Reproductive biology and feeding habits of Nile tilapia *Oreochromis niloticus* (Linnaeus, 1758) (Pisces: Cichlidae) in Lake Boyo, Ethiopia

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ABSTRACT

Lake Boyo is among the few lakes hidden behind the major lakes of Central Ethiopian Rift Valley Region. It is a shallow, turbid and an open lake. Neither fishery activity nor fishery research has ever been conducted before in Lake Boyo. This research was conducted to provide baseline information on the reproductive biology and feeding habits of *O. niloticus*. It was conducted from May, 2021 to September, 2022. A total of 379 (197 males and 182 females) samples of *O. niloticus* were collected using gill nets of 6, 8 and 10 cm mesh size and beach-seine of 6 mm mesh size. The results indicated that the sex ratio (Male: Female) was 1: 0.92; ($p > 0.05$). Length at first sexual maturity was 10.0 cm (TL) for males and 7.7 cm (TL) for females. Fecundity ranged from 216 to 1,157 eggs per fish. *O. niloticus* breeds throughout the year in the lake and the peak breeding months were from July to September and February to March. The length to weight relationship for males was 3.04, females 3.18 and combined sexes 3.12, and it showed slight positive allometric growth pattern. The stomach content analysis showed that detritus, macrophytes and phytoplankton were the major food items while insects and zooplankton were less important. According to this study, it was concluded that *O. niloticus* is omnivorous. Further research should be carried out on the phytoplankton primary productivity and phytoplankton biomass of the lake for fish production.

Key words: Condition factor**;** Feeding; Lake Boyo; *O. niloticus*; Reproduction
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INTRODUCTION

O. niloticus is the most important fish among the members of the family Cichlidae in the ecology and fisheries of tropical African inland waters (Lowe Mc-Connell, 1982). It is native to East, Central and West Africa, as well as to the Middle East and it is widely distributed in the African freshwater systems along the Nile basin (Trewavas, 1983). *O. niloticus* is the most important fish species in tropical and subtropical freshwaters, often forming a basis of commercial fisheries in many African countries (Mohammed and Uraguchi, 2013).

Despite being native to Africa, *O. niloticus* has been introduced into other countries (Demeke Admasu, 1996). *O. niloticus* is becoming increasingly well-known in fresh water aquaculture in many regions of the world, and is extensively studied in African waters due to its economic importance. Additionally, *O. niloticus* is widely distributed in Ethiopian lakes, rivers and reservoirs (Abebe Getahun, 2017), playing a vital role by contributing nearly 50% of the total fish supply in Ethiopia (Gashaw Tesfaye, 2014). Specifically, it is widely found

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in the Rift valley lakes, as well as the Abay, Awash, Baro-Akobo, Omo-Gibe, Tekeze and Wabishebele-Genale River basins, along with other Ethiopian highland lakes and rivers (Golubtsov and Mina, 2003). This species constitutes a substantial portion of both captured fishery and the commercial inland fish catch (Tsegay Teame *et al.*, 2018; Degsera Aemro *et al.,* 2020). In Ethiopia, *O. niloticus* is the most edible fish species (Assefa Mitike, 2014), serving as an irreplaceable protein source for local community residing around the lakes (Degsera Aemro *et al.,* 2020). It also supports substantial populations of fish-eating birds in East African saline-alkaline lakes (Kavembe *et al.,* 2016).

High tolerance to environmental conditions and its ability to accept formulated and natural feeds make *O. niloticus* economically viable (Adeyemi, 2009). The advantages for *O. niloticus* are its extended breeding seasons and short generation time reproductive biology, presenting other advantages (Coward and Little, 2001). Additionally, the herbivorous nature and its mouth-brooding habits of *O. niloticus* contribute to its suitability for aquaculture (Penda-Mendoza *et al*., 2005).

The breeding season and maturity size of *O. niloticus* in some lakes in Ethiopia have been studied by several investigators where the species breeds continuously throughout the year (Lemma Abera, 2013; Workiye Worie and Abebe Getahun, 2014; Tsegay Teame *et al.*, 2018).

The food and feeding habits of *O. niloticus* in different water bodies in Ethiopia showed that the species feeds on different food items mainly phytoplankton (Alemayehu Negasa and Prabhu, 2008; Filipos Engidaw *et al*., 2013; Workiye Worie and Abebe Getahun, 2015; Mulugeta Wakjira, 2016). In addition to phytoplankton, detritus and macrophytes were also reported from some rift valley lakes (Filipos Engdaw *et al.,* 2013).

