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MATURATION, SEX RATIO AND FECUNDITY OF THE NILE PERCH *LATES NILOTICUS* (L.) (PISCES: CENTROPOMIDAE) IN LAKE CHAMO, ETHIOPIA

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ABSTRACT: Length-weight relationship, length at first maturity and sex ratio of the Nile perch *Lates niloticus* (L.) were studied from 342 fish samples collected between February 1995 and May 1996. The relationship between total length (TL) and total weight (TW) for both sexes was curvilinear and statistically significant. The regression equation for the males was $TW=0.0044TL^{3.27}$ ($r^2=0.978$, $P<0.001$) and that for the females was $TW=0.0058TL^{3.2}$ ($r^2=0.991$, $P<0.001$). 50% maturity size of males and females were found to be 88 cm and 106 cm TL respectively. The overall male to female sex ratio of 1: 0.64 was significantly different from the theoretical 1:1 ratio ($\chi^2=16.0$, $P<0.001$). Generally males were more numerous at smaller size classes while females predominate at larger size classes. Forty-nine fish samples that ranged in length from 106.8 cm to 192 cm TL and in weight from 17,000 g to 108,000 g TW were used in fecundity estimates. The weight of ripe ovaries ranged from 325 g to 5,600 g with the mean weight of 934 g. Fecundity ranged between 1.24 million and 37.44 million eggs. The total and relative mean fecundity of *L. niloticus* was 6.35 million eggs female^{-1} and 162 eggs g^{-1} TW. The average number of eggs g^{-1} of ovary ranged from 6,200 to 9,300 with the mean number of 8,100. The relationships between fecundity and TL ($F=0.0034TL^{4.32}$, n=49, $P<0.01$) and fecundity and TW ($F=0.4357TW^{1.55}$, n=49, $P<0.01$) were curvilinear while the relationship between fecundity and ovary weight (OW) ($F=8{,}017OW-84{,}461$, n=49, $P<0.01$) was linear.

Key words/phrases: Fecundity, Lake Chamo, *Lates niloticus*, maturity, sex ratio

INTRODUCTION

L. niloticus is a very fecund fish and one of the few freshwater fishes to spawn pelagic eggs that are shed freely in the water column (Hopson, 1972). Despite this rare trait there have been few studies on the reproductive biology of the species. The fish is known for its sexual dimorphism where the females grow to larger sizes than the males in all areas for which data are available (Hopson, 1972; 1982; Acere, 1985; Ogutu-Ohwayo, 1988; Hughes, 1992). Sexual difference at the length of first maturity has been also documented and considered to be the result of sexual bimaturism (Wiley, 1974), the term used to indicate sexual differences in age at first reproduction (Hopson, 1972; Hughes, 1992). These authors assumed similar growth rates of both sexes (Hughes, 1992) and pointed out the low representation of males at larger sizes to be the result of higher mortality of males at older ages (Hopson, 1972; 1982). But recent study conducted concurrently with this on age and growth of *L. niloticus* in Lake Chamo (Yosef Tekle-Giorgis, 2002) indicates that females grow faster than males and at sexual maturity both sexes are of comparable age even though their sizes are much different.

Unequal sex ratios in different size classes were well documented where males dominate in smaller size classes and females dominate in larger size classes (Hopson, 1972; Hughes, 1992). Hopson (1972) associates this phenomenon to sexual segregation where the females tend to congregate near the spawning grounds away from the open water. But, Hughes (1992) proposed protandrous sex reversal, with a few fish maturing as primary females. *L. niloticus* has the smallest egg sizes so far reported for African fish species (Okedi, 1970; Ogutu-Ohwayo, 1988). After hatching the larvae (1.2–19 mm TL) are pelagic and feed on zooplankton until they move to the littoral regions and start feeding on insect larvae and fish fry (Hopson, 1972).

