore), where there is relatively dense macrophyte, is 0.5-1m deep and about 1-1.5 km away from site one.

Total weight (TW) and total length (TL) of all specimens were measured to the nearest 0.1 gram and 0.1 cm, respectively. Each fish was dissected, and its stomach content removed and preserved in a plastic bag containing Lugol's Iodine solution and/or 5% formaldehyde. Gonad of each fish was removed and weighed to the nearest 0.01 g and the maturity level of gonads was determined according to Babiker and Ibrahim (1979). The number of fish with ripe gonads were also recorded and their gonads preserved in Gilson's fluid for fecundity study. The samples were transported to Addis Ababa University, fisheries laboratory, for further studies.

3.2. Length – weight relationship and Condition factor

Length-Weight relationship was computed using least squares regression analysis (Bagenal and Tesch, 1978): logTW = log a + blogTL, where log a is the intercept and b is the slope of the regression line. Length- weight relationship was calculated separately for the sexes.

Condition factor of the fish was determined by computing Fulton's condition factor as in Bagenal and Tesch (1978), i.e.

$$FCF = \frac{TW}{TL^3} \times 100$$

Where, FCF = Fulton's condition factor

TW = total weight in grams

TL = total length in centimeter

Two way ANOVA was employed to investigate differences in FCF between sampling months and sexes and to test the sex by month interaction (Sokal and Rohlf, 1981).

3.3. Food and feeding habits

3.3.1. Stomach contents

Stomach contents preserved in Lugol's iodine and/or 5% formaldehyde solution were analyzed for food composition. Then identification of stomach contents was made visually for large food items and microscopically for others.

Food items were identified using descriptions from several sources (e.g. Blomqvist, 1981; Defaye, 1988; Dussart and Fernando (1988); John et al., 2002). The algae in the stomach contents were counted by the transect method (Lind, 1974).

3.3.2. Relative contribution of major food items

The relative importance of the different food items found in the stomach was determined using numerical method i.e. Percentage frequency of occurrence and percentage composition by number (Windell and Bowen, 1978) as described below:-

i. Percentage frequency of occurrence: In this case the number of stomachs in which each of the food items occurred was recorded and the percentage of this was calculated relative to the total number of stomachs containing food. This value, therefore, estimates the proportion of fish in the population ingesting a particular food item. This method also gives a general indication of the food spectrum and illustrates changes in the diet with age and size.

ii. Percentage composition by number: It expresses the relative abundance of a particular food category as a percentage of the food items of the total gut contents. This method appears to give a better indication of the contribution of various food items to the diet.

3.3.3. Seasonal feeding periodicity

Seasonal difference in the food habit of *O. niloticus* was studied from the frequency of empty stomachs and the relative contribution of major food items based on results from frequency of occurrence and numerical abundance methods.

3.4. Reproductive biology

3.4.1. Sex-ratio and length at maturity

Sex-ratio (female to male) for various size classes was determined at different sampling occasions. To determine the length of maturity, average length of 50 percent maturity was also determined graphically (Tweddle and Turner, 1977). Sex-ratio was tested using Chi-square to determine if it varied seasonally and with fish size as in Demeke Admassu (1994).

3.4.2. Fecundity estimation

Fecundity was estimated by direct counting method (Synder, 1983). Least squares regression was used to find the relationship between fecundity and total length, total weight and gonad weight as in Demeke Admassu (1994). The diameter of the ripe ova was measured using micrometer fitted into the microscope (Fryer and Iles, 1972)

3.4.3. Breeding season

Breeding season of *O. niloticus* was determined based on the frequency of fish with ripe gonads and on Gonadosomatic index (GSI). The GSI for each fish was computed as the weight of the gonads as the percentage of the total body weight.

$$GSI = \frac{\text{Gonad weight}}{\text{Total weight}} \times 100$$

where, Gonad weight in gram

Total weight in gram

4. Results

4. 1. Length – Weight relationship and condition factor

The relationship between total length and total weight for fish between 4 cm and 24 cm TL and 6g – 140g TW was curvilinear (Fig. 5) and statistically significant ($P < 0.05$). The equations separated by sex were as follows:

Males: $TW = 0.0742 \times TL^{2.7}$, $n = 200$, $r = 0.94$

Females: $TW = 0.1005 \times TL^{2.3}$, $n = 828$, $r = 0.9$

The same equation combined for the sexes was as follows:

$$TW = 0.0564 \times TL^{2.6}, n = 1028, r = 0.94, P<0.05$$

Mean ± S.E. Fulton's condition factor (FCF) values ranged from 1.2 ± 0.06 to 2.0 ± 0.04 for females whereas from 1.3 ± 0.01 to 2.6 ± 0.04 for males. Average FCF (± SE) combined for the sexes was 1.65 ± 0.03; that of females was 1.5 ± 0.02 whereas that of males was 1.8 ±0.04. FCF varied highly significantly (ANOVA, $P<0.0001$) between sampling months and between sexes (ANOVA, $P< 0.05$).However, sex by month interaction was insignificant (ANOVA, $P>0.05$). Thus, temporal variation in FCF for both sexes was similar (Fig. 6). Generally, lower values of FCF were recorded in March and April and in September. Values tended to increase in August and November, particularly for males (Fig. 6). In addition, mean FCF in November, 2003 which was similar for the sexes was larger than the rest of months.

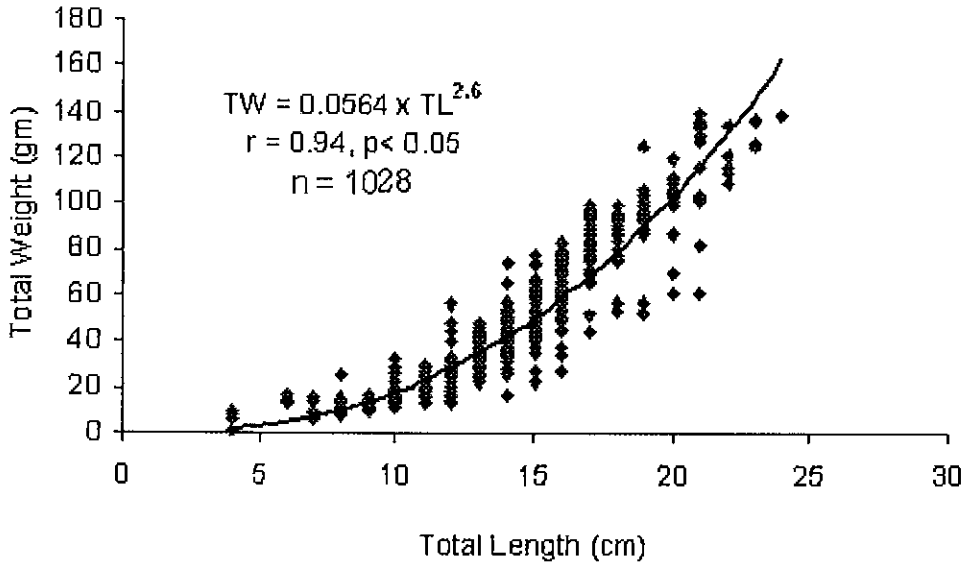

Fig. 5. Length – Weight relationship of *O. niloticus* from Lake Beseka.

