Reproductive Biology of Nile Tilapia (*Oreochromis niloticus)* in Lake Chamo, Ethiopia

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Abstract: *The objectives of the study were to determine the breeding season, fecundity rate, size at first maturity and sex ratio of O. niloticus in Lake Chamo. Data (total length (TL), total weight (TW), sex, maturity stages and number of eggs) were collected. A total of 1,245 samples (968 females and 277 males) were collected during the sampling period (December 2019 to November 2020). The collected data were summarized using descriptive statistics (percentage, graphs, tables) and analyzed with the application of Microsoft Excel 2010 and Sigma plot 13.0 Software. There was significant deviation in sex ratio (Females: Males) from hypothetical 1:1 ratio (χ^2 = 393.0; $p<0.05$). The mean fecundity was 1,138 eggs/ fish and it was positively correlated with TL and TW. The size at first sexual maturity (TL_{50}) was 23.4 and 22.0 cm for females and males respectively. The O. niloticus in Lake Chamo breeds throughout the year. The peak breeding season was observed from March to May and August to November. It is recommendable to reduce commercial fishing of O. niloticus during the peak breeding seasons in order to minimize the capture of breeding fish. The size at first maturity in the present study for both sexes was 23.6 cm which is too smaller than the earlier study (39.6 cm). This might be due to heavy fishing together with illegal fishing activities, fishing during the breeding season, breeding ground destruction by buffer zone agricultural practices around the lake. Therefore, appropriate fishery management tools such as closing season during peak breeding, buffer zone conservation and mesh size regulation should be implemented for sustainable fishery utilization in Lake Chamo.*

Keywords: Breeding season, fecundity, length at first maturity, sex ratio, total length, total weight

1. Introduction

Tilapia (Family Cichlidae) is 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 and Ruwet, 1982). Among Tilapia, *Oreochromis niloticus* is more widely distributed in Africa than in any other tropical region (Balarin and Hatton, 1979). 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 (Ted1a, 1973).

The study of reproduction is one of the major aspects in the study of fish biology (Khallaf and Authman, 1991). Description of reproductive strategies and the assessment of fecundity are fundamental topics in the study of biology and population dynamics of fish species and also for evaluation of the reproductive potential of individual fish species (Shalloof and Salama, 2008; Costache *et al*., 2011). Of course, this will increase our knowledge about the state of a stock and improves standard assessments of many commercially valuable fish species (Hunter *et al*., 1992; Murua *et al*., 2003). Moreover, the availability of data based on reproductive parameters and environmental variations could lead to a better understanding of observed fluctuations in reproductive output and enhances our ability to estimate recruitment (Kraus *et al*., 2002). Information on the breeding and fecundity of *O. niloticus* can provide basic knowledge for the proper management of the resource (Nikolskii, 1980).

Reproductive biology of *O. niloticus* in Lake Chamo appears to have higher growth and better condition than the same species in the other Ethiopian rift valley lakes. In Lake Chamo, the smallest size of mature fish for both sexes was 39 cm TL and TL_{50} was 42 cm. The fecundity of *O.*

niloticus in Lake Chamo is high and enables the fish to produce in the lake rapidly (Teferi, 1997).

According to Shishitu *et al*., (2019), a large numbers of *O. niloticus* were being removed before they grow and replace their populations. Out of the total estimated annual catch, over 95% of *O. niloticus* catch ranged in length between 19 to 41 cm and more importantly, the length groups' 25 to 37 cm total length composed about 63% of the total catch.

When fish is under heavy fishing pressure, the length at first maturity (TL_{50}) becomes smaller and also the reproductive biology may vary based on the situation. So, in order to manage the fish resource properly, study on reproductive biology is crucial. The present study was aimed to provide information on sex ratio, maturity stages, fecundity and breeding season of *O. niloticus* in Lake Chamo. These details are needed for the establishment of *O. niloticus* production potential and recruitment which will enhance better rational exploitation, planning and management procedures.

2. Materials and Methods

2.1. Description of the study area

Lake Chamo is geographically located at 5°42′– 5°58′ N Latitude and 37°27′– 37°38′ E Longitude and it is one of Ethiopian Rift Valley lakes with an area of 551 km^2 and a maximum depth of 16 m (Belay and Wood, 1982). The lake is located at an altitude of 1108 m and about 515 km south of the capital city Addis Ababa (Dadebo *et al*., 2005).

