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Full Length Research Paper

Observations on the biology of Nile tilapia, *Oreochromis niloticus* L., in Tekeze Reservoir, Northern Ethiopia

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The study was done to examine some aspects of the reproductive biology of Nile tilapia (*Oreochromis niloticus*) in Tekeze Reservoir a newly man made hydropower reservoir. A total number of 1826 specimens of Nile Tilapia (O. niloticus) were collected from the reservoir from July 2015 to June 2016. Size at first maturity, sex ratio, gonado-somatic index (GSI), breeding season and fecundity were studied. The overall sex-ratio female: Male (F: M) was 1.6:1 which is deviated from the expected 1:1 sex ratio ($\chi 2 = 10.13$; $p<0.05$). Length at first maturity was 14 and 15 cm for females and males respectively. The breeding period of females extended from January to September. Two annual breeding seasons were noticed. A minor breeding season which extended from January to March and a major breeding season from July to September and monthly Condition Factor (CF) (mean ± SD) value of *O. niloticus* in the reservoir ranged from 1.73±0.03 in July to 2.05±0.02 in November for males and 1.61±0.02 in July to 1.99±0.05 in April for females. Fecundity ranged between 399 to 2129 g. Fecundity correlated well with total weight (r = 0.086), total length (r = 0.77) and ovary weight (r = 0.72) than with gonadal weight (r = 0.86). Nile tilapia at Tekeze Reservoir showed isometric growth pattern (b=2.92), indicating that the reservoir was favorable for the fish growth. For proper management of the fish species in the reservoir, it is better for the fishermen not to capture the fish during the breeding season of the year in the reservoir.

Key words: Reproductive biology, *Oreochromis niloticus,* Gonado-somatic index, fecundity.

INTRODUCTION

Nile tilapia (*Oreochromis niloticus*) is an important fish in the ecology of tropical and sub-tropical region including Ethiopia and of great commercial importance in the fisheries in many African lakes (Britton and Harper, 2008). It is also the most popular species of the bony fish for aquaculture in Africa (Abdel et al., 2007). This is attributed to many positive qualities including tolerance to poor water quality, wide range of food, and plasticity in growth, firm flesh and good taste (Fryer and Iles, 1972).
Other advantages are its herbivorous nature and its mouth – brooding habits (Pena-Mendoza et al., 2005); extended breeding seasons and their short generation

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time (Ibrahim et al., 2008). Tsegay et al. (2016a) reported that, *O. niloticus* is the most dominant and commercially important species in the newly formed Tekeze Reservoir, and accounts about 82.4% of the total production of fish in the reservoir. Nile tilapia is the most popular fishes in Ethiopia as well as around the reservoir due to its value as a commercial and subsistence fishes for most of the inhabitants living around the reservoir. This is because it has fewer bones in its flesh compared to the *Barbus* species.

Descriptions of reproductive strategies and the assessment of fecundity are fundamental topics in the study of the biology and population dynamics of fish species and also for evaluation of the reproductive potential of individual fish species. This will increase our knowledge about the state of a stock and improves standard assessments of many commercially valuable fish species (Murua et al., 2003). Moreover, the availability of data based on reproductive parameters and environmental variation leads to a better understanding of observed fluctuations in reproductive output and enhances our ability to estimate recruitment (Kraus et al., 2002).

Previous work carried out on *O. niloticus* in Tekeze Reservoir focused mainly on proximate composition and mineral content, and types of diet of *O. niloticus* (Tsegay et al., 2016b). This investigation provides information on sex ratio, maturity stages, gonado somatic index, breeding season and fecundity of *O. niloticus* obtained from the Tekeze Reservoir to form a base-line data which can be used as fish species for sustainable utilization and better management of Tekeze Reservoir fisheries.

MATERIALS AND METHODS

Study area

The study was conducted at Tekeze reservoir. The reservoir is constructed for hydropower generation which was built in 2009 over Tekeze River, the major river in Ethiopia and is a tributary of Nile River. Tekeze Reservoir is located at the border of Amhara and Tigray regions. The reservoir has a catchment area of about 30,390 km^2 while a maximum total water storage capacity is about 9.293 billion m^3. Tekeze reservoir has maximum length of 75 km and maximum width of 6 km, and covering an area of about 16,040 hectares with mean depth of 58 m. The reservoir extends from 13°20'N and 38°44' and 12°49'N and 38°41'E with an altitude of 3,750 ft. The catchment area is characterized by annual dry and rainy seasons. The rainy seasons extends from June to August while the dry season extends from September to May. The substratum of the reservoir is mainly rocky. Shoreline is without vegetation. The rock which is submerged is eventually decomposed by weather change and there is formation of sand in the reservoir.