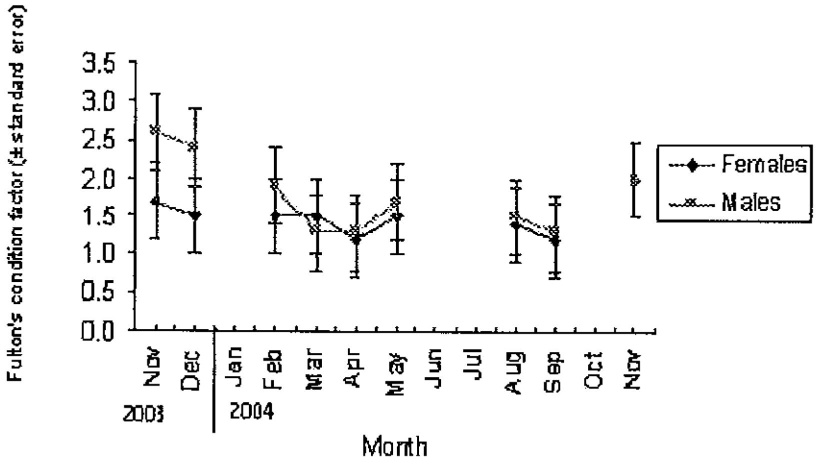

Fig. 6. Temporal variation in Fulton's condition factor (mean ± SE) of *O. niloticus* from L. Beseka for both sexes.

4.2. Food and feeding habits

4.2.1. Stomach contents

The samples used in this study were 690 fish (200 males and 490 females) whose total length ranged from 4–23 cm. Of these 155 (23.12%) had empty stomachs. Items encountered in the stomach contents are listed in Table 3. The stomach content was found to be composed of diverse items. A total of 22 algal genera belonging to 3 families were identified. In addition, unidentifiable animal remains (partially digested) of zooplankton origin, macrophyte tissues, detritus and sand grains were also present (Table 3).

Table 3. Items encountered in the stomach contents of *O. niloticus* in L. Beseka.

Cyanophyceae (Blue Greens)	*Chlorophyceae* (Greens)	*Bacillaiophyceae* (Diatoms)	Unidentified
Microcysts	*Botryococcus*	*Pinularia*	Macrophytes
Oscillatoria	*Cosmarium*	*Navicula*	Sand grains
Lyngbya	*Pediastrum*	*Thallassiosira*	Detritus
Anabaena	*Nitella*	*Cymbella*	Animal remains
Rivularia	*Tetraedron*	*Cyclotella*	(Zooplankton)
	Scendsmus	*Stephanodiscus*	
	Asterococcus	*Melosira* (*Aulacoseria*)	
		Surirrlla	
		Neidium	
		Nitzschia	

4.2.2. Relative importance of major food items

i. Frequency of occurrence

In general, *O. niloticus* in L. Beseka was found to feed on phytoplankton with a low relative importance of zooplankton. In terms of frequency of occurrence, phytoplankton was ingested by all specimens whose stomachs were examined in this study. Unidentified animal remains of zooplankton origin, which are partially digested, were encountered in 41% of the samples. Among phytoplankton, diatoms were the most frequent (47.7%), followed by cyanophytes (40.7%) and chlorophytes (11.83%) (Table 4). The high frequency of cyanophytes was mainly due to one genus (*Microcysts*) which was encountered in almost all specimens. The percentage frequency of cyanophytes genera was below 20% except *Oscillatoria*, which was 66%. The frequency of chlorophytes was far below the others and the highest value was 20% (Table 4). Most diatom genera, however, had frequencies ranging from 39% to 78%, and they were the most diverse in the diet of the fish (Table 4). On average, therefore, diatoms were the most frequent algal groups in the diet of *O. niloticus* in L.Beseka.

Among diatoms, whose frequency of occurrence was 23% to 78%, *Navicula* was the most frequent genus. It was followed by *Cyclotella* (64%), *Thalliasiossira*

(66.5%), and *Cymbella* (59%). Among the blue greens, whose frequency of occurrence was 11.3 to 98.7%, *Microcysts* was the most frequent genus. It was followed by *Oscillatoria* (66%) and *Rivularia* (17%). Among Green algae whose frequency of occurrence was 2.2% to 20%, *Cosmarium* was the most frequent (20%) and it was followed by *Botryoccocus* (12.8%) and *Scendesmus* (11.4%) (Table 4).

Table 4. Relative importance of different food items present in the stomach contents of *O. niloticus* in L. Beseka.

Food items	Numerical abundance (%)	Frequency of occurrence (%)
Cyanophceae (blue greens)	32	40.7
Microcysts	15.7	98.7
Oscillatoria	6.6	66
Anabaena	3.7	11.3
Lyngbya	3.3	11.7
Rivularia	2.3	17
Chlorophyceae (green algae)	11	11.83
Cosmarium	2.9	20
Botryococcus	2.3	12.8
Scenedesmus	1.7	11.4
Tetraedron	1.5	4.3
Asterococcus	0.46	2.2
Pediastrum	0.55	2.8
Nitella	0.38	3.0
Bacillariophyceae (diatoms)	57	47.7
Navicula	11.1	78
Cyclotella	9.8	64
Cymbella	8.1	59
Thaliasiossira	7.6	66.5
Stephanodiscus	6.8	44.7
Surirrela	5.1	44
Nitzschia	4.9	39
Melosira	1.6	26.6
Pinularia	1.5	27
Neidium	1.1	23

ii. Frequency of animal remains by size class

The food of *O. niloticus* in L. Beseka was also found to vary with fish size. Animal remains (zooplankton) were encountered in fish of all size groups. However, it was most frequent in fish that were 6 cm and below (64%). The frequency gradually decreased with fish size and the lowest being recorded in the fish having 19 and 23 cm length class (10%) (Fig. 7).

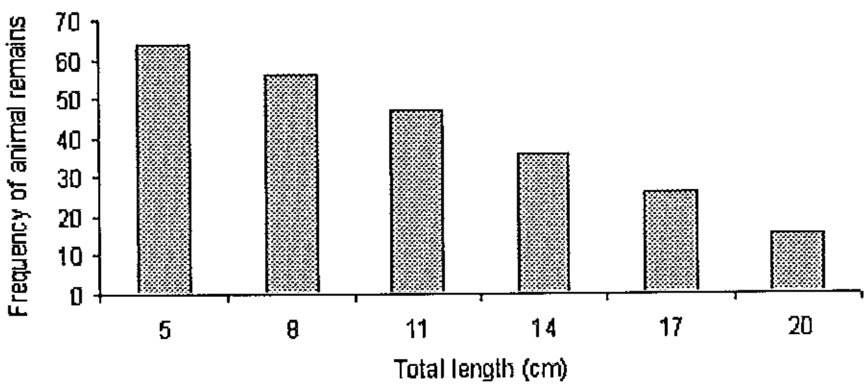

Fig. 7. Frequency of animal remains in different size classes of *O. niloticus* in L. Beseka

iii. Numerical abundance

Based on percentage composition by number, diatoms were the most important diet of *O. niloticus* in L. Beseka which contributed 57 % of the total food ingested. Blue greens contributed 32% and green algae 11 % (Table 4).

Among diatoms *Navicula, Cyclotella, Cymbella* and *Thallasiossira* contributed 11.1 %, 9.8%, 8.1% and 7.6%, respectively, of the total food counted (Table 4). Among blue greens, *Microcysts* accounted for 15.7% of the total number of food item ingested. *Oscillatoria* and *Anabaena* also contributed 6.6% and 3.7%, respectively. *Microcysts* was the most abundant genus not only from its group but also from the total food ingested. Numerically the most important green algal genera were *Cosmarium, Botryococcus* and *Scendsmus* which contributed 2.9%, 2.3% and 1.7%, respectively (Table 4). Animal remains of zooplankton origin, macrophyte tissues, amorphous detritus and sand grains were also observed frequently in the diet of the fish.