Some studies have been conducted on the reproductive biology of other fish species in Lake Chamo, such as *Bagrus docmak* (Forskål) (Hailu Anja, 1996), *O. niloticus* (Yirgaw Teferi *et al*., 2001) and *Labeo horie* (Heckel) (Elias Dadebo *et al*., 2003). But the reproductive biology of *L. niloticus* in Lake Chamo is unknown. The purpose of this study was therefore, to elucidate some aspects of reproductive biology, such as sex ratio, size at first maturity and fecundity of *L. niloticus* in Lake Chamo, where the species is indigenous and considered to be one of the most commercially important fishes. Since there is no previous study available on reproductive biology of this fish in Lake Chamo, the present study could provide the basic information needed for future management of the species.

MATERIALS AND METHODS

Study site

Lake Chamo (5°42′– 5°58′ N: Latitude and 37°27′–37°38′ E: Longitude) is the most southern of the Ethiopian Rift Valley lakes, with an area of 551 km^2 and a maximum depth of 16 m. It is located at an altitude of 1108 m and about 515 km south of the capital city Addis Ababa (Fig. 1c). The fish fauna of Lake Chamo, and also that of Lake Abaya, consists of Soudanian species (Beadle, 1981). The fish species are more diverse than those of the other Rift Valley lakes of the country, possibly due to the free passage of the Soudanian species from the Nile system via the interconnections of Lakes Turkana and Chew Bahir (Beadle, 1981).

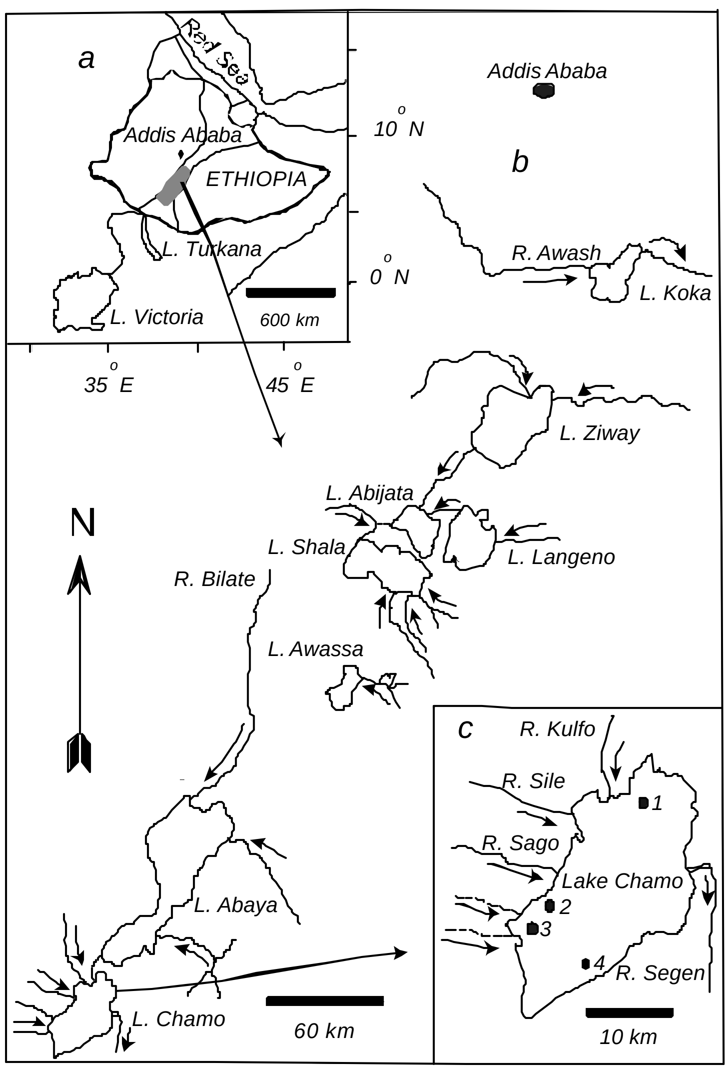

Fig. 1. Map of eastern Africa with the relative location of the Ethiopian Rift Valley lakes highlighted (a), the Ethiopia Rift Valley lakes and their drainage pattern (b) and Lake Chamo with the sampling stations indicated (c) (1- Deset, 2- Bedena, 3- Bole, 4- Suga).