Lake Chamo is part of the Ethiopian Rift Valley Lakes Basin (ERVLB) in the Abaya–Chamo drainage sub-basin (ACB). The ERVLB comprises eight natural lakes and their tributaries. The ACB comprises Lake Chamo and Lake Abaya, and rivers and streams entering the lakes. The two lakes are connected via surface hydrology. Outflow from Lake Abaya enter Lake Chamo through River Kulfo, and an overflow from Lake Chamo through Metenafesha joins Sermale River in Amaro Woreda (Bekele, 2006). Earlier studies stated that, Lake Chamo has a surface area of 551 km^2 and a maximum depth of 16m (Belay and Wood, 1982). However, according to Bekele (2006), the surface area of the lake declined to about 335 km^2. The high rate of evaporation of water and the diversion of the feeder river, Kulfo, for agricultural activities are the reasons for the decline in the surface area of the lake (Kebede, 1996).

The fishery on Lake Chamo is almost exclusively conducted with a surface gillnet, although long–lines are also used to some extent to African catfish (*Clarias gariepinus*) and *Bagrus docmak*. The nets are prepared locally by fishers themselves or by some other people involved in fishing gear making activity. Also a monofilament gillnet is obtained commercially from abroad illegally which is dangerous and causes recruitment overfishing. The gill nets are the most important fishing gears and are typically set in the afternoon and hauled early in the morning. They are removed only to change the fishing ground or when maintenance is necessary.

2.2. Methods of sampling and data collection

Samples from the commercial catch at Lake Chamo were taken from two randomly selected landing sites at monthly periods from December 2018 to November 2019. The fish were caught by gillnetting. Immediately after capture, total length (TL) and total weight (TW) of each specimen were measured to the nearest 0.1 cm and 0.1 g, respectively. Each fish specimen was opened ventrally from the anus to the pectoral fin and its sex and stage of gonadal maturation determined visually (Roberts, 1989). All gonads were removed, weighed and gonadal stages noted (Hyndes *et al.*, 1992). The ovaries collected from each fish specimen were preserved separately in modified Gilson's fluid (Simpson, 1951; Barbieri, 1989). The preserved ovaries were periodically shaken to ensure the separation of eggs from ovarian tissues and all the eggs in each pair of ovaries were determined by direct counting. Then, the average number of eggs g^{-1} of the 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). A chi square test was employed to determine if the sex ratio varies between male and female *O. niloticus*.