The high occurrence of zooplankton in the diet of *O. niloticus* was reported in some of the Ethiopian lakes, for example, in Lake Ziway (Alemayehu Negasa and Prabhu, 2008) and in Lake Hayq (Workiye Worie and Abebe Getahun, 2015). Studies conducted in different water bodies of Ethiopia indicated that phytoplankton was the most important food item consumed in dry season (Alemayehu Negasa and Prabhu, 2008; Filipos Engdaw *et al.,* 2013; Workiye Worie and Abebe Getahun, 2015; Mulugeta Wakjira, 2016). In wet season, however, macrophytes, detritus, zooplankton and aquatic insects were reported dominant in most of the water bodies (Alemayehu Negasa and Prabhu, 2008; Filipos Engdaw *et al.,* 2013). The rainy season of Ethiopia triggers the high abundance of macrophytes and insects in the diet of *O. niloticus* in wet season. Fish movements to shallow parts of lakes for reproduction could explain the increase of ingested macrophytes in the wet season. The high dietary proportion of detritus in the diet of the fish in the wet season might also have emerged from decayed plant and animal materials flooding in to the lake during the rainy season (Workiye Worie and Abebe Getahun, 2015). Fishery is unknown in the study area and therefore there has never been any research to improve its productivity. The reasons for that could be inaccessibility of the lake and lack of awareness about fishery amongst the local community. Therefore, this research was conducted to fill the gap by providing information on the reproductive biology and feeding habits of *O. niloticus* in the Lake Boyo.

MATERIALS AND METHODS

Description of the study area

Lake Boyo (Figure 1) is among the few lakes hidden behind the major lakes of Central Ethiopian Rift Valley Region. It is a shallow and turbid lake surrounded by swampy wetland. It is an open lake where Guder and Wera rivers flow into and Merancho River flows out of it. The climate around Lake Boyo is generally characterized by warm, wet winter (most of the rainfall occurring from June to September) and dry, cold and windy summer (from December to March). The mean monthly rainfall of the area ranges from 9 mm in December to 195 mm in July. Maximum temperature of the area reaches 27.4 ºC during the warmest month, i.e., April, and a minimum of 13.6 ºC in the coldest month, December. As a result, the area can be characterized as a semi-arid climate with a long winter season. Three fish species exist in the lake, namely *O. niloticus*, the straightfin barb *Enteromius paludinosus* (Peters 1852) and the lapping minnow *Garra quadrimaculata* (Rüppell, 1835). The littoral area of Lake Boyo is surrounded by farmlands, human settlements and vast scattered patches of plantations of *Eucalyptus globulus*. Some scattered trees of *Ficus vasta* and *Acacia* spp. are found in the surrounding farmlands. *Eriochloa fatmensis* and *Eriochloa meyeriana* grasses that are important for cattle grazing dominate the wetland, and *Typha angustifolia*, which is used for thatching roofs of huts. *Aeschynomene elaphroxylon* is also present in the wetland, which local people use as firewood.

More than 99% of the people surrounding the lake are farmers, where they depend on subsistence agriculture (crop farming and animal husbandry). Maize (*Zea mays*), wheat (*Triticum aestivum*), sorghum (*Sorghum bicolor*), teff (*Eragrostis tef*) and green chilli (*Nahuati chilli*) are the main crops grown in the area. The area is excessive degraded, deforested, and irrigated resulting in vast sedimentation and increasing soil salinity (Dagnachew Legesse and Tenalem Ayenew, 2006). Settlements to the surrounding wetland are increasing because of the rapid human population growth. Soil erosion in the surrounding hills has also a substantial negative impact on the continuity of the wetland.

According to the local people, the wetland has been full of grasses and harbored a large number of Hippopotamus (*Hippopotamus amphibius*). It was also known as one of the important bird concentration areas of Ethiopia (Yilma Delelegn, 1998; Hadis Tadele, 2018). Wattled cranes (*Bugeranus carunculatus*), Common cranes (*Grus grus*), Black crowned cranes (*Pavonina pavonina ceciliae*), Egyptian geese (*Alopochen aegyptiacus*) and Spur-winged geese (*Plectropterus gambensis*) used to winter in the wetland. The wetland is suitable breeding ground for Black crowned cranes (*Pavonina pavonina ceciliae*) and Egyptian geese (*Alopochen aegyptiacus*) until now.