The main effluents of the lake are Kulfo River that enter in at the north end of the lake, and Rivers Sile and Sago from the west (Fig. 1c). Lake Chamo is connected to Segen River by a broad channel, a river that rises from the northeastern corner of the lake. The morphometric, physical and chemical characteristics of Lake Chamo are given in Elizabeth Kebede (1996). Like many other African freshwater lakes, the dominant cation is sodium and the dominant anions are bicarbonate and carbonate (Elizabeth Kebede *et al*., 1994). The surrounding region receives two rainy seasons per year, March - May (long rains) and September-October (short rains). The mean annual rainfall of the area is about 1,000 mm (Daniel Gamachu, 1977).

Diatoms and blue-greens dominate the phyto-plankton community of the lake (Elizabeth Kebede, 1996). Dominant zooplankton groups include *Thermocyclops*, *Mesocyclops* and *Moina* (Seyoum Mengistou, personal communication). There are more than 20 fish species in Lake Chamo and the inflowing rivers (Getachew Teferra, 1993). The commercially important species are *Oreochromis niloticus* (L.), *L. horie* (Heckel), *B. docmak* (Forskål) and *Clarias gariepinus* (Burchell). Capture of *L. niloticus* has been banned as a result of sharp decline of the stock due to over-fishing.

Sampling

Samples of *L. niloticus* were obtained from the commercial landings between February 1995 and May 1996. The commercial gill nets used for *L. niloticus* fishery are polyfilament nets of 28, 32, 36, 40 and 44 cm stretched mesh size. Fishermen usually set their gill nets late in the afternoon and lift them the following morning. Smaller specimens were obtained from commercial gill nets that were set to capture *O. niloticus* and *L. horie* (14–18 cm stretched mesh size). Total length and total weight of fish were taken immediately after capture using a measuring board and Salter Model 235 6S balance respectively. All fish were measured to the nearest centimetre. Fish under 1,000 g were weighed to the nearest 5 g, fish between 1,000 and 5,000 g were weighed to the nearest 25 g, and fish over 5,000 g were weighed to the nearest 100 g. After dissection the sex and maturity stage of each fish were determined following Holden and Raitt (1974) by categorizing fish as immature (I), recovering spent or developing virgin (II), ripening (III), ripe (IV) and spent (V). Ripe ovaries were removed and weighed to the nearest 1 g and preserved in 4% formalin solution.

Length-weight relationship

We calculated the length-weight relationship using the following formula:

$$TW = a\,TL^{b} \quad (1)$$

where

TW is total weight in g,

TL is total length in cm, and

a and *b* are intercept and slope of the length-weight regression equation, respectively.

Length at first maturity

The percentages of male and female *L. niloticus*, having gonad stages three, four and five in different length groups, were plotted against length for each sex. The size at which 50% of the fish were mature (L_{m50}) was determined from the relationship between the percentages of mature fish (P) of length class (L), and coefficients (V1 and V2) as described by the logistic function below (Echeverria, 1987):

$$P = e^{(V1 + V2)} / (1 + e^{V1 + V2L}) \quad (2)$$

and the value of L_{m50} can be estimated from the expression:

$$L_{m50} = -V_1 / V_2 \quad (3)$$

Fish collected during the spawning season (*i.e.*, March-June 1995) were used to estimate L_{m50}. The proportion of mature fish for each 5-cm length class was calculated for both males and females and V_1 and V_2 were estimated using Marquardt's (1963) algorithm for non-linear least squares regression.

Sex ratio

A chi-square test was used to determine if the sex ratios varied between different size classes (Sokal and Rohlf, 1995).