Generally diatoms and blue greens as a group contributed the bulk of the diet, and were the most important food of *O. niloticus* in L. Beseka. Green algae were consumed regularly but in very small quantity. The relative contribution of the major groups of food items are shown in (Table 4).

4.2.3. Seasonal feeding periodicity

The frequency of fish with empty stomach varied throughout the sampling months. Fish with empty stomach were most frequent in April (43%) and September (42%) whereas the lowest in February (20%) and November (21%) (Fig. 8). Phytoplankton and animal food items were ingested by the fish in all sampling months, but their contribution appeared to vary (Fig 7) and (Fig. 9).

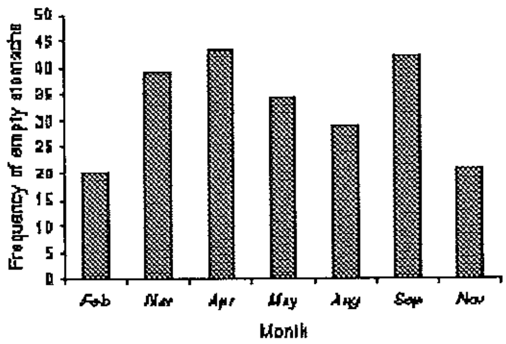

Fig. 8. Frequency of *O. niloticus* with empty stomachs from Lake Beseka.

Numerical contribution of diatoms ranged from 1.1% – 11.1% with relatively high proportions in May and also in September and November, and the lowest value was in February (Fig 9a). The value for blue greens ranged from 2.3% – 15.7% with relatively high proportions in February and the lowest value in April. Also, the numerical contribution of green algae ranged from 0.4% –2.9% with relatively high proportions in February; the lowest value was recorded in September (Fig. 9a).

In terms of percentage frequency of occurrence diatoms ranged from 23%-78% (Table 4) with relatively the highest values in February and March and the lowest values in April and May (Fig. 9b). However, *Navicula* and *Cyclotella* were encountered most frequently in the stomach of the fish in the month of May. The value for blue greens ranged from 11.3% to 98.7% with the highest values being recorded in February and March and the lowest values in August and September. Green algae, on the other hand, varied from 2.2% - 20% (Table 4) with the highest values recorded in February and April and the lowest values in March and May (Fig. 9b). The frequency of animal remains (zooplankton) also ranged from 17% to 64% with relatively highest value being in May and lowest value was in the month of April (Fig. 9c).

Generally, in terms of percentage composition by number, diatoms appeared to be more abundant than the others (Fig. 9a). In addition, blue greens and green algae were the least at times when diatoms were more abundant. Based on percentage frequency of occurrence, however, diatoms and blue green algae were of comparable importance in the study period (Fig. 9b). Marked seasonality was evident for green algae whose frequency and numerical contribution was highest in February and November (Fig. 9a) and (Fig. 9b).

(a)

(b)

(c)

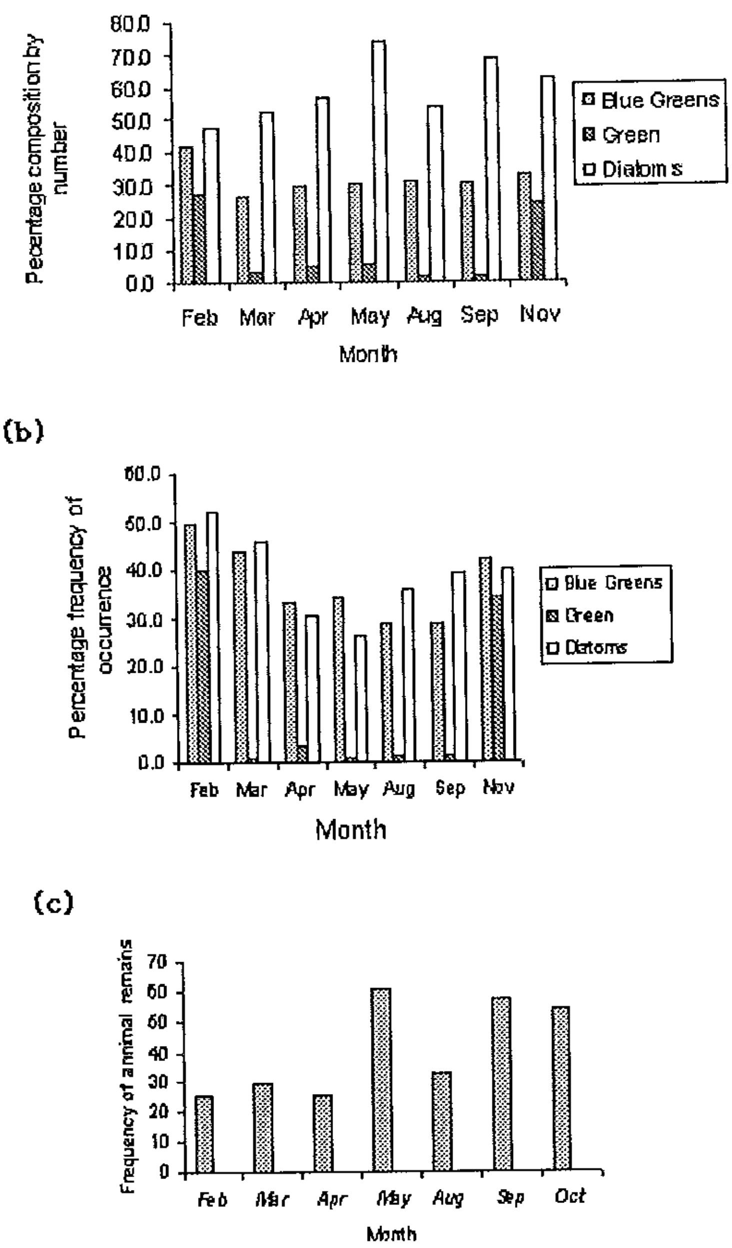

Fig. 9. Relative importance of various food items of *O. niloticus* in L. Beseka determined using (a) percentage composition by number and (b) percentage frequency of occurrence c) for animal remains only

4.3. Reproductive biology

4.3.1. Sex ratio and length at maturity

Sex ratio (female: male) of *O. niloticus* from L. Beseka was 1:0.2 in the total sample, which was highly significantly different (Chi-sq = 319.2) from 1:1 in favor of females (Table 5). In addition, females significantly outnumbered males in all samples except in those taken in November and December (2003) (Table 5). Furthermore, females outnumbered males in all size classes between 4 cm and 18 cm TL (Table 6). However, males were numerous in larger size classes, and significantly so between 19 cm and 24 cm TL (Table 6).

The smallest sexually mature *O. niloticus* that was caught in this study was a female fish of 6 cm TL. The smallest sexually mature male was 10 cm TL. 50% maturity length (L_{50}) was estimated to be 12 cm TL for females (Fig 10a) and 14 cm TL for males (Fig 10b). All fish above 20 cm TL were sexually mature (Fig. 10). On the average females appeared to attain sexual maturity at relatively smaller size than males.

Table 5. Number of females and males *O. niloticus* from Lake Beseka showing sex ratio by sampling month, and chi-square test results.