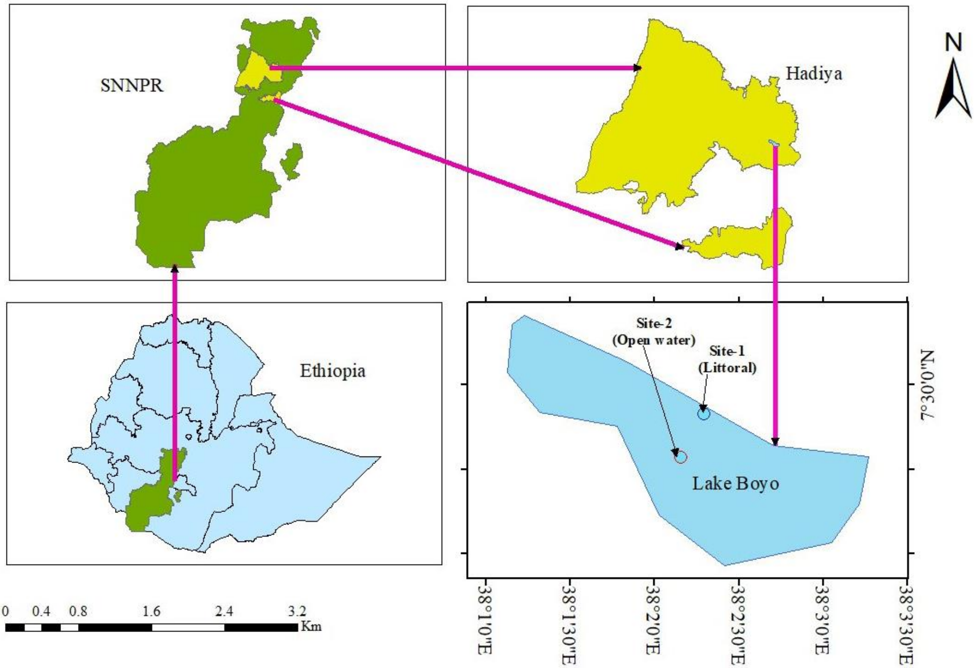

Figure 1. Location map of Lake Boyo

Sampling

Samples of *O. niloticus* were collected from the eastern part of the lake, the littoral and open lake sites for 15 months from may 2021 to September 2022 using gill nets of 6, 8, and 10 cm mesh size and a beach-seine of 6 mm mesh size. Total length (TL) and standard length (SL) of each fish sample was measured from the tip of the snout to the extended tip of the caudal fin using a measuring board to the nearest millimeter. Total weight (TW) of all fish samples was also measured to the nearest 0.1 g using Scaltec digital balance. Then, the fish samples were dissected and sex and sexual maturity of each fish were determined by visual examination of the gonads and using a five-point maturity scale with the characteristic features of the gonad stages (Holden and Raitt, 1974; Nagelkerke, 1997) (Table 1).

Soon after the collection, the specimens of ripe female gonads were measured to the nearest 0.1 g using Scaltec digital balance and preserved in 5% formalin solution for further fecundity estimation. The stomach contents of all non-empty fish samples were preserved in 5% formaline solution and brought to the fishery laboratory of Aquatic Sciences, Fisheries and Aquaculture of Hawassa University. The food items found within the fish stomach were identified and quantified in the Laboratory.

Table 1. Gonad maturity stages of fishes and their descriptions (Adapted from Holden and Raitt, 1974; Nagelkerke, 1997).

Gonad stage	**Testes**	**Ovaries**
I	Immature, impossible to distinguish females frommales. Gonads are a pair of transparent strings running along the body cavity.	Immature, impossible to distinguish females from males. Gonads are a pair of transparent strings running along the body cavity.
II	Unambiguously male, very small testes, white-reddish,not lobed, tube-shaped strings.	Unambiguously female, very small ovaries, tube-shaped and reddish, eggs not visible (recovery spent or developing virgin).
III	Larger testes, white-reddish, somewhat lobed startingto flatten sideways (Ripening).	Ovary somewhat larger and starting to flatten sideways, eggs visible, but very small (Ripening).
IV	Large testes, white-reddish, lobed, flattened sideways(Ripe).	Large ovary flattened sideways and almost covering body cavity wall, eggs yellowish (Ripe).
V	Large, white testes, some milt runs out when testis iscut (for *Labeobarbus* species). *This stage is marked as spent for other fish species	Large and full ovary, completely covering body cavity wall, yellowish eggs run out when ovary is cut (for *Labeobarbus* species). *This stage is marked as spent for the other fish species
VI	Large white testes, running, large amount of milt runsout when testis is cut	Running, yellow eggs can be extruded by puttingpressure on the abdomen
VII	Spent, empty testes, reddish and wrinkled	Spent, wrinkled ovary, reddish, containing a few yellow eggs

Reproductive biology

Sex ratio

Sex ratio of the fish species was determined by calculating male to female ratio at different months of the year and different size classes (Vazzoler, 1996). Pearson`s Chi-squared (χ^2) test was employed to determine any significant deviation from the hypothetical 1:1 sex ratio.