Fecundity

We estimated total fecundity by weighing all the eggs in the ovaries and counting three sub-samples of 0.25 g of eggs from various parts of the ovaries. The average number of eggs g^1 of preserved wet weight of the ovary was calculated, and multiplied by the total weight of each ovary giving the total number of eggs ovary $^{-1}$ (Snyder, 1983). The relative fecundity was calculated by dividing the number of eggs $fish^{-1}$ by its body weight. The relationship between fecundity (F) and some morphometric measurements such as total length in cm (TL), total weight in g (TW) and ovary weight in g (OW) were determined. The relationship between F and TL and between F and TW were of the form:

$$F=aX^b \qquad (4)$$

where

a is the proportionality constant and
b is the exponent.

RESULTS AND DISCUSSION

Length-weight relationship

Length-weight relationship of *L. niloticus* in Lake Chamo was curvilinear and statistically significant (r^2=0.98, P<0.001) (Fig. 2). The regression equation for the males (n=208) was $TW=0.0044TL^{3.27}$, r^2=0.978 and that for the females (n=142) was $TW=0.0058TL^{3.2}$, r^2=0.991.

The length-weight regression coefficients for males (b= 3.27) and females (b=3.2) indicate considerable allometric growth pattern. Males were heavier and also much older than females of the same length. Length-weight regression coefficients in Lake Chad (b = 3.00), Lake Victoria (b = 3.01) and Lake Turkana (b = 3.13) were close to the cube indicating isometric growth pattern (Gee, 1969; Hopson, 1972; 1982). On the other hand Hughes (1992) reported allometric growth pattern for *L. niloticus* in Lake Victoria (b = 3.44). It is evident that high quality and quantity of food has a direct effect on the condition of fish and thus increases the length-weight regression coefficient (Getachew Teferra, 1993; Zenebe Tadesse *et al.*, 1998).