Water quality parameters

Physico-chemical parameters of the reservoir water were tested according to standard methods described by American Public Health Association (APHA) (1995, 2005). The physical parameters, including color, odor and transparency were measured. The pH and water temperature were detected using a waterproof digital pH meter and thermometer (CP-411, ELMETRON). Dissolved oxygen concentrations and conductivity were measured using a waterproof digital, dissolved oxygen meter (conductivity/oxygen meter CCO-401, ELMETRON). Transparency was measured using secchi disc attached to graduated plastic rope.

Fish sampling and measurements

A total of 1826 individuals (981 female and 845 male) specimens were caught during the study. Fish samples were collected on monthly basis from July 2015 to June 2016 at three sampling stations. Fish were captured by gill nets (stretched mesh sizes of 6, 8, and 10, 12, and 14 cm). Soon after collection, total length (TL) and total weight (TW) were measured for each fish using measuring board and digital sensitive balance, to the nearest centimeter and gram, respectively. Each fish was dissected and the sex of the fish was identified through macroscopic examination of gonad stages using keys (Holden and Raitt, 1974; Babiker and Ibrahim, 1979). After dissection, the sex and maturity stage of each fish were determined following standard methods (Siddiqui, 1997; Babiker and Ibrahim, 1979). The maturity level of each gonad was classified into six groups and graded as immature:

(1) Recovering spent
(2) Developing virgin
(3) Ripening
(4) Ripen and
(5) Spent

Samples of ovaries in maturity stage IV were removed and preserved in a labeled plastic can containing Gilson's fluid for fecundity estimation (Begeanal, 1978). The preserved ripe gonads were taken to Abergelle Agricultural Research Center Laboratory, for further investigation. The percentage of male and female *O. niloticus* having gonad stages III, IV and V in different length groups were plotted against length for each sex. The length at first maturity, L_{50}, was determined from the relationship between the percentages of mature fish at different size classes using the logistic function (SPSS Program).

Length-weight relationship and condition factor

Length- weight relationship of *O. niloticus* was calculated using least squares regression analysis as described in Bagenal and Tesch (1978) as follows:

$$TW = a\,TL^b$$

Where,

TW= total weight in grams, TL= total length in centimeters, a and b= are intercept and slope of the regression line, respectively.

The well-being or condition factor of each fish was determined by computing Fulton condition factor as described by Bageanal and Tesch (1978). The condition factor of individual fish was calculated and then monthly mean values were determined for each sex separately. Condition factor of each fish was calculated as:

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

Where:

Table 1. Morphological, physical and chemical characteristics of Tekeze reservoir.

Parameters	Values	Parameters	Values
Altitude (m.a.s.l)	1096	Catchments area (km^2)	30.390
Surface area (Km^2)	160.4	Mean annual rainfall (mm)	850
Total storage (billion m^3)	9.293	Nitrate(mg/L NO_3)	1.06±0.30
Maximum depth (m)	183	Nitrite(mg/L NO_2)	0.01±0.00
Mean depth (m)	58	Ammonia (mg/L NH_3)	0.39±0.11
Maximum length (km)	75	Phosphate (mg/L PO_4)	0.16 ±0.03
Maximum width (km)	6	Sulphate (mg/L SO_4)	6.47±1.21
Conductivity (uS/cm)	361.42±20.57	Chloride (mg/L Cl)	10±1.23
Alkalinity (mg/L)	138.02±6.55	Secchi disk depth (m)	2.63±1.25
pH	8.01±0.88	Total hardness (mg/L $CaCO_3$)	244.71±13.36
Dissolved Oxygen (g/L)	5.82±1.74	Average Chl-a (µg/L)	81±5.25
Water temperature (^{0}C)	26.9±2.12	TDS	1.30±0.21

Data are expressed as mean ± SD of twelve separated determinations.