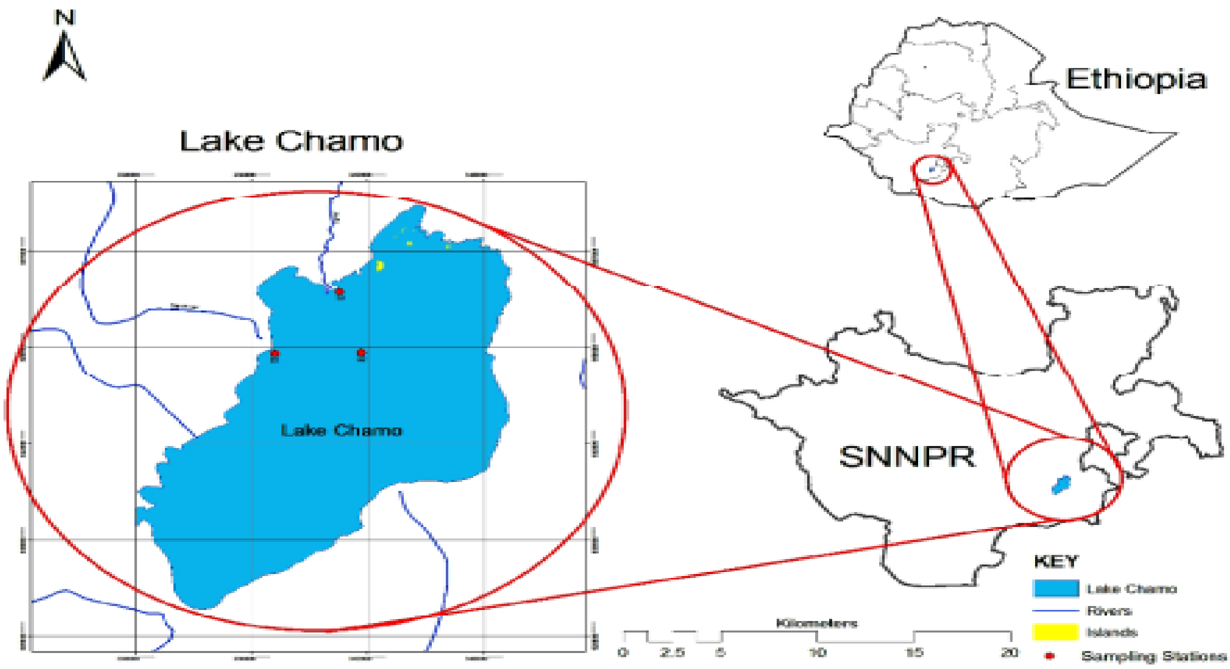

Figure 1: Location of Lake Chamo, Southern Ethiopia (Utaile and Sulaiman, 2016)

3. Results and Discussion

3.1. Sex ratio and length at first maturity

3.1.1. Sex ratio

Totally 1,245 *O. niloticus* fish samples, ranged from 20 to 38.5 cm in total length, and 132 to 1,056 g in body weight were collected. Among these sampled fishes, 968 were females (77.75 %) and 277 (22.25%) were males. Females were more numerous throughout the year (Table 1). The sex ratio was 1:3.49 (Males: Females) and it significantly differs from the hypothetical 1:1 sex ratio ($\chi^2 = 393.0$; $p < 0.05$).

Contrarily of this result, it was pointed out that water bodies in African, are commonly dominated by male populations because they generally present more growth than females without this representing a risk situation for fishery (Fryer and Iles, 1972; Offem *et al*., 2007, 2009). The sex disparity could be a result of the differential survival to certain environmental conditions and is described as a mechanism for regulation in fishes. Females could possibly emigrate from spawning areas towards feeding grounds located where they are caught. 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 Admassu (1994) in Lake Hawassa and by Teferi (1997) in Lake Chamo for the same species.

Table 1: The number of males, females, the total number and sex ratio in monthly samples of *O. niloticus* caught from Lake Chamo. The last column shows chi-square values, significant at 95% CI, ($p<0.05$)

Months	Male	Female	Total No. fish	Sex ratio (M: F)	chi-square (x^2)
December	15	38	53	1:2.53	10.0
January	18	54	72	1:3	18.0
February	28	99	127	1:3.53	39.7
March	12	85	97	1:7	54.9
April	16	83	99	1:5.19	45.3
May	21	93	114	1:4.43	45.5
June	22	85	107	1:3.86	37.1
July	22	72	94	1:3.27	26.6
August	26	68	94	1:2.62	18.8
September	37	109	146	1:2.95	35.5
October	31	90	121	1:2.9	28.8
November	29	92	121	1:3.17	32.8
Total	277	968	121	1:3.49	393.0

3.1.2. Length at first maturity

The relation between body length and gonadal development was examined in 620 fish samples randomly selected from the commercial catches. The smallest mature female and male fish was 14.5 cm and 17.0 cm long in TL, respectively. While, the smallest ripe female and male was 14.5 cm and 17.5 cm long in total length, respectively. Using logistic curve fitted values (Fig. 2), the estimated mean lengths at sexual maturity (TL_{50}) were 23.6 cm, 23.4 cm and 22.0 cm for combined sex (A), females (B) and males (C), respectively. It appears that males attain maturity earlier in life with a size of around 1.4 cm smaller than females.

The 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). The smallest size of mature fish for both sexes was 39 cm TL and the length at first maturity (TL_{50}) was found to be 41.5 cm TL for females and 42.5 cm TL for males of *O. niloticus* in Lake Chamo (Teferi, 1997).

The length at first maturity (TL_{50}) in the present study was higher than that of Lake Hayq 12.8 for females and 12.9 for males (Tessema *et al*., 2019), Tekeze Reservoir 15 for females and 14 cm for males (Teame *et al*. (2018), Lake Langano 16.4 for females and 15.8 for males (Temesgen *et al*., 2018) and Lake Hawassa 20.8 for females and 20.3 for males (Muluye *et al*., 2016). The length at first maturity (TL_{50}) in this finding was lower than the estimated value of the previous study in Lake Chamo (42 cm for both sexes) as indicated by Teferi and Admasu, (2002).