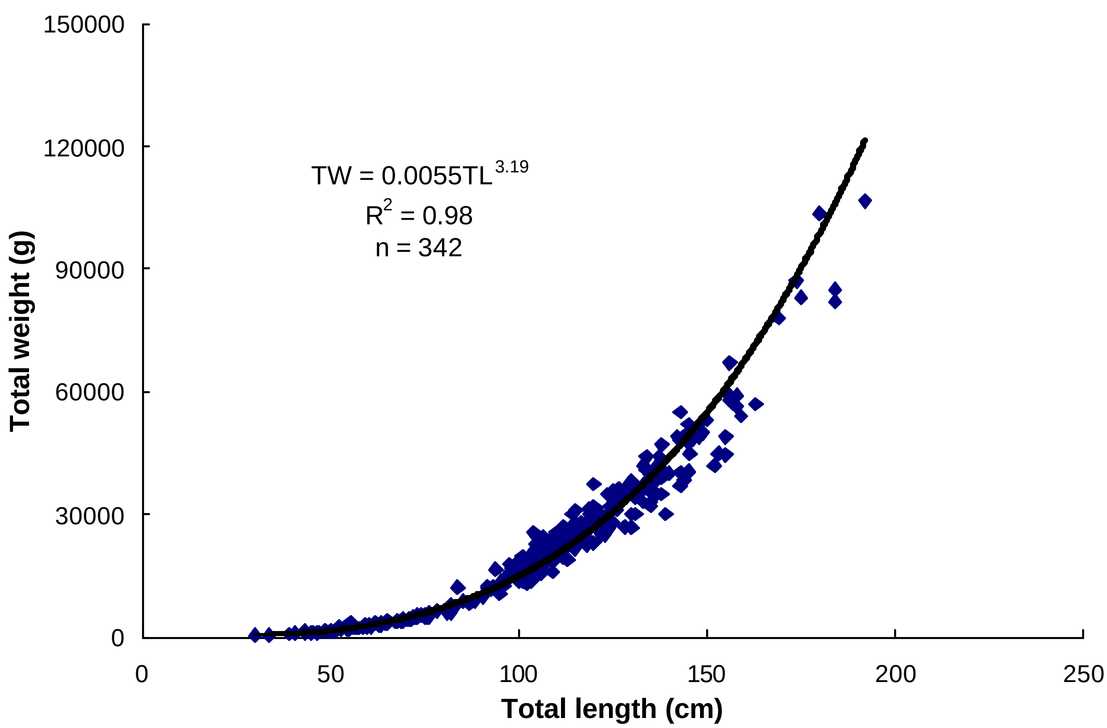

Fig. 2. Length-weight relationship of *L. niloticus* in Lake Chamo.

Length at first maturity

The length at first maturity (L_{m50}) of both male and female *L. niloticus* (Fig. 3) were estimated to be about 88 cm and 106 cm, respectively. The results indicate that males mature at a smaller size than the females. The smallest male found with ripe gonads was 81.8 cm and weighed 7,800 g while the smallest female with ripe gonads was 98.5 cm and weighed 15,600 g.

Sexual growth dimorphism exists in *L. niloticus* where females grow faster than the males (Yosef Tekle-Giorgis, 2002). As a result adult female *L. niloticus* are larger than conspecific males of the same age in the population. In the present study differences at the size of first maturity was large between males and females (Fig. 3). Due to this fact the management practice used in Lake Chamo should consider the L_{m50} of both sexes in order to decide the minimum size of fish allowed in *L. niloticus* fishery. Previous studies have also indicated differences in growth rates between sexes (Hopson, 1972; 1982; Acere, 1985; Hughes, 1992) and pointed out sexual differences in size at first reproduction (Wiley, 1974), where males start reproduction at an earlier age than females (Hopson, 1972; Hughes, 1986). However, recent studies on the age and growth of *L. niloticus*, using otoliths macrostructure analysis, revealed that both sexes start reproduction at similar ages but females attain larger size than the males (Yosef Tekle-Giorgis, 2002).

Sex ratio

From the total number of 342 fish sampled 208 (60.8%) were males while 134 (38.2%) were females. Except the size class 50– 69.9 cm TL, there was no significant variation in sex ratios of smaller fish <90 cm TL (Table 1). Males were more numerous in fish between 90 cm and 130 cm TL. More females were caught in larger fish >130 cm TL (Table 1). The size of males caught ranged from 33.6 cm to 163 cm TL and weighed between 460 g and 59,000 g. The size of females caught ranged from 30 cm to 192 cm TL and weighed between 350 g and 108,000 g. Generally females are larger than males. The largest female weighed nearly twice the weight of the largest male.