Size at first maturity (Lm50)

The percentage of male and female *O. niloticus* having gonad stages III, IV, and V (Holden and Raitt, 1974), were plotted against length for each sex using data from the breeding season. The Lm50 of both sexes of the fish species was determined from the percentages of mature fish that were grouped in a 2 cm size classes as described by the logistic function (Echeveria, 1987).

$$P = 1/\left(1+ e^{(\alpha+\beta L)}\right) \quad (1)$$

Where P = estimated proportion of mature fish, L= total length in centimeters, and α and β are coefficients. Equation (1) can be transformed into logarithmic form as indicated below:

$$\text{Ln}\,(1\text{-}P/P) = \alpha - \beta L \quad (2)$$

From the above linear regression, Lm50 of both sexes was estimated as $Lm_{50} = -\alpha/\beta$.

Fecundity

Fecundity of *O. niloticus* was determined by counting all the eggs in the ovaries by using the total count method. The relationship of fecundity was determined by relating total fecundity (F) to TL and TW using the following formulae (Crim and Glebe, 1990):

$$F = a \times TL^b \quad (3)$$

$$F = a \times TW^b \quad (4)$$

Where *a* and *b* are parameters of the fitted line.

Breeding season

Breeding season of *O. niloticus* was determined from the matured ovaries at stage IV in all months of the year.

Food and feeding habits

Stomach content analysis

Stomach content analysis was conducted in the Fishery Laboratory of the Department of Aquatic Sciences, Fisheries and Aquaculture, Hawassa University. In the laboratory, the stomach contents were emptied into a petri dish to identify each food item. Food items were identified using a dissecting microscope (Leica, MS5, magnification-10x) and a compound microscope (Leica DME, magnification-100x), and using the identification key as described in the phytoplankton identification manual (Verlencar, 2004).

In frequency of occurrence, the number of stomach samples containing one or more of a given food item were expressed as a percentage of all non-empty stomachs examined (Hyslop, 1980). The role of each food item category in the total stomach contents was analyzed by the percentage frequency of occurrence (%Oi) and percentage contribution volume (%Vi) (Assis, 1996). The frequency of occurrence was computed as:

$$\%Oi = \frac{Ji}{Pi} \times 100$$

Where: Ji is the number of fish containing food items and p is the number of fish with food in their stomach. The volumetric technique (%Vi) was also computed as:

$$\%Vi = \frac{\text{Number of points allocated to component i}}{total\ points\ allocated\ to\ subsampple} \times 100$$

where %Vi is the percentage volume of the prey component i.

The frequency of occurrence (%Oi) provides evidence of the proportion of fish stomachs comprising a specific prey item (Hyslop, 1980). The volume role of each food item is visually measured relative to all of the food items existing in the stomach. The frequency of occurrence (%Oi) and volumetric contribution (%Vi, ml) were used to estimate the index of food preponderance (IPi). To determine the importance of each food item, the index of preponderance (PIi) (Tomojiri *et al.*, 2019) was calculated as:

$$IPi = \frac{\%\ Oi \times \%Vi}{\sum(Oi + \%Vi)} \times 100$$

Where %Vi is the percent composition by volume of species i and Oi is the frequency of occurrence of species i. To simplify assessments amongst species, IPi was transformed into percent IPi (% IPi).

Statistical analysis

Tables and figures were used to illustrate the data obtained through analysis. Pearson`s Chi-squared (χ^2) test was employed to compare sex ratios of the fish at different size classes and months of the year. Length-weight relationships and relationships between fecundity (F) and TL and TW were estimated using least squares regression. Logistic function was used to estimate Lm50 from the relationship between the percentages of mature fish at different size classes. The data generated from the stomach contents were analyzed using descriptive statistics.

RESULTS AND DISCUSSION

Sex ratio

A total of 379 specimens of *O. niloticus* were examined for sex ratio determination. Out of these, 197 (52%) were males and 182 (48%) were females. The samples collected in the rainy months were considerably larger than those in dry months. This happened because the lake`s water over flows in to the littoral zone of the lake thereby increasing the volume of the water in the lake, hence more fish were caught by using the beach-seine net. The overall sex ratio (male: female) was 1:0.92 which was not significantly different from the hypothetical 1:1 sex ratio ($p > 0.05$). The result also showed that there were more males than females in December, while females dominated in July and September. For the rest of the months (January –April), male and female *O. niloticus* numbers were almost equal in proportion (Table 2). The result on the analysis of sex ratio at different size classes of *O. niloticus* showed that there were significantly more males than females for the size classes 7.0-8.9 and 9.0-10.9 cm TL, while for the size classes 17.0-18.9 cm TL, females were more represented than males. However, for the other size classes, there was no significant difference at 5% level of significance (Table 3). The overall sex ratio of *O. niloticus* in Lake Boyo in different months of the year showed that males and females were nearly equally distributed in the lake and the ratio did not significantly vary from the hypothetical distribution of 1:1 sex ratio (male: female) (Table 2).