Overfishing can alter population structure, impair growth and earlier maturation depended on the selectivity of the fishery, (Jorgensen *et al*., 2007). Illegal fishing activities, utilization of a greater number of narrow mesh size gillnets lower TL_{50} values in lakes as reported for Lake Victoria in Kenya, (Yongo *et al*., 2018). Fishing pressure or fishing intensity is one of the major factors for early maturation and stunt growth in *O. niloticus*. Because, they allocate more resources for reproduction than somatic bodybuilding in water bodies where there is fishing pressure (Bandara and Amarasinghe, 2018). According to Shishitu *et al*., (2019), *O. niloticus* of Lake Chamo is experiencing growth overfishing due to the application of reduced mesh size gillnets (<11 cm, below the recommended). The lower TL_{50} values reported in the present study in Lake Chamo might be associated mainly with illegal fishing activities, fishing during breeding season, and buffer zone agricultural activities that have been practiced around the lake.

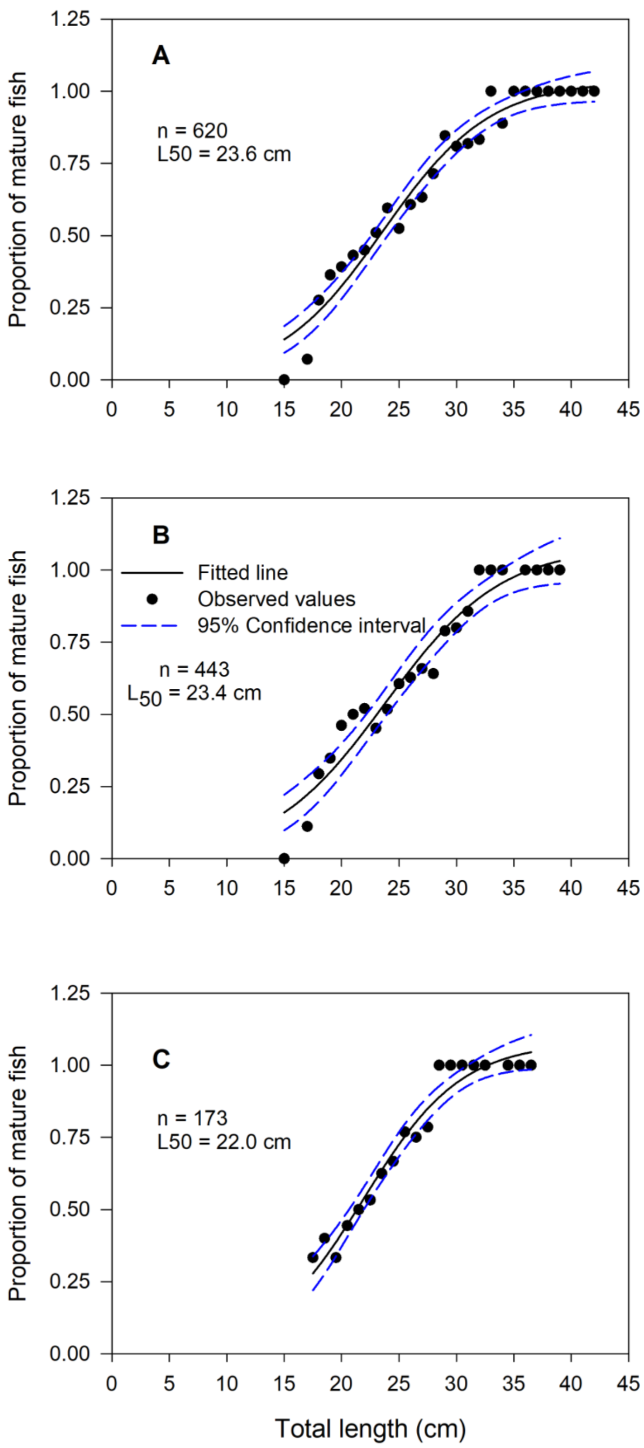

Figure 2: The proportion of size at first maturity (TL_{50}) of combined sex (A), females (B) and males (C) of *O. niloticus* in Lake Chamo

3.2. Breeding Season and Fecundity Estimation

3.2.1. Maturity stages

Samples of *O. niloticlis* were caught at various stages of gonad development and reproduces in almost all months. However, their frequency varied with the month fish were caught. The percentage of each gonadal development stage is illustrated in Fig. 3. According to the female's gonadic maturation stages, 12.3% of the total fish were immature (stage I), 15.91% were maturing (stage II), 20.87% were mature (stage III), 31.82% were ripe (stage IV) and 19.11% were spent (stage V). Therefore, 52.69% of the female fish were in the reproductive process. In the case of males, 17.22% of the total fishes were immature (stage I), 20.51% were maturing (stage II), 21.98% were mature (stage III), 28.94% were ripe (stage IV) and 12.45% were spent (stage V). Therefore, 50.92% of the male fishes were in the reproductive process. In general, 50.92-52.69% of *O. niloticus* in Lake Chamo were in the reproductive process.