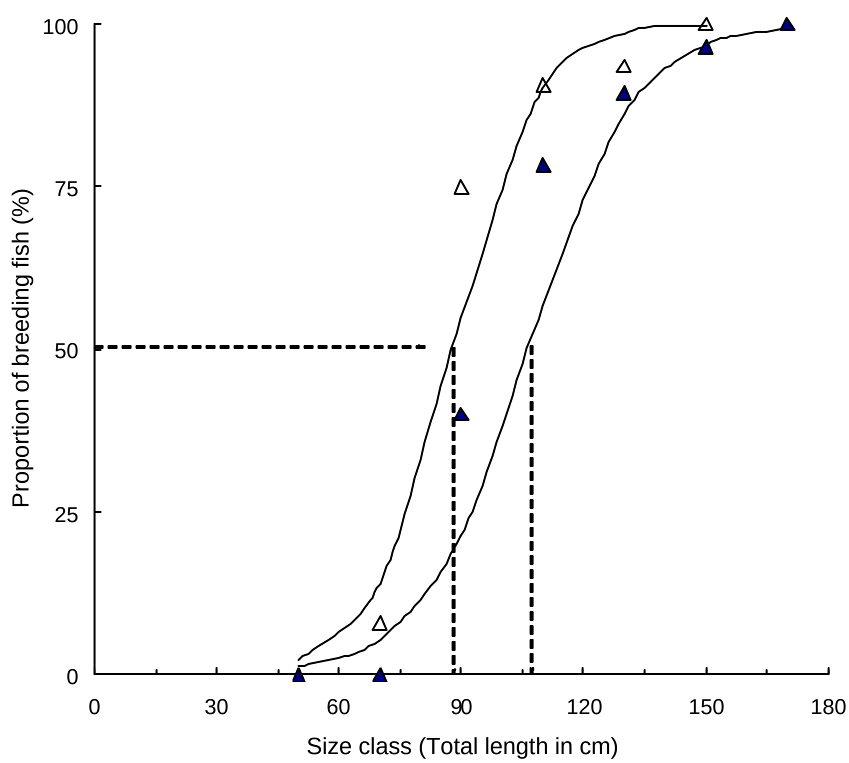

Fig. 3. Length at first maturity of *L. niloticus* obtained by determining the average length at which 50% of the fish of both sexes reach maturity (? - males, ? - females).

Table 1. Number of males and females and the corresponding sex ratios in samples of *L. niloticus* in Lake Chamo. Samples were grouped in 20-cm size classes.

Length (cm)	Males	Females	Sex-ratio (male: female)	Chi-square
30.0– 49.9	6	8	1:1.33	0.25
50.0– 69.9	28	17	1:0.61	5.38*
70.0– 89.9	15	18	1:1.2	0.27
90.0–109.9	84	5	1:0.06	70.0***
110.0–129.9	61	30	1:0.49	10.56**
130.0–149.9	11	39	1:3.55	15.68**
150.0–169.9	3	11	1:3.67	4.57*
170.0–189.9	-	5	-	–
>190.0	-	1	-	–
Total	208	134	1:0.64	16.01**

*- significant, (P < 0.05), **- highly significant, (P < 0.01), ***- very highly significant, (P < 0.001).

The overall sex ratio of *L. niloticus* in Lake Chamo was significantly different from the theoretical 1:1 value (x^2 = 16.0, P < 0.001). A preponderance of males over females was evident at size classes between 90 and 130 cm whereas more females were caught in larger fish over 130 cm TL. Variations in sex ratios have been attributed to segregation of the sexes at different habitats (Hopson, 1972; 1982). Although sexual segregation was not observed in *L. niloticus* during the present study, this phenomenon was observed in the tiger fish (*Hydrocynus forskahlii* Cuvier), another piscivorous fish, in Lake Chamo. From March to June 1995 more females were caught (male: female; 1:45) in shallow areas of the lake whereas males predominantly made up the catch early August with a sex ratio of 1:10 (female: male) was recorded (Elias Dadebo, 2002).

A tendency of one sex preceding the other in moving to breeding grounds has been well documented in other fish species (Morgan and Gerlach, 1950; Lowe McConnell, 1958). Mansueti (1961) reported that the white perch *Morone americanus* (Gmel.) preceded females to the spawning grounds in the Patuxent River, Maryland. As a result during the early migration to the breeding grounds males outnumbered females, but sampling in the estuary downstream almost simultaneously revealed that females were more abundant than the males. Hughes (1986) associates low number of females at lower size classes in Lake Victoria possibly due to protandrous hermaphroditism. This has to be, however, supported by direct evidence where developmental stages of oocytes are found within testicular tissues (Nolan *et al.*, 2001). Population structure alone can not indicate sex change, because many other biological mechanisms such as differential growth or maturity rates, differential mortality rates, or differential migratory patterns between males and females may cause unequal sex ratios at different size classes (Sandovy and Shapiro, 1987; Matsuyama *et al.*, 1988).