Month	F	M	F:M	Chi-Sq
Nov, 03	12	19	1:1.58	1.58*
Dec, 03	18	8	1:0.4	3.8*
Feb, 04	42	14	1:0.3	14
Mar, 04	68	11	1:0.16	41.2
Apr, 04	53	26	1:0.49	9.2
May, 04	56	40	1:0.71	2.67*
Aug, 04	158	21	1:0.13	104.8
Sep,04	220	31	1:0.14	142.4
Nov,04	226	30	1:0.13	150
Total	837	200	1:0.2	319.2

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

Table 6. Number of female and male of *O. niloticus* of various size classes showing sex ratio and chi-square test results.

Size class in cm	F	M	F:M	Chi-sq
4-6	6	0	---	
7-9	51	2	1:0.04	45.4
10-12	235	7	1:0.03	214.8
13-15	400	54	1:0.35	263.6
16-18	118	74	1:0.63	10.08
19-21	20	51	1:2.55	13.4
22-24	7	12	1:1.7	1.4*
Total	837	200	1:0.2	319.2

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

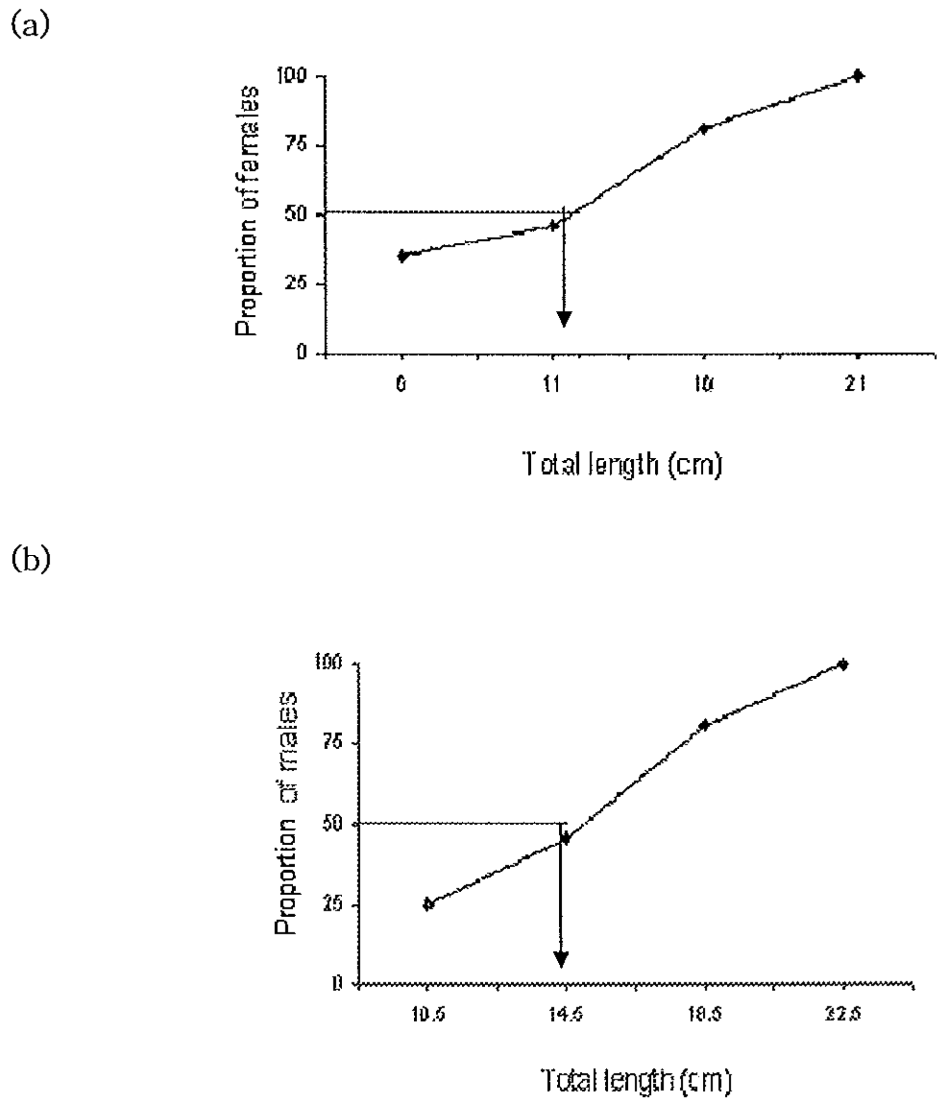

Fig. 10. The proportion of mature females (a) and males (b) out of the total fish caught in 4 cm length interval.

4.3.2. Fecundity estimation

Fecundity of 101 ripe females was estimated; their total length and total weight ranged from 10–23 cm and 14–81g, respectively. The number of eggs per individual ranged from 110 to 235 with a mean ± SE of 154 ± 2.8. The diameter of ripe ova of *O. niloticus* in L. Beseka was found to be between 1.5 mm and 2.5 mm. Fecundity was linearly related to total length, total weight and gonad weight (Fig. 11). Regression equations fitted for the relationships were:

$F = 0.59 \times TL^{1.5}$

$F = 1.8321TW + 77.95$

$F = 92.2 \times GW^{0.67}$

where, F = fecundity, TL = total length in cm, TW = total weight in gram and

GW = gonad weight in gram.

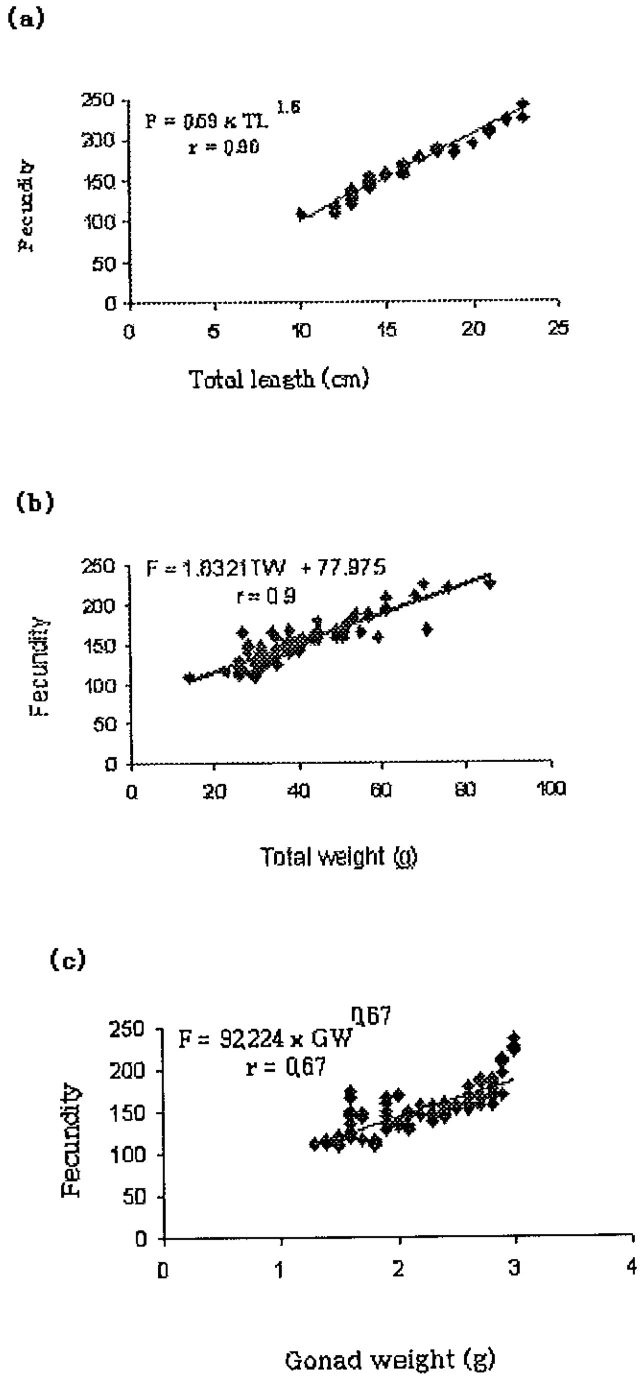

Fig. 11. Fecundity (F) of *O. niloticus* in L. Beseka in relation to:

(a) Total Length (TL)
(b) Total weight (TW)
(c) Gonad weight (GW)

4.3.3. Breeding season

Mean gonadosomatic index (GSI) ranged from 0.7 – 3.5 for females and from 0.6 – 2.1 for males. GSI values varied highly significantly between sampling periods for both sexes (ANOVA, $P < 0.0001$). Temporal variation in GSI was remarkably similar between males and females (Fig. 12). Thus, there was a biannual cycle in which GSI increased from February peaking in April, also from August peaking in September (Fig. 12). GSI values were lower at other sampling occasions.

The cycle in GSI was also reflected in monthly variation in the frequency of fish with ripe gonads (Fig. 13). The frequency was found to be high in April and also in September for both sexes (Fig. 13) which was concomitant with peak GSI values. In addition, lowest frequency of ripe fishes was recorded at times of lowest GSI values.

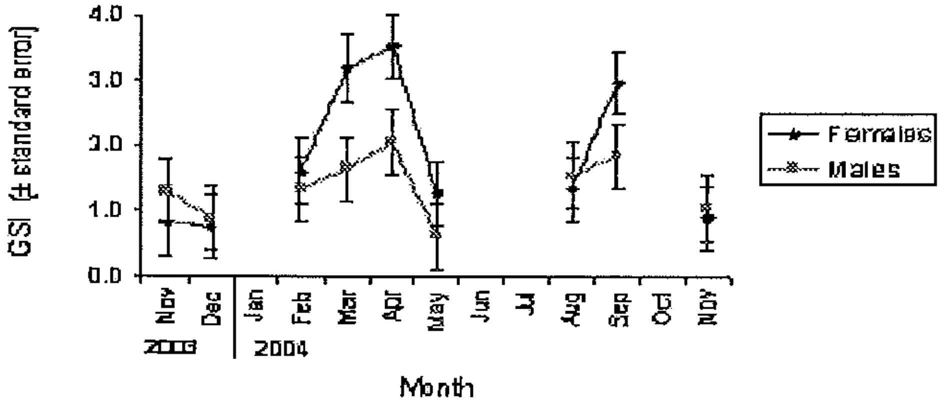

Fig. 12. Temporal variation in gonadosomatic index (GSI ±SE) of *O. niloticus* from L. Beseka determined for both sexes separately.

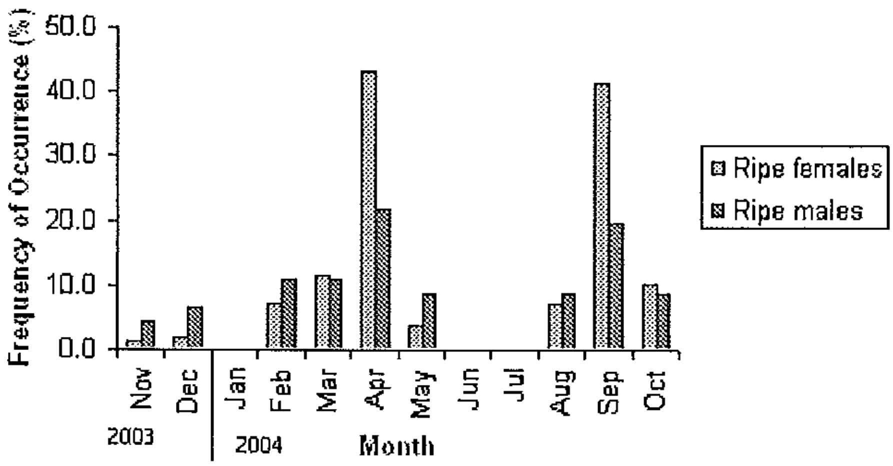

Fig. 13. Temporal variation in frequency (%) of ripe female and male *O. niloticus* in L. Beseka.

5. Discussion

5.1. Length – Weight relationship and Condition factor

The relationship between total length and total weight of *O. niloticus* in L. Beseka was significant (ANOVA, $P<0.05$) and curvilinear (Fig. 5). The finding is in agreement with the principle of fish growth (Bagenel and Tesch, 1978). However, the regression coefficient calculated in this study, which was 2.6, is much lower than the cube. The coefficient for the females (2.3) was even much lower than the expected 3.0. This coefficient is expected to be around 3.0 since growth in weight represents an increase in three dimensions whereas that in length is measured in one dimension. Therefore, at least theoretically, the coefficient would be three if growth is isometric (Allen, 1938 cited in Demeke Admassu, 1990). Thus, our result suggests that growth of *O. niloticus* in L. Beseka is strongly allometric. The coefficient for the same species in other Ethiopian lakes was much higher. It was, for instance, 2.9 in Lake Awassa (Demeke Admassu, 1990), 2.95 in Lake Chamo (Yirgaw Teferi, 1997), 2.74 in Lake Tana (Zenebe Tadesse, 1997) and 3.03 in Lake Ziway (Zenebe Tadesse, 1988). Thus, it is evident that allometric growth in *O. niloticus* of L. Beseka is unparalleled by any other tilapiine population so far reported from Ethiopian rift valley lakes. However, the same was reflected in the condition factor of the Tana tilapia population (Zenebe Tadesse, 1997).

Mean FCF, in the present study, was 1.65 which was lower than that of tilapia in Lake Ziway (1.89), L. Chamo (2.03) and in L. Awassa (2.35) (Zenebe Tadesse, 1988; Yirgaw Teferi, 1997; Demeke Admassu, 1998). The largest fish in total length caught in this study was 24cm whose total weight was 140g. From length-weight relationship equations provided by respective authors a fish of similar total length would be 304g, 235g and 358g in Lakes Ziway, Awassa and Chamo, respectively (Demeke Admassu, 1989; Zenebe Tadesse, 1988; Yirgaw Teferi, 1997).

Evidently, growth rate of *O. niloticus* in L. Beseka is quite slow as compared to tilapia population in other Ethiopian lakes. The reason could be related to low food quality and quantity in L. Beseka. This needs further investigation. Low food quantity and competition for the available food resources was attributed to reduced length-weight coefficient of *O. niloticus* in Lake Tana (Zenebe Tadesse, 1997). In addition to poor food quality, reduced availability (quantity) has been suggested to affect seasonal growth cycle of *O. niloticus* in Lakes Ziway, Langeno and Chamo (Demeke Admassu, 2000). Temperature, another factor affecting growth performance of all organisms, shouldn't be limiting the growth of tilapia in L. Beseka whose water temperature is quite similar to other lakes. It could be even higher than the middle Rift Valley lakes of Ethiopia. For instance, the mean water temperature of L. Beseka was 28^0C, which was measured during the present study, is higher than that of L. Chamo (25^0C) (Yirgaw Teferi, 1997) throughout the year. Even if high water temperature is conducive for fish to digest and absorb the food more efficiently, the fish in L. Chamo (relatively cooler lake) is in better condition than the fish in L. Beseka.