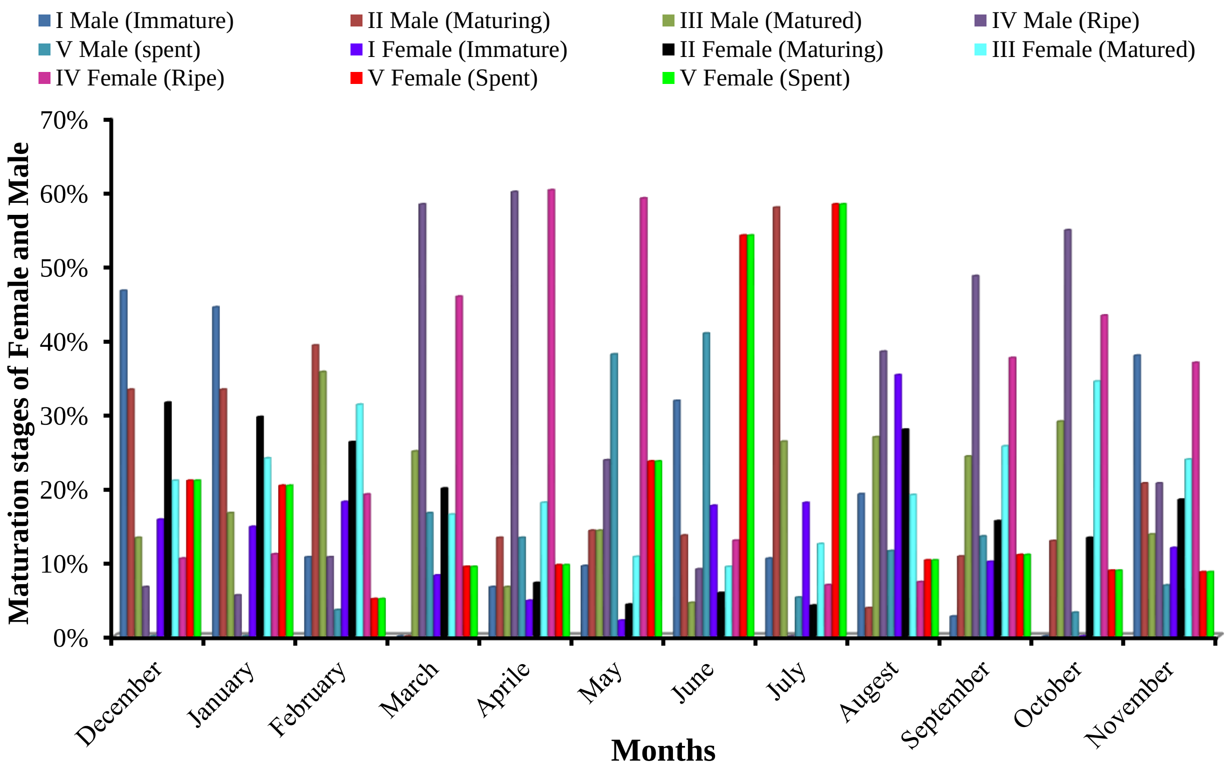

Figure 3: Seasonal variation of maturity stages for male and female *O. niloticus* in Lake Chamo

3.2.2. Breeding season

The frequency of temporal variation between ripe males and females and the pattern of gonad development for both sexes was almost similar (Fig. 4). The frequency was found high from March to May and from August to November. Ripe males occurred at high frequencies ranged 20.69 - 60% during March, April, May, August, September, October and November whereas females occurred in March, April, May, September, October and November which ranged from 36.96 - 60%. The low frequency of ripe fish of both sexes was recorded in December to February and June to July. Mature ovaries were available all year round and this is an indication that the fish breeds throughout the year. Based on the result of this study, it is evident that *O. niloticus* in Lake Chamo breeds throughout the year with peak breeding activity in March to May and August to November.