CF= condition factor, TW= total weight in grams and TL=total length in centimeters

The Gonado Somatic index (GSI)

The Gonado Somatic index (GSI) used as an indicator parameter for reproduction; was calculated for each specimen as the percentage of gonad weight to that of the fish total weight (Khallaf and Authman, 2010) using the following equation:

$$GSI = \frac{GW}{TW} \times 100$$

Where:

GW is the weight of gonads (ovary and testes) in gram and TW is total weight of fish in gram.

Statistical analysis methods

First data were tested for its homogeneity of variances using Levene's test. A chi-square test was applied to decide if the sex-ratio of captured fish were varied between months (Sokal and Rohlf, 1981). A two tailed *t* test was used to compare the estimates of L_{50}, fecundity, condition factor, and Gonado Somatic Index (GSI). Analysis of variance (ANOVA) was also used to define variations between the monthly GSI and condition factor (CF) values. To test relationship between total length and total weight of the fish, fecundity and total length; fecundity and total weight linear regression method was applied. All statistical analyses were performed using statistical package for social science (SPSS) Version 18 and significance of differences was judged at $p < 0.05$.

RESULTS AND DISCUSION

Physico-chemical parameters of the reservoir

The mean depth of the reservoir was 58 m, and the maximum depth of 183 m. Data on water temperature, dissolved oxygen, pH, conductivity, maximum depth and chlorophyll *a* are presented in Table 1. During the present study, the area was characterized by two seasons: a dry season (October to May) and a rainy season (June to September). The reservoir water level increased from June to September as a result of heavy rains. During the study, the mean water temperature of Tekeze reservoir was 26.9°C, and the mean dissolved oxygen and pH were 5.82±1.74g/L and 8.01±0.88, respectively. The mean chlorophyll *a* content was 81±5.25µg/L whereas ammonia and alkalinity were 0.39±0.11 mg/L and 138.02±6.55mg/L, respectively (Table 1).

Sex ratio and length at maturity

A total of 1826 *O. niloticus* were studied of which 845 (46.28 %) were males and 981 (53.72%) were females. The overall sex ratio was 1:1.16 (males: females), with significant deviations from one on chi-square analysis ($\chi2 = 10.13$; $p<0.05$) (Table 2). The fish specimens ranged from 6 to 37 cm in total length and the total weight ranged from 5 and 795 g. During the study, higher proportion of the sampled fishes for both sexes ranged in size between 20 and 34 cm. The peak was between 22 and 30 cm for both sexes. This length group alone was about 36% for females and 29% for males. Fish over 34 cm and below 10 cm TL were least represented in the sample.

Length at first maturity (L_{50}) has a great importance in the determination of optimum mesh size (Mehanna, 2007). The smallest sexually mature male was 14 cm TL whereas the same for female was 12.5 cm TL. Based on graphical methods, male *O. niloticus* reached 50% sexual maturity ($L_{50\%}$) at 15 cm TL and females at 14 cm TL. Although the sizes of $L_{50\%}$ were not significantly different from each other ($p > 0.05$), females appeared to reach sexual maturity at a relatively smaller size than males. The smallest length recorded in the catch of sample was 11.0 cm, which is slightly less than L_{50}. This means that

Table 2. Monthly numbers of males and females and sex ratio of *O. niloticus* in Tekeze reservoir.

Month	No. of male	No. of female	Sex ratio (M:F)	Chi-square
June (2015)	77	91	1:1.18	1.17
July	104	121	1:1.16	1.28
August	87	93	1:1.07	0.2
September	71	84	1:1.18	1.09
October	28	46	1:1.64	4.38
November	41	52	1:1.27	1.30
December	76	61	1:0.80	1.64
January (2016)	90	75	1:0.83	1.36
February	81	103	1:1.27	2.63
March	68	83	1:1.22	1.49
April	55	98	1:1.78	12.08*
May	67	74	1:1.11	0.35
Total	845	981	1:1.16	10.13*

*= Significant at 5% significance level.

O. niloticus in this reservoir was slightly exploited specially at spawning period, so it is recommended to increase the mesh size used to catch fish for lengths greater than 14.0 cm. Humason (1972) pointed out that length at maturity was 11.7 cm (males) and 12.0 cm (females) for *O. niloticus* in Coatetelco Lake, Mexico.