Differences in FCF between the sexes and between sampling months were evident in the present study (Fig. 6). The differences between the sexes could be attributed to differences in onset of sexual maturity. Females were found to mature at relatively smaller length than males which could be the reason for their lower body condition. This will also be discussed further below. In addition, as it will be discussed below, low FCF values were at periods of peak reproduction activity (Fig.12 and Fig. 13). During spawning periods tilapias are actively engaged in reproductive activities which reduce feeding intensity (Fryer and Iles, 1972). Males build and guard spawning nests, and fertilize eggs from several females in the spawning period (Lowe-McConnell, 1959). Females, on the other hand, incubate fertilized eggs, brood and protect their young in their mouth for several days. This might take about two or three weeks as reported for other tilapia populations (Fryer and Iles, 1972; Tudorancea et al., 1988; Demeke Admassu, 1998). Thus, in addition to the energy cost of eggs and sperm production, spawning activity significantly reduces feeding intensity in *O. niloticus* (Fryer and Iles, 1972). This could be the reason for reduction in FCF of *O. niloticus* during the peak breeding periods. The same was concluded for tilapia in several other lakes (Zenebe Tadesse, 1988; Tudorancea et al., 1988; Demeke Admassu, 1994; 1996; Yirgaw Teferi, 1997).

5.2. Food and feeding habit

The study showed that *O. niloticus* in L. Beseka feeds on a variety of food items. Phytoplankton, zooplankton, macrophytes, detritus and some other unidentifiable organism groups are ingested by the fish (Table 3). The findings confirm the fact that, tilapia is opportunistic, which is capable of shifting from one diet to another depending on temporal and/ or spatial variations in availability of the diet in the habitat (Fryer and Iles, 1972; Philipart and Ruwet, 1982; Matipe and De Silva, 1985). The food items ingested by *O. niloticus* in the present study were also reported for the same fish in other Ethiopian water bodies (Getachew Teferra, 1987; Zenebe Taddese, 1988; Tudorancea et al., 1988) and El-Sayed and Alne-na-ei (1987) in Nile Canal. These studies have variously reported that adult *O. niloticus* feeds mainly on phytoplankton and occasionally on macrophytes and detritus. In addition foods of animal origin, mostly zooplankton, are also consumed by adult fish on a regular basis (Fryer and Iles, 1972; Moriarity, 1973; and Getachew Tefera, 1987).

Although phytoplankton were dominant in the diet, the contribution of zooplankton was quite significant for *O. niloticus* in the present study. Zooplankton were ingested by all size groups of the fish and in all sampling occasion (Fig. 7 and Fig. 9c). Zooplanktivorous feeding habit has been reported for *O. niloticus* in other water bodies (Moriarity, 1973; Fryer and Iles, 1972; Zenebe Tadesse, 1988). Generally, however, *O. niloticus* is considered to be omnivorous when young (up to 5 or 6 cm TL), but shifts to a phytoplanktivorous habit afterwards (Moriarity, 1973). According to Moriarity (1973), for instance, after reaching 6 cm TL phytoplankton forms the entire diet of the fish. This is similar to the findings of several other authors on Ethiopian *O. niloticus* populations (Getachew Tefera, 1987; Zenebe Tadesse, 1988; Tudorancea et al. 1988; Yirgaw Teferi, 1997). The authors reported that juvenile *O. niloticus* feed on animal matters mainly zooplankton. Tudorancea et al. (1988) has also reported the importance of chironomid larvae for juvenile *O. niloticus* in Lake Awassa. However, with in the size range considered (Fig. 7) in this study and based on the frequency of occurrence zooplankton appeared almost as important as phytoplankton to the diet of *O. niloticus* in L. Beseka.

Macrophyte pieces and detritus were also the other very common items in the diet of *O. niloticus* in L.Beseka. Detritus were also reported to be important food item for the same fish species in Lake Langeno (Zenebe Tadesse, 1999) and for *O. mossambicus* in Lake Valencia, Venzuela (Bowen, 1980). Macrophyte pieces have also been reported from the stomach of *O. niloticus* in Lake Ziway (Zenebe Tadesse, 1988) and tilapia in general in other water bodies (Fryer and Iles, 1972; Philipart and Ruwet, 1982). Sand grains were also encountered in significant quantities and frequencies in the stomach contents of *O. niloticus* in the present study. Similar results have also been reported by other authors (Fagade, 1971; Zenebe Tadesse, 1988). The importance of sand grains to the fish diet has been controversial. They might be ingested accidentally when the fish is feeding on benthic organisms and /or detritus. However, it is also believed that they may provide nutritional benefit through the dark coating of organic material on their surface (Getachew Teferra et al, 2000). Thus, further investigation, particularly using chemical method may reveal important results on the role of sand grains in fish feeding.

Among the algal diet encountered in the stomach of the fish, diatoms and blue greens as a group were found to be the most important food items of *O. niloticus* in L. Beseka (Table 4). Similar results have been reported for the species in Lakes Awassa (Tudorancea et al. 1988), Ziway (Zenebe Tadesse, 1988), Chamo

(Yirgaw Teferi et al., 2000) and Haiq (Kebede Alemu, 1995). It was also the case for the fish in Lake Rudolf (Harbott, 1975) as well as that in Nile Canal (El-Sayed and Alne-na-ei, 1987). The dominance of blue greens as a group in the stomach of the fish in this study, however, was mainly due to *Microcysts* (Table 4). *Microcysts* is relatively more dominant in the phytoplankton community of the Ethiopian water bodies because of its wide range of salinity tolerance (Wood and Talling, 1988; Elizabeth Kebede and Willen, 1998) and this could be the reason for its dominance particularly in terms of frequency of occurrence in the stomach of the fish in this study. The high importance of blue greens, especially, *Microcysts*, has been reported for the same species in several other water bodies (Kebede Alemu, 1995; Getachew Teferra, 1993; Yirgaw Teferi et al., 2000).

Considering the average importance of algal genera, however, diatoms were most important to the diet of *O. niloticus* in L. Beseka. Other than *Microcysts*, the diatoms *Navicula*, *Cyclotella,* and *Cymbella* were most frequently encountered. Also, numerically, *Navicula* (11%) was only slightly below the most frequent blue green - *Microcysts* (15.7%) (Table 4). Thus, *Microcysts* and *Navicula* are the most important algal genera to diet of *O. niloticus* in L. Beseka. This is in agreement with that of Kebede Alemu (1995) for the fish population in Lake Haiq. The dominance of diatoms (such as *Navicula*) in the diet of this species in Lake Chamo has been reported by others (Getachew Teferra, 1993; Zenebe

Tadesse, 1998; Yirgaw Teferi et al., 2000). However, different results have been reported by some authors, For instance, the diet of the fish is dominated by *Botryococcus* (green algae) and *Oscillatoria* (blue green algae) in Lake Awassa (Getachew Teferra, 1987; Tudorancea et al, 1988), whereas *Lyngybya* (blue green algae) for that in Lake Ziway (Zenebe Tadesse, 1988). In addition, green algae are reported to be dominant in the stomach content of *O. niloticus* in Nile Canal (El-Sayed and Alne-na-ei, 1987). Such differences are not unexpected, because they could be reflections of habitat differences. Moreover, in lakes dominated by a single herbivorous fish species, the quality of the food is determined by the existing algal population on which the fish grazes indiscriminately (Greenwood, 1973; Lobel, 1981; Bowen, 1982)