This result is in agreement with other studies reported on *O. niloticus* in the two Ugandan crater lakes (Bwanika *et al.,* 2004), and in Itapaji Dam, Nigeria (Omotayo *et al.* 2019). However, the dominance of female *O. niloticus* was reported from other water bodies including Ethiopian lakes and reservoirs like Lake Hawassa (Demeke Admasu, 1996), Lake Beseka (Lemma Abera, 2013), Lake Hayq (Workiye Worie and Abebe Getahun, 2014), and Tekeze Reservoir (Tsegay Teame *et al.*, 2018). On the other hand, the dominance of male *O.*

niloticus population over females was reported in Lake Tana (Zenebe Tadesse, 1997), Lake Victoria (Njiru *et al.,* 2006), Lake Babogaya (Lemma Abera, 2012) and Wadi Hanifah (Mortuza and Al-Misned, 2013). The sex ratio shows significant variation for the same species in different water bodies, but usually it is close to one, and the predominance of sex may differ due to sexual segregation during spawning period, difference in habitat preference, behavioural variances between the sexes, vulnerability to fishing gear nature and fishing site (Tsegay Teame *et al.*, 2018).

Table 2. Male to female sex ratio of *O. niloticus* sampled in different months of the year from Lake Boyo

Sampling month	Male	Female	Sex ratio (M:F)	Chi-square
May	15	11	1:0.73	0.62
June	22	13	1:0.6	2.31
July	26	32	1:1.23	0.62
August	28	27	1:0.96	0.02
September	25	36	1:1.44	1.98
October	8	5	1:0.63	1.23
November	12	9	1:0.75	0.29
December	15	5	1:0.33	5.0*
January	17	17	1:1	0.0
February	13	11	1:0.85	0.17
March	6	7	1:1.17	0.08
April	10	9	1:0.9	0.05
Total	**197**	**182**	**1:0.92**	**0.6**

1 * indicates significant differences (p<0.05)

Table 3. Male to female sex ratio of *O. niloticus* at different size classes from Lake Boyo

Size class	Male	Female	M:F Sex ratio	Chi-square
3.0- 4.9	10	6	1: 0.6	1
5.0- 6.9	35	26	1: 0.74	1.33
7.0- 8.9	43	23	1: 0.53	6.1*
9.0- 10.9	51	18	1: 0.4	15.8**
11.0- 12.9	15	23	1: 1.5	1.7
13.0- 14.9	17	23	1: 1.4	0.9
15.0- 16.9	12	14	1: 1.2	0.2
17.0- 18.9	8	35	1: 4.4	17.0**
19.0- 20.9	4	10	1: 2.5	2.6
21.0- 22.9	1	2	1: 2	0.33
23.0- 24.9	1	1	1: 1	0
25.0- 26.9	1	1	1: 1	0
Total	**197**	**182**	**0.92**	**0.6**

1 * indicates significant differences (p<0.05)

Length at first maturity (Lm50)

The Lm50 (Figure 2) of *O. niloticus* in this study was 10.0 cm TL for males and 7.7 cm for females. The Lm50 also showed that female *O. niloticus* reached sexual maturity in smaller size than males. The early sexual maturity of *O. niloticus* could be related to the stress and lack of adequate food in the study lake. The Lm50 result obtained for *O. niloticus* in the current study was smaller than the same species in Amerti Reservoir (18.9 cm for females and 21.5 cm for males) (Mathewos Hailu, 2014). Compared to males, smaller female *O. niloticus* managed to reach sexual maturity. These values agree with the findings of Demeke Admasu (1994) in that female *O. niloticus* in lakes Ziway and Hawassa matured while still smaller than males. The lower value of length at first maturity of the fish species might be due to competition for resources in the lake (Hilge *et al.*, 2015).