While, Pena-Mendoza et al. (2005) found that these lengths for *O. niloticus* at Emiliano Zapata dam, Morelos, Mexico were 15.1 and 15.2 cm for females and males, respectively. The size at first maturity in the Nile at Khartoum for males and females *Tilapia nilotica* is 11.4 and 14.3 cm, respectively (Babiker and Ibrahim, 1979). While, Morales (1991) mentioned that the tilapias attain their sexual maturity at three months old with a total length of 8 to 16 cm. It was cited (de Graaf *et al.,* 1999) that the first maturation size for reared Nile tilapia is 30 to 50 g. These differences arise because the sexual maturity is a function of the size and may be influenced by the abundance and seasonal availability of food, temperature, photoperiod and other environmental factors and different localities. Siddiqu et al. (1997) reported that fish size at maturity was influenced by the feeding level, which affects the growth (Table 2).

Distribution of matured stages

Monthly variations of the gonadal developmental stages for female *O. niloticus* from Tekeze reservoir are presented in Figure 1. All the different stages appeared in all months. The immature stages (I and II) represented the dominant maturity stages throughout the year with a peak in June, November, April and May. Mature stage (III), spawning stage (IV) and spent stage (V) of *O. niloticus* reached maximum percentages in July to September. The active reproductive period could be expected by the sum of the percentage of stages III and IV. Active reproductive period was recorded during January to February in minor peak and July to September with a major peak for both sexes. The number of each gonadal development stage in females is illustrated in Figure 2. According to gonadic maturation stages (Figure 2), 38.370% of the total fishes were maturing (II), 42.33% were mature (III) and 18.85% were ripe (IV). Therefore, 61.18% of the fishes were in the reproductive process. The highest proportion of average mature (III) and ripe (IV) gonadal stage in females was found in July (Figure 2).

Breeding season

Nile tilapia individuals with ripe gonads were caught throughout the year. However, the frequency of ripe male and female varied considerably between months (Figure 3). The main reproductive period for females, was July, August and September which was followed by a reproductively quiescent period between January and February. In Tekeze Reservoir, *O. niloticus* spawned all year round. However, the main breeding season occurred between July and September followed by a minor one between January and March. Similar studies conducted on *O. niloticus* in the rift valley Lakes Ziway and Hawassa (Zenebe, 1998; Demeke, 1996) also revealed bi-modal breeding patters. Njiru et al. (2006) reported that most tilapia species breed continuously throughout the year with increased breeding during periods of intense sunshine or rainfall. Several studies indicated that the peak breeding season of *O. niloticus* could be triggered by increase in temperature, solar radiation or rainy season and rise in water level (Trewavas, 1983; Stewart, 1988). Thus the main breeding season of *O. niloticus* in

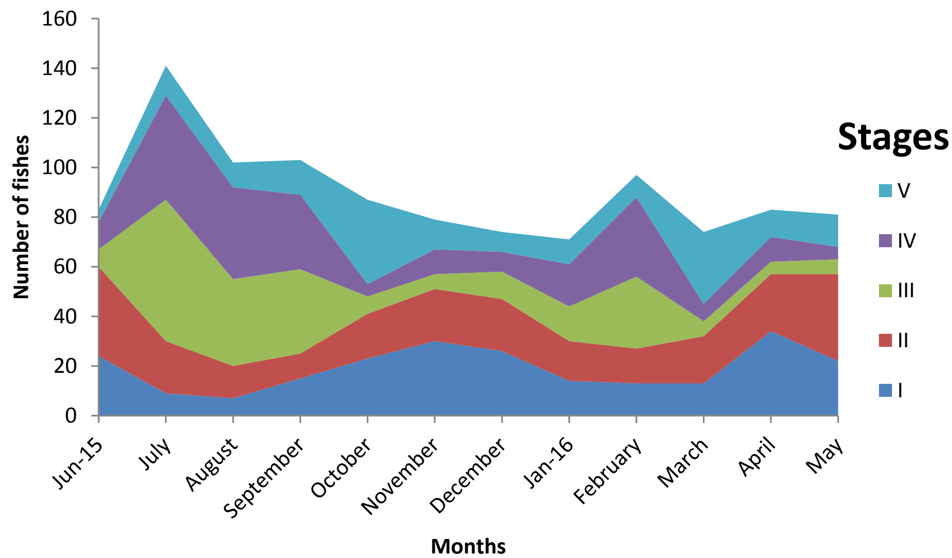

Figure 1. Monthly variations of all maturity stages of female *O. niloticus* from Tekeze reservoir.