In Lake Ziway, *O. niloticus* was found to breed throughout the year, but more intensively between December and March (Tadesse, 1988), whereas in Lake Hawassa it breeds twice a year, i.e., January to March and August to October (Admassu, 1994). *O. niloticus* in Lake Turkana breeds continuously but has an increased breeding activity from March to July (Stewart, 1988). The principal breeding season for most species of tilapia in Lake Victoria is at high water levels from January to March (Lowe-McConnell, 1987). The *O. niloticus* in Lake Chamo breeds intensively from March to June with some breeding activity occurring in other months (Teferi, 1997). But, the present study showed two intensives (peak) breeding seasons which includes March to May and August to November. The peak breeding season variation with the earlier study might be due to climate change and other factors.

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 photoperiod are the most important factors associated with the timing of fish breeding in waters at higher latitudes (Billard and Breton, 1978). In tropical waters, the 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). The abundance of food has also been considered as an important clue for the timing of breeding in some fish at low latitudes (McKaye, 1977).

Although environmental factors such as photoperiod and temperature do not vary much in Ethiopian lakes, there are annual peaks of reproduction activity for *O. niloticus* in most lakes (Teferra, 1987; Tadesse, 1988; Admassu, 1989; 1994). The main breeding time in most cases corresponds with the onset of the rainy season. In the current investigation, the occurrence of intensive breeding activity during March to May indicated the relation with the increase of solar radiation and sunshine that activates phytoplankton production while August to November was linked to heavy rainfall. Thus, in Lake Chamo, the reproduction of *O. niloticus* is higher during the rainy and sunny season than the rest of the year.

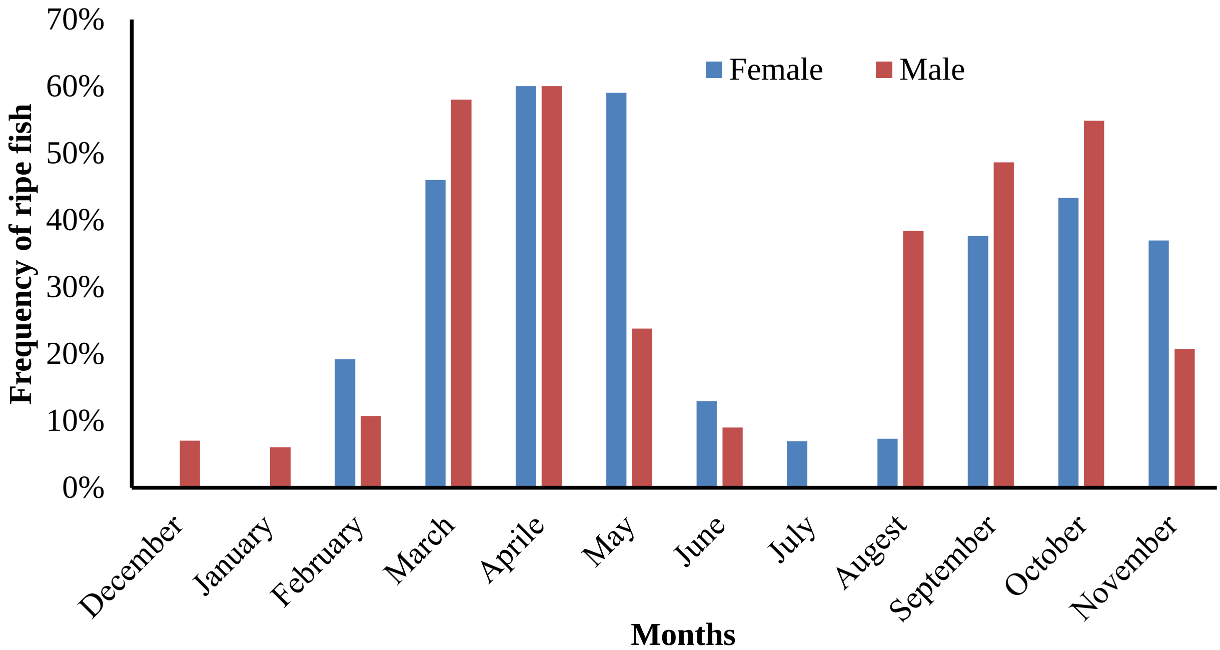

Figure 4: Temporal variation in frequency (%) of ripe female and male *O. niloticus* in Lake Chamo

3.2.3. Fecundity estimation

Fecundity of *O. niloticus* in Lake Chamo varied from 325 to 1,764 eggs for females whose length was between 20 and 30 cm and weight was between 132 and 464 g with mean fecundity of 1,138 eggs. Fecundity was curvilinearly related to total length (Fig. 5) and linearly related to the total weight (Fig. 6). The correlation between fecundity and body length was smaller ($r = 0.83$, $p < 0.05$) than the fecundity-body weight correlation ($r = 0.94$, $p < 0.05$).