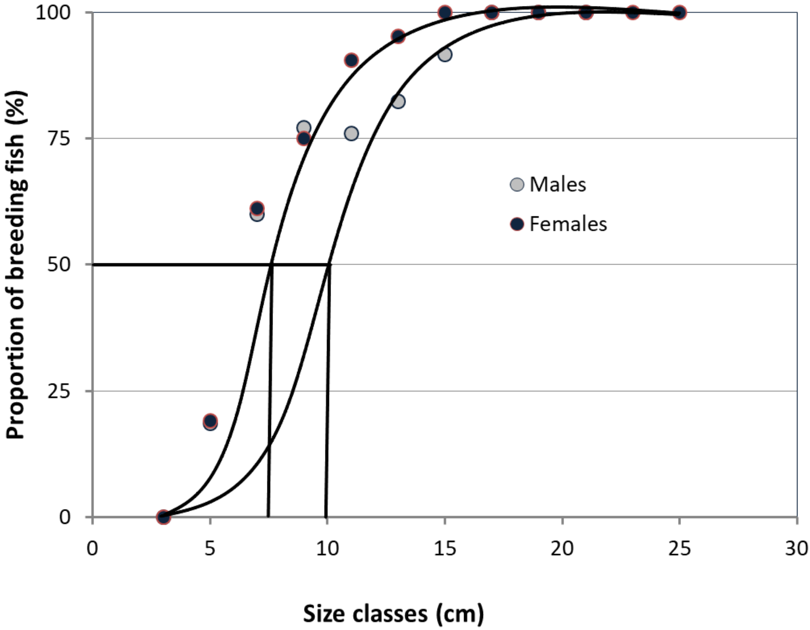

Figure 2. Lm50 of *O. niloticus* sampled from Lake Boyo

Fecundity

The number of eggs in the examined ripe ovaries ranged from 216 to 1,157 eggs per fish. The relationship of fecundity with total length and total weight of the fish were linear and increased with increasing fish length and body weight (Figure 3a and b). Fecundity increased with body length, as a relationship described by the equation: F = 67.493TL - 408.12, R^2 = 0.7454 (Figure 3a), where: F = fecundity, TL = total length of individual fish (cm) and the correlation was significant ($R^2 = 0.745$, $p < 0.05$). The relationship of fecundity with TW of

O. niloticus was linear (R^2= 0.75, p<0.05) and increased with increasing fish length (Figure 3b). It was expressed by the equation: F=4.0847TW + 311.78, R^2 = 0.75. Fecundity obtained for *O. niloticus* in this study was very comparable with the finding in Lake Tana (495 to 1,243 eggs per ovary) (Zenebe Tadesse, 1997) but was lower than the fecundity of same species in Lake Chamo (1,047 to 4,590 eggs per ovary) (Yirgaw Teferi *et al.,* 2001).

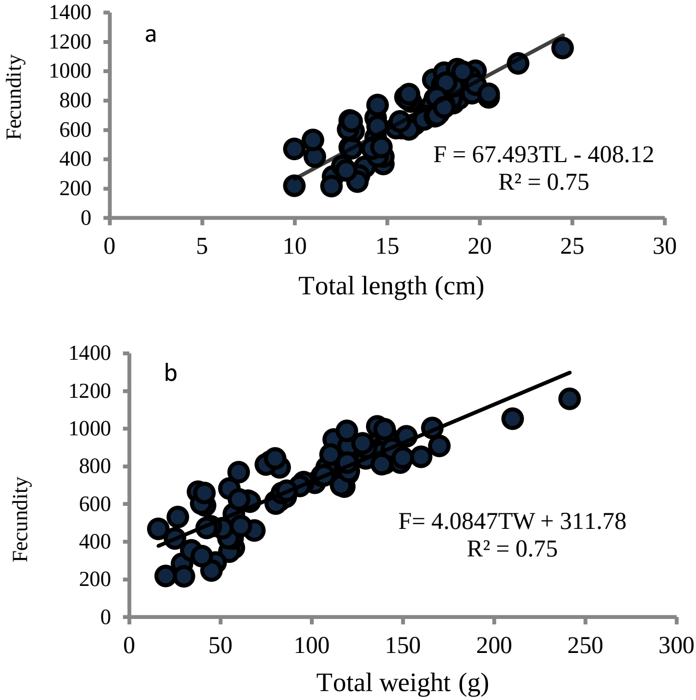

Figure 3. The relationship between fecundity and total length (a) and total weight (b) of *O. niloticus* in Lake Boyo

Breeding season

The result of gonad maturity stages in this study showed that *O. niloticus* breeds throughout the year and it had also two peak breeding seasons: the first peak from February to March and the second peak from July to September (Figure 4). Similar peak breeding time for the same fish species was reported from Lake Chamo (Yirgaw Teferi *et al.,* 2001) that the fish breeds from January to July. Lemma Abera (2013) also reported that *O. niloticus* in Lake Beseka could breed throughout the year with the peak breeding time from August to September. Elias Dadebo (2000) reported that several environmental factors such as the onset of the rainy season, subtle change in water temperature and changes in water level could be responsible for the high breeding activity of tropical fish.

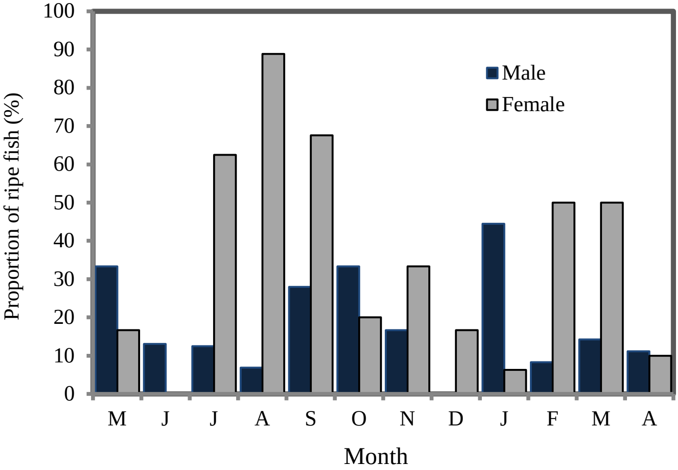

Figure 4. Breeding season of *O. niloticus* sampled in different months from Lake Boyo

Length-length relationship

The relationship between TL and SL of *O. niloticus* was linear (n= 439; R^2= 0.993, $p<0.05$) and it is expressed by the equation: SL = 0.791TL + 0.013.