Fecundity

The weight of ripe ovaries ranged from 325 to 5,600 g with the mean weight of 934 g. Fecundity varied from 1.24 million eggs to 37.44 million eggs. The total and relative mean fecundity of *L. niloticus* was 6.35 million eggs female^{-1} and 162 eggs g^{1} of body weight respectively. The average number of eggs g^{1} of ovary ranged from 6,200 to 9,300 with the mean value of 8,100 eggs g^{-1}.

The relationship between F and TL (Fig. 4a), F and TW (Fig. 4b) and F and OW (Fig. 4c) were all positive and statistically significant. The best-fit equations to the relationships respectively were:

$$F=0.0034TL^{4.322}, r^2=0.779, n=49, P<0.01 \quad (5)$$

$$F=0.4357TW^{1.546}, r^2=0.845, n=49, P<0.01 \quad (6)$$

$$F=8017ow-84461, r^2=0.987, n=49, P<0.01 \quad (7)$$

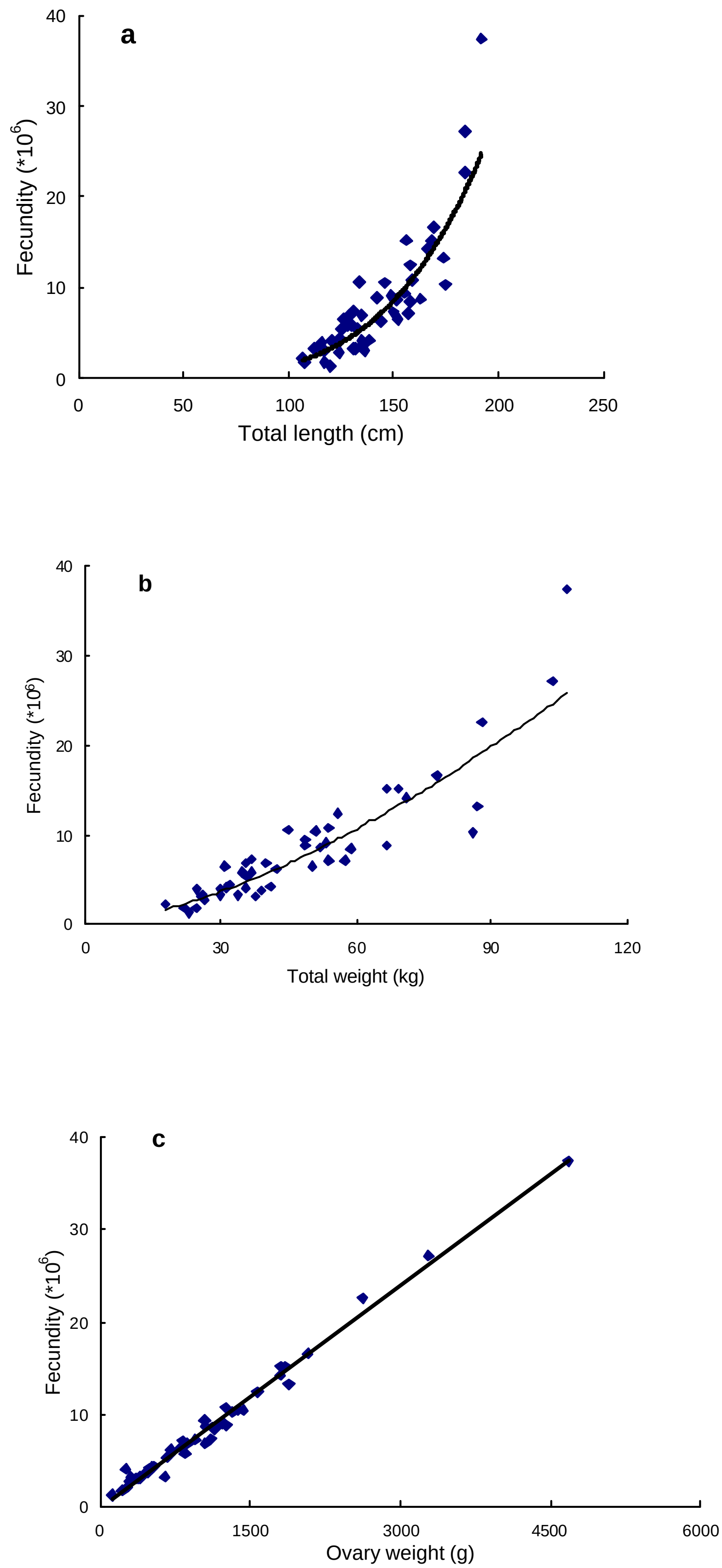

Fig. 4a, b and c. Relationship between fecundity and total length (a), fecundity and total weight (b) and fecundity and ovary weight (c) of *L. niloticus* in Lake Chamo.

Fecundity of *L. niloticus* in Lake Chamo increased in proportion to 4.32 power of length. Wootton (1979) estimated fecundity of 62 different species and reported *b* values between 1 and 5, most values ranging between 3.25 and 3.75. Fecundity values estimated in this study were higher for larger fish and lower for smaller ones compared to the values reported by Ogutu-Ohwayo (1988). Since Ogutu-Ohwayo (1988) used standard length (SL) for his estimate, empirical formula relating the two types of measurements (TL = 1.12SL+4) was used for comparative purposes. Taking into consideration the large size at first maturity of Lake Chamo females (106 cm), it is expected that fecundity will be low at the low end, in comparison with the fecundity of Lake Kyoga females that mature at relatively smaller size (96 cm) (Table 2). Fish of the same size could be first-time spawners in Lake Chamo, while they could be repeat spawners in Lake Kyoga. First-time spawners normally produce less number of eggs than repeat spawners in fish (Wootton, 1998).

Table 2. Length at first maturity of *L. niloticus* in different lakes of Africa. The lengths marked with asterisks are the ones that have been converted using the equation TL = 1.12 SL+4.

Water body	Males (TL, cm)	Females (TL, cm)	Reference