In the earlier study, the fecundity of *O. niloticus* in Lake Chamo was ranged from 1,047 to 4,590 eggs (Teferi, 1997). For the same species from Lakes Ziway (Tadesse, 1988) and Hawassa, (Admassu, 1994) estimated values ranging from 198 to 934 and from 304 to 967 eggs, respectively. The fecundity of *O. niloticus* in the present study is smaller than the earlier study in Lake Chamo but is more fecund than in Lakes Hawassa and Ziway. Because *O. niloticus* in Lake Chamo matures at bigger sizes than in Lakes Hawassa and Ziway, they produce a larger number of eggs and broods. The highest number recorded in the ripe ovaries of mouth brooding *Tilapia aurea* from Lake Tiberias is 4,300 (Fryer and Iles, 1972). In *Tilapia galilaea*, females have been found to contain as many as 5,010 eggs (Ben - Tuvia, 1960). As was indicated in the result of this study, *O. niloticus* showed high fecundity and may enable the fish to reproduce in the lake rapidly than Lakes Hawassa and Ziway.

Fecundity of *O. niloticus* in Lake Chamo was related to the cube (b = 3.01) of their length (Fig. 5). This is a similar relationship with substrate spawners where fecundity is related to the cubic of their length (Simpson, 1951; Lowe-McConnell, 1959). It was mentioned that in mouth brooding cichlids, the fecundity is considerably low because the parents assure the survival of the offspring and in consequence less mortality (Moyle and Cech, 2000). Within a given species, fecundity may vary as a result of different adaptations to environmental habitats (Witthames *et al*., 1995). Even within a stock, fecundity is known to vary annually, undergo long-term changes and has been shown to be proportional to fish size and condition (Kjesbu *et al*., 1989). In addition, the variation in fecundity may be attributed to the differential abundance of food within the members of the population. Also, Siddiqui *et al*. (1997) pointed out that fecundity increased with increased feeding levels. Lake Chamo is characterized by a relatively high phytoplankton biomass and production rate which may indicate the abundance of food for fish in the lake (Tefera, 1993). High productivity of the water that results in high food availability and high temperature of the area could be the main reasons for the larger size of the fish and thus higher fecundity.

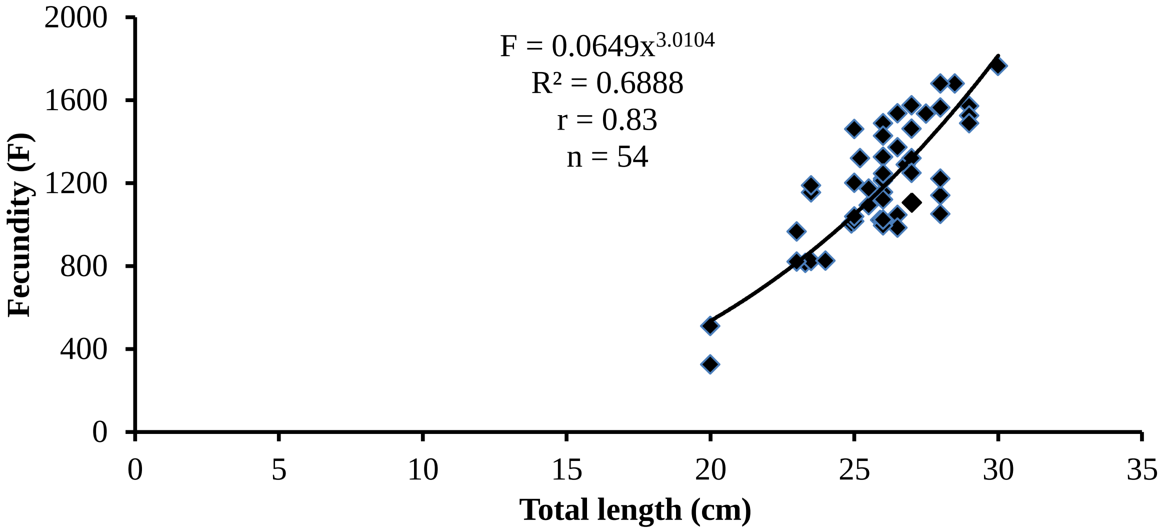

Figure 5: Relationship between fecundity and total length of *O. niloticus* in Lake Chamo