Length-weight relationship

The length-weight relationship of *O. niloticus* in Lake Boyo with the value of regression co-efficient 3.05 for males, 3.18 for females, and 3.13 for combined sexes exhibited slight positive allometric growth pattern. These values were within the range of 2-4 recommended by Bagenal and Tesch (1978) as ideal for fresh water fishes. The results in this study were in agreement with the results reported by Njiru *et al.* (2006) from Lake Victoria (b=3.20). The "b" value obtained for *O. niloticus* in Lake Boyo was greater than that reported for the same fish species from Lake Beseka (b= 2.69) (Lemma Abera, 2013).

Condition factor

Monthly mean Fulton condition factor (FCF) values ranged from 1.55 to 1.91 for males and 1.5 to 2.0 for females. The average FCF value for males was 1.73 and for females 1.77. The result thus showed that females were in a better condition than males (Figure 5). The average FCF value (1.77) of *O. niloticus* in this study (Figure 5) was lower than the values reported for the same fish species from Lake Hawassa (2.03) (Eyualem Abebe and Getachew Teferra, 1992) and Chamo (2.35) (Yirgaw Teferi *et al.*, 2001). The variation in the FCF value could be due to changes in the environmental conditions of the lake and thereby changes in the nutritional status of the fish. For instance, there are different agricultural activities taking place around the lake and these activities might disturb and break the chain of food availability for the fish. Variations in the condition factor of many fishes is believed to be related to their reproductive cycle (Narejo *et al.*, 2002), feeding rhythms, physiochemical factors of environment, age, physiological state of fish or some other unknown factors (Dar *et al*., 2012). In general, the FCF values of females were higher than that of males in some of the studied period and it might be due to the higher gonad weight of females that result in higher total body weight as well as mobilization of energy for building and guarding of nests which might reduce total body weight in males.

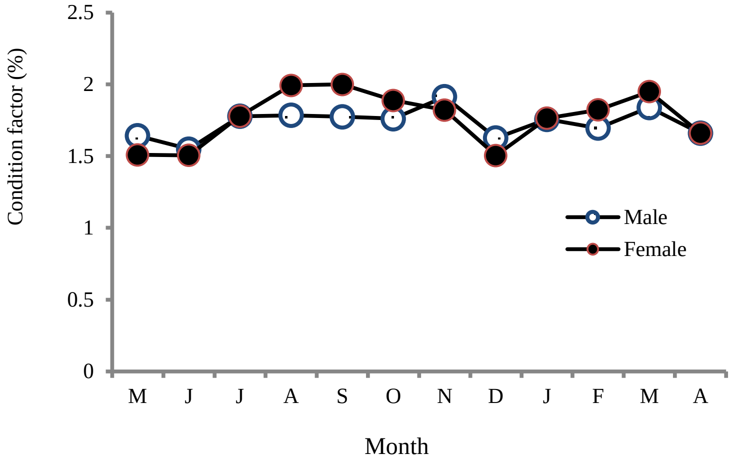

Figure 5. Condition factor of male and female *O. niloticus* sampled from Lake Boyo

Food and feeding habits

During this study, 315 samples of *O. niloticus* were analysed for feeding habits. From these 71 (22.5%) were with empty stomachs while 244 (77.8%) were with some food items in their stomach.The stomach content analysis indicated that *O. niloticus* fed on a variety of food categories in the lake including food from plant and animal origins. Five different categories of food items were identified and categorized as detritus, macrophytes, insects, zooplankton and phytoplankton. Detritus occurred in 99.2%, macrophytes in 77.1%, phytoplankton in 42.5%, insects in 11.0%, and zooplankton, in 4.9% fish stomachs. Volumetrically it consisted of 73.6% Detritus, 11.7% macrophytes, 13.4% phytoplankton, 1.2% insects and 0.2% zooplankton of the food items. The %IP (index of food preponderance) depicted that detritus accounted for approximately 79.1%, macrophytes 9.8%, phytoplankton 6.2%, insects 0.14%, and zooplankton 0.01% of the diet (Table 4). Thus detritus was the most preferred food item in the lake. Similarly, several authors have reported the high abundance of detritus in the diet of *O. niloticus* in different parts of Ethiopia following phytoplankton (Filipos Engidaw *et al.*, 2013; Workiye Worie and Abebe Getahun, 2015). However, other findings revealed that phytoplankton is the major food item in the diet of the same fish species (Mathewos Temesgen *et al.*, 2022; Solomon

Wagaw *et al.*, 2022). The contribution of insects and zooplankton was less in the diet of *O. niloticus* in Lake Boyo.