In spite of a single sampling conducted with in the short period of the rainy season, the species composition of phytoplankton in L. Beseka was thoroughly investigated by Elizabeth Kebede and Willen (1998). According to these authors among the blue greens, *Merismopedia*, with in the green algae, *Scenedesmus, Tetrastrum*, and *Tetradron*, and among diatoms, *Thallassosiria, Mellosira, Surrirela, Cymbela*, and *Navicula* were the dominant genera in the lake. The aforementioned algal species, except the genus *Tetrastrum* and *Merismopedia,* were commonly encountered in the gut of *O. niloticus*. The absence of the two genera may be attributed to selective feeding habit of the fish under study. The fact that all the diatoms genera recorded by Elizabeth and Willen (1998) are found in the gut of *O. niloticus* might indicates that diatoms play key role in the diet of the fish in L. Beseka. This is supported by their high percentage composition (57%) and frequency of occurrence (47.7%) recorded during the present study (Table 4).

The food of *O. nilotics* in L. Beseka was also found to vary with fish size (Fig. 7). This indicates the fry and juveniles are omnivorous and feed on animal remains of zooplankton origin. As the fish grow older and increased in body size, however, tend to eat progressively more phytoplankton. This result is in a complete agreement with other authors (Fryer and Iles, 1972; Zenebe Tadesse, 1988).

Rainfall pattern appeared important in determining variation in the composition of the food of *O. niloticus* in L. Beseka. The contribution of blue greens and greens was relatively highest towards the end of the rainy season (Fig. 3) in November and February (Fig. 9a). In addition, samples taken in these months were also light brown in color suggesting high level of organic matter (Bowen, 1980). Thus, an increase of phytoplankton in the diet of *O. niloticus* could be due to an increase in biomass following nutrient loading by run off (allochtonous) and/or autochthnously (Getachew Teferra, 1987; Zenebe Tadesse, 1988).

On the other hand in May, one of the driest months, numerical contribution of blue greens and greens decreased where as that of diatoms and occurrence of zooplankton remains was high (Fig. 9a and Fig. 9c). Sand grains were also ingested frequently in large quantities in this month (May) during which the water was relatively clearer (personal observation). The result is difficult to explain, because there is no information on seasonal variation of phytoplankton composition in L. Beseka. However, if clearance of the water in May is due to sedimentation, it might have settled down particles with organic nutrients. As reported by Wetzel (2001), this makes organic particles less available to filter feeding consumers. Thus, it might be possible that the fish was feeding at alternative sites and items to compensate for this condition. Stomach contents of the fish in May could suggest bottom feeding due to dominance of sand grains. The diatoms might have been ingested from the sediments as they easily settle, but took longer time to decompose. Diatoms, due to their silica cell wall contain less organic matter (Getachew Teferra, 1993). Therefore, ingestion by *O. niloticus* in May of more sand grains, which could be coated by organic matter (Getachew Teferra et al.,2000), and more zooplankton could be a selection mechanism to compensate for low availability of organic matter (phytoplankton etc.) in the water column.

Another seasonal variation in the feeding of *O. niloticus* in L. Beseka was also indicated by temporal variation in frequency of empty stomachs. Highest frequency of fish with empty stomach was recorded in April and September (Fig. 8). This coincided with peak spawning months of the fish in this lake (Fig. 12 and Fig. 13). Thus, reduced feeding activity in these months could be attributed to peak spawning activity. Spawning *O. niloticus* spend most of the time in spawning than feeding activities (Getachew Teferra, 1987; Zenebe Tadesse, 1988; Demeke Admassu, 1994; 1996; Yirgaw Teferi, 1997). For instance, similar results have been found for the same species in Lake Ziway (Zenebe Tadesse, 1988) and in Lake Chamo (Yirgaw Teferi, 1997).

5.3. Reproductive biology

The study showed a large preponderance of females over males of *O. niloticus* in L. Beseka (Table 5 and Table 6). However, this is not necessarily an indication of the sex ratio of the population in the lake. This is because sex ratio in *O. niloticus* samples are known to depend on sex based differences in activity, particularly spawning, and on sampling gears used and sampling sites (Lowe- McConnell, 1959; Demeke Admassu, 1994; Zenebe Tadesse, 1988; 1997). Spawning males as noted above stay at their spawning nests which they build at the bottom in shallow waters (Lowe-McConnell, 1959). Females, on the other hand, move to the nests for fertilization after which they peak fertilized eggs and move to their brooding sites (Lowe-McConnell, 1959). Brooding sites are normally situated in macrophyte vegetations higher in the water column (Lowe-McConnell, 1959; Fryer and Iles, 1972). Thus, females being more active than males, they are more susceptible to be caught by passive fishing gears such as gillnet. Samples taken by gillnets, therefore, show preponderance of females as it was found and discussed by Demeke Admassu (1994) for tilapia in Lake Awassa. On the other hand, samples taken by active fishing gears such as trawls sampling in the lake bottom show preponderance of males over females. This was the result and explanation provided by Zenebe Tadesse (1997) for tilapia in Lake Tana.

However, a similar explanation is unlikely for the sex ratio in the present study. A beach seine, an active fishing gear, was used in this study. Therefore, as found by Zenebe Tadesse (1997) from L. Tana, preponderance of males over females would have been expected. Our results, however, were contrary to this explanation. The reason could be associated with the lack of abundant macrophyte vegetation in L. Beseka. Macrophyte vegetation is sparse, and even in some sites totally lacking (Personal observation). Thus, it appears that spawning females lacking suitable brooding sites may not move away from the spawning nests where a single male fertilizes several females. This suggests an overlapping of spawning and brooding sites for *O. niloticus* in L. Beseka. Therefore, since several females are fertilized by a single male; our samples may indicate sex ratio of the spawning population sampled from an overlapping sampling site (nests and brooding sites). However, further study comparing various types of sampling gears and sampling sites is necessary to validate the explanation suggested here.

Length of sexual maturity (females 12 cm, and males 14 cm) (Fig.10) for the fish in this study was smaller than values estimated for the same species in other lakes (Zenebe Tadesse, 1988; Demeke Admassu, 1994; Yirgaw Teferi, 1997). Those authors reported values of 18cm for the populations in Lakes Ziway and Awassa (Zenebe Tadesse, 1988; Demeke Admassu, 1994) and 39.5 cm for that in L. Chamo (Yirgaw Teferi, 1997). Length of maturity in many fish species depends on demographic condition and is determined by genes and the environment (Fryer and Iles, 1972; Lowe-McConnell, 1987). Generally, the fish in poor condition has been found to mature at smaller size than those in good condition (Lowe-McConnell, 1958; 1959; 1987). Thus, smaller maturity length of *O. niloticus* in L. Beseka than those in other lakes could be due to differences in body condition. This in turn might be a reflection of lower food quantity and poor food quality which needs further investigation.

In addition, scarcity of shore line vegetation in L. Beseka might contribute to poor body condition, which in turn reduce onset of sexual maturity. The lack of shore line vegetation denies the fish suitable shelter and feeding grounds (Fryer and Iles, 1972; Demeke Admassu, 1996). Macrophyte vegetation also provides habitat for organisms that are food for young tilapia (Tudorancea et al., 1988). The same explanation has also been given for the fish from other lakes (Harbot and Ogari, 1982; Stewart, 1988).