Lake Albert	60*	85*	Holden (1963)
Lake Chad	50	62.5	Hopson (1972)
Lake Turkana	65	90	Hopson (1982)
Lake Victoria	54	68	Acere (1985)
Lake Kyoga	50*	96*	Ogutu-Ohwayo (1988)
Lake Chamo	88	106	Present study

Differences in fecundity among studies might result from differences in techniques used or factors such as geographical location; temperature and feeding regimes have also been reported (Barbin and McCleave, 1997). Difference in the productivity level of water bodies may also produce variation in size at first maturity and fecundity (Barbin and McCleave, 1997).

The values of exponents when fecundity was related to length and weight of *L. niloticus* in the present study were comparable to values reported for temperate marine fish species (De Silva, 1973; Wootton, 1979; Gibson and Ezzi, 1980). The total number of eggs (about 37 million eggs) produced female^{-1} was also the highest so far reported for *L. niloticus*. High productivity of the lake (108 μg l^{-1} Chl *a*, Ahlgren and Ahlgren, personal communication), that result in high density of prey fish, and high temperature of the area could be the main reasons for larger size of *L. niloticus* and thereby higher total number of eggs produced female^{-1}.

In conclusion, length-weight relationships of both sexes of *L. niloticus* were positively related and statistically significant. The species exhibited sexual growth dimorphism where adult females were much larger than conspecific males of the same age in the population. Because of this sexual growth dimorphism, L_{m50} of females was larger than males. A preponderance of male was evident at smaller size classes whereas the proportion of females was high at larger size classes. Various factors could be responsible for variations in sex ratios at different size classes, such as differential growth or maturity rates, differential mortality rates, or differential migratory patterns between the sexes. The total and relative mean fecundity of *L. niloticus* in Lake Chamo were among the highest so far reported for the species. High productivity of the water that results in high prey availability, and high temperature of the area could be the main reasons for larger size of the fish and thus higher fecundity.

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