Table 4. Summary of the different food items consumed by *O. niloticus* using the index of food preponderance methods of analyses in Lake Boyo (n=245)

Food item	$\%O_i$	$\%V_i$	$\%V_i X\%O_i$	%IP
Detritus	99.2	73.6	7299.648	79.12
Macrophytes	77.14	11.73	904.8522	9.81
Insects	11.02	1.17	12.8934	0.14
Zooplankton	4.9	0.15	0.7335	0.008
Phytoplankton	42.5	13.4	568.83	6.166

NB: percentage frequency of occurrence (%Oi), percentage of volumetric contribution (%Vi), percentage index of preponderance (%IP)

The current study also showed a seasonal variation in food composition of *O. niloticus*. In the wet season (Table 5) detritus occurred in 100%, macrophytes in 84.6%, phytoplankton in 27.64%, insects in 1.62% and zooplankton in 2.43% fish guts. Volumetrically it consisted of 72.96% detritus, 13.94% macrophytes, 12.98% phytoplankton, 0.07% insects and 0.048% zooplankton of food items. The %IP depicted that detritus accounted for 80.22%, macrophytes for 12.96%, phytoplankton for 3.95%, insects for 0.001%, and zooplankton for 0.001% of the diet (Table 5).

Table 5. Summary of the different food items consumed by *O. niloticus* in wet season using the index of food preponderance methods of analyses in Lake Boyo (n=123).

Food item	$(\%O_i)$	$(\%V_i)$	$\%O_i X\%V_i$	%IP
Detritus	100	72.96	7296	80.22
Macrophytes	84.6	13.94	1178.627	12.96
Insects	1.62	0.07	0.113	0.001
Zooplankton	2.43	0.048	0.11664	0.001
Phytoplankton	27.64	12.98	358.7672	3.945

NB: percentage frequency of occurrence (%Oi), percentage of volumetric contribution (%Vi), percentage index of preponderance (%IP)

The result thus depicted detritus as the dominant food item in the wet season. Macrophytes and phytoplankton were also preferred food items following detritus. The high dietary proportion of detritus in the diet of the fish in wet season might have emerged from dead plant and animal materials flooding in the wet season (Workiye Worie and Abebe Getahun, 2015). The dominance of detritus in the diet during the rainy season agrees with observations made in Lake Ziway (Mulugeta Wakjira, 2016).

In the dry season (Table 6) food items consumed (%Oi) ranged between 7.4% of insects and 98.4% detritus. Volumetrically (%Vi) it ranged between 0.22% for zooplankton and 74.01% for detritus. Food preponderance (%IP) also ranged between 0.02% for zooplankton and 77.08% for detritus. Thus the result showed that detritus was the main food item followed by phytoplankton and macrophytes in dry season for *O. niloticus* in the lake. The high contribution of phytoplankton in the stomachs of *O. niloticus* during the dry season was similar with the finding of Mathewos Temesgen *et al.* (2022) in Lake Langano.

Table 6. Summary of the different food items consumed by *O. niloticus* in dry season using the index of food preponderance methods of analyses in Lake Boyo (n=122).

Food item	%O_i	%V_i	%Oi X %V_i	%IP
Detritus	98.4	74.01	7279.62	77.08
Macrophytes	69.7	10.27	715.51	7.58
Insects	20.5	1.89	38.73	0.41
Zooplankton	7.4	0.22	1.62	0.02
Phytoplankton	57.4	13.61	780.94	8.27

NB: percentage frequency of occurrence (%Oi), percentage of volumetric contribution (%Vi), percentage index of preponderance (%IP)

CONCLUSION

This study is the first of its kind to be conducted on *O. niloticus* in Lake Boyo. In this study we have confirmed that the distribution of male and female fish was fair and followed natural distribution of 1:1 ratio. Early maturity of the fish species was commenced and the fish reproduced throughout the year. This could be to avoid some environmental stresses that can hinder the reproduction of the fish species. *O. nilotcus* breeds year round, with two peak breeding times in the lake that the peak breeding time of most fish species was at the onset and at time of rainy season. The omnivorous feeding behaviour and seasonal variation of the food composition indicates the feeding mechanism in which the fish species cope up with the availability of food items. The high amount of detritus and the low amount of phytoplankton in the dry season, along with the lower condition factor of the fish compared to other lakes indicate that the productivity of Lake Boyo was low. Researches on the lake productivity and phytoplankton biomass are vital to better understanding of the lake`s status for fish production and conservation of the lake ecosystem.

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Conflict of interest

The authors declare no conflict of interest.

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