The study showed that females mature at relatively smaller length than the males (Fig. 10). The same was found for the species in Lakes Ziway (Zenebe Tadesse, 1988), Awassa (Demeke Admassu, 1994), and Chamo (Yirgaw Teferi, 1997). Since onset of sexual maturity is more costly in females than in males

(Lowe-McConnell, 1982; Demeke Admassu, 1989; 1994), 50% maturity length is likely to give smaller values for females. Age and growth estimation, which is another study required, could shed light on this and other results in the present study.

Gear specification: that is 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 catch fish less than 6 cm TL, the smallest size of sexual maturity.

Fecundity of *O. niloticus* in L. Beseka, which ranged from 110 to 235 eggs, was lower than the same species in other Ethiopian lakes. For instance, it ranges from 198 to 934 in L. Ziway (Zenebe Tadesse, 1988), 304 to 967 in L. Awassa (Demeke Admassu, 1994) and from 1047 to 4590 in L. Chamo (Yirgaw Teferi, 1997). Low fecundity of *O. niloticus* in L. Beseka could be due to its lower body condition and growth, which in turn is a reflection of less favorable biotic and abiotic factors. It is evident that fish in poor body condition would have less fecundity than those in better condition (Lowe-McConnell, 1959). The observed regression coefficient (1.5) between fecundity and total length can also be similarly explained. The coefficient for the same species is reported to be 2.39 in L. Ziway (Zenebe Tadesse, 1988), where as 2.16 in L. Awassa (Demeke

Admassu, 1994). This value for the mouth brooders is expected to be 2.0 in contrast with a value of 3.0 for substrate spawners (Jalabert and Zohar, 1982).

O. niloticus from L. Beseka having 81 g total weight had a fecundity of 235 eggs and the same fish from Lakes Ziway and Awassa, based on fecundity-total weight relationship equations provided by Zenebe Tadesse (1988) and Demeke Admassu (1994), was estimated to be 235 and 182 eggs, respectively. Thus, total weight rather than total length may be important in affecting fecundity.

The correlation between fecundity and gonad weight in this study was weak (0.67). This could be due to variation in egg size as reflected in fecundity. As pointed out by Zenebe Tadesse (1988), some individuals could have fewer but larger eggs while others could have high fecundity but small sized eggs. Egg size (diameter) of *O. niloticus* in this study ranged from 1.5 mm to 2.5 mm. The observed range in egg diameter is comparable to that reported for the species in Lake Chamo, 1.4 mm to 3 mm (Yirgaw Teferi, 1997). Interestingly, despite differences in body condition between these two populations being quiet large, their egg diameters are comparable. Apparently body condition and growth may affect fecundity but may not egg diameter. This needs further investigation, however.

Based on the results on GSI (Fig. 12) and frequency of ripe gonads (Fig. 13), *O. niloticus* in L. Beseka appear to breed intensively in March and April and August and September. However some individuals in breeding condition may be present at any time of the year. Samples were not taken in the months of January, June, July and October, 2004. Therefore, it is not possible to determine annual reproduction cycle of the fish with confidence. However, from studies on the species in other lakes (Demeke Admassu, 1994; 1996) it is possible to suggest a biannual reproduction cycle for the species in L. Beseka. Peak breeding periods of this species is also approximately concomitant with those of the species in Lakes Awassa (Demeke Admassu, 1994; 1996) and Ziway (Zenebe Tadesse, 1988; Demeke Admassu, 1998). The fish in Awassa, for instance, breeds intensively during January to March and less intensively during July to September (Demeke Admassu, 1996). However, intensive breeding of this species is during December to March in L. Ziway (Zenebe Tadesse, 1988), April to August in L. Chamo (Yirgaw Teferi, 1997) and during April to August (Peak in June - July) in L. Tana (Zenebe Tadesse, 1997). Stewart (1988) reported that *O. niloticus* in L. Turkana breed continuously, but has increased breeding activity during March to July.

Peak breeding activity of *O. niloticus* in L. Beseka was coincident with the onset of rainy season. The role of rainfall in timing reproduction is well documented (Fryer and Iles, 1972; Balarin and Hatton, 1979; Lowe-McConnell, 1982). Rainfall through associated biotic and abiotic factors acts as a cue for tilapia to breed intensively, so that, offspring is produced at times of better growth and survival (Lowe-McConnell, 1982). Thus, rainfall might have the same role in the breeding cycle of *O. niloticus* in L. Beseka as well. Run off, for instance, could increase nutrients resulting in increased food availability, and improved quality of food (Jalabert and Zohar, 1982; Zenebe Tadesse, 1988; Demeke Admassu, 1996).

Correlation between rainfall and peak spawning has also been reported for other tilapia populations in Ethiopia (Zenebe Tadesse, 1988; 1997; Demeke Admassu, 1994; 1996; Yirgaw Teferi, 1997) and elsewhere (Fryer and Iles, 1972; Jalabert and Zohar, 1982; Lowe-McConnell, 1982; Stewart, 1988). These authors have variously suggested the above mentioned role of rainfall in *O. niloticus* breeding. Demeke Admassu (1996), for instance, reported that peak breeding of the fish in L. Awassa is coincident with rainfall and associated increase in phytoplankton biomass. In addition the quality of the available food in the lake is believed to be improving during and immediately after the rains (Getachew Teferra, 1987). Furthermore; zooplankton biomass is likely to improve following those events. Seyoum Mengistou and Fernando (1991) also showed an increase in the zooplankton biomass of L. Awassa during the rainy season. Other workers on *O. niloticus* in Ethiopia have also given similar explanation for the correlation between rainfall and peak breeding. However, it is also notable that the correlation is not direct, because intensive breeding is associated with little rains, while less intensive breeding is associated with heavy (main) rains. This is one line of detailed investigation.

The presence of fish in breeding condition throughout the study period indicates some individuals could breed at any time of the year. This has been reported by others for the same species in other water bodies (Stewart 1988; Zenebe Tadesse, 1988; 1997; Demeke Admassu, 1994; 1996; Yirgaw Teferi, 1997)

6. Conclusions and Recommendations

The length-weight relationship of *O. niloticus* in L. Beseka was found to be TW = 0.0564 X $TL^{2.6}$. The value of b (2.6) is much lower than the cube and the fish has allometric growth.

The food of *O. niloticus* in L. Beseka is composed of a variety of food items. Diatoms, blue greens and green algae, animal remains of zooplankton origin macropohytes, amorphous detritus and sand grains were ingested by the fish. The blue greens, particularly *Microcysts* and the diatoms, *Navicula* were the most important algal genera that make up the bulk of the diet of the fish. Moreover, zooplankton were ingested by all size groups of the fish in all sampling occasion.

Fecundity was found to have linear relationship with total length, total weight, and gonad weight and the smallest sexually mature *O. niloticus* that was caught in this study was 6 cm TL for females and 10 cm for males.

In L. Beseka, *O. niloticus* breeds intensively in March and April and also in August and September with some breeding activity occurring throughout the year. Peak breeding activity of the fish was coincident with the onset of the rainy seasons.

Very little is known about Lake Beseka in general. Therefore, detailed studies and investigations are required on:

- The seasonal variation on phytoplankton and zooplankton composition of the lake,
- The physical and chemical limnology of the lake,
- The age and growth estimation of different fish species in the lake.

7. References

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