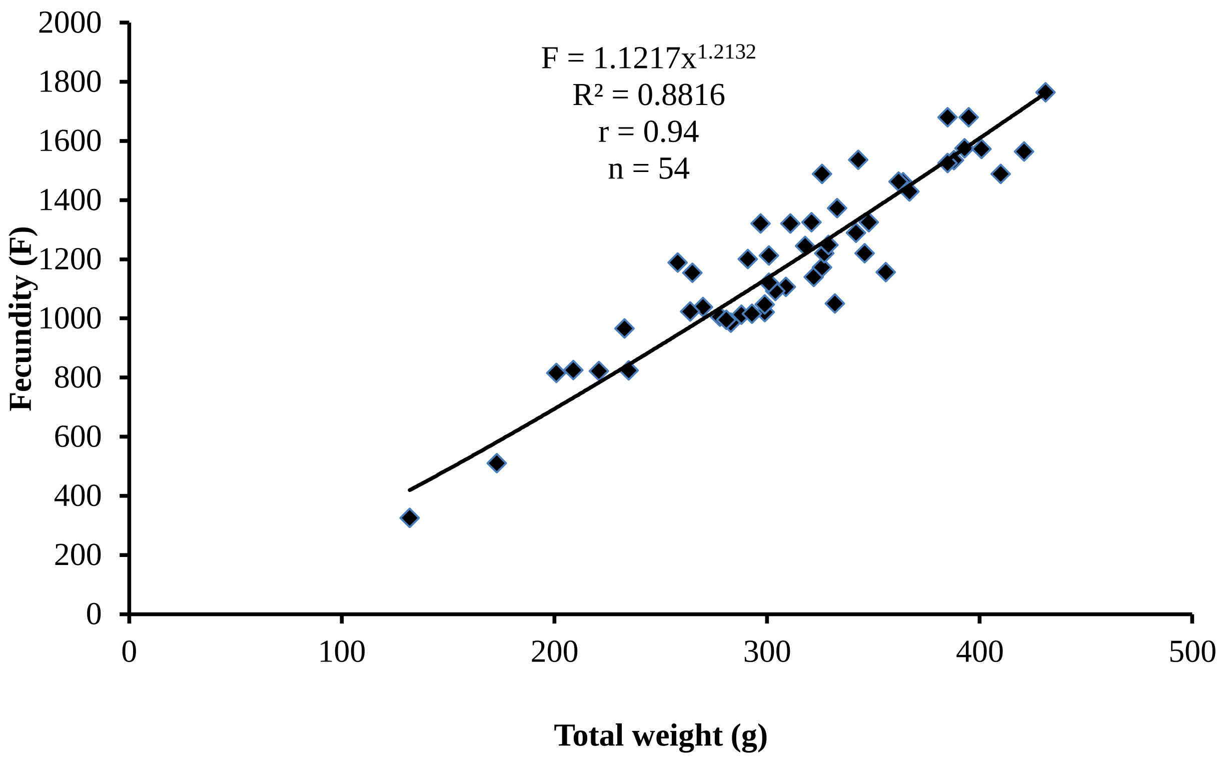

Figure 6: Relationship between fecundity and the total weight of *O. niloticus* in Lake Chamo

4. Conclusion and Recommendations

Female *O. niloticus* was dominated over the male throughout the year. This may possibly be due to females emigrate from spawning areas towards feeding grounds where they are caught. Fecundity of *O. niloticus* in Lake Chamo varied from 325 to 1,764 eggs with mean fecundity of 1,138 eggs. *O. niloticus* in Lake Chamo breeds throughout the year with peak breeding season of March to May and August to November. It is recommendable to reduce commercial fishing of *O. niloticus* during the peak breeding seasons in order to minimize the capture of breeding fish. The size at which 50% of the fish sexually mature was about 23.6 cm total lengths for both sexes. The size at first maturity (TL_{50}) in the present study for both sexes was too small than the earlier study (39.6 cm) in Lake Chamo for the same species. The smallness of TL_{50} might be due to heavy fishing together with illegal fishing activities, fishing during the breeding season, breeding ground destruction by buffer zone agricultural practices around the lake. Therefore, appropriate fishery management tools such as closing season during peak breeding, buffer zone conservation and mesh size regulation should be implemented for sustainable fishery utilization in Lake Chamo.

Conflicts of interest

The authors declare that there is no conflict of interest in publishing the manuscript in this journal.

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