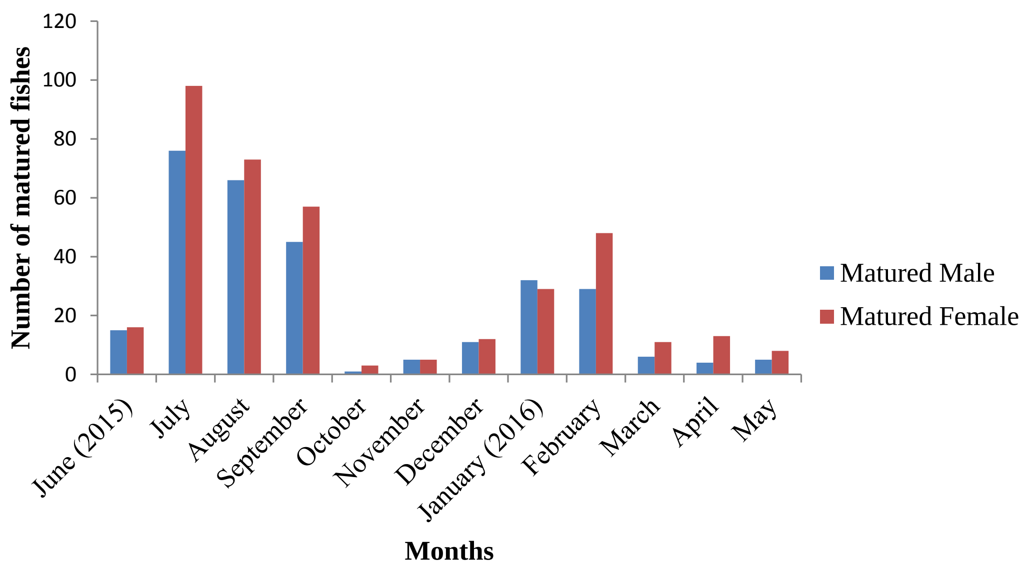

Figure 2. Monthly number of matured males and females of *O. niloticus* in Tekeze reservoir.

Tekeze Reservoir might be triggered by the main rainy season which increases the availability of food (plankton) and the minor breeding period of the fish in the reservoir could be associated with the high temperature and solar radiation (Figure 3).

Condition factor (CF)

The mean monthly CF value of *O. niloticus* significantly varied between months ($p<0.05$). However, no significant difference was observed between sexes ($p>0.05$). Monthly CF (mean ± SD) values ranged between 1.73±0.03 in July and 2.05±0.02 in November for males and from 1.61±0.02 July to 1.99±0.05 in April for females. Lowest monthly CF was recorded in July in both sexes (Table 3). The average CF values of *O. niloticus* for male and female were 1.91 and 1.82, respectively. Similar results were reported by Gashaw and Zenebe (2008) in Lake Koka (1.87), Lake Ziway (1.81) and Lake Langano

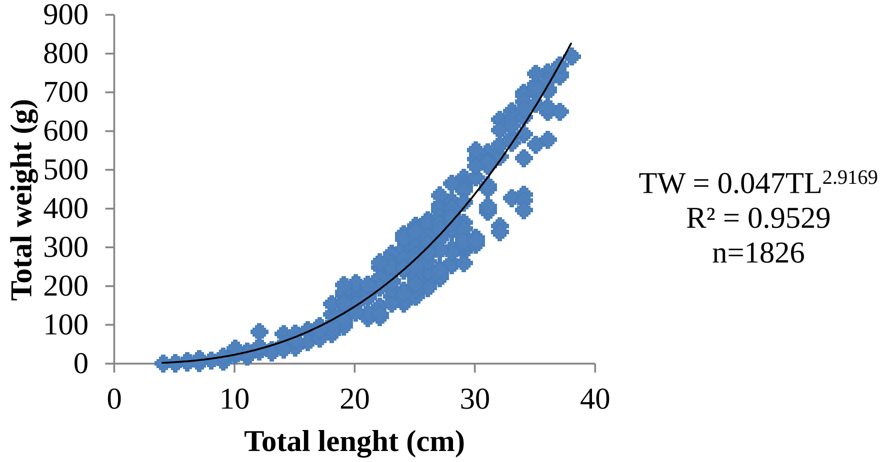

Figure 3. Total length and total weight relationships for both sexes.

Table 3. Monthly (Mean ±SE) of the Fulton Condition Factor of *O. niloticus* captured from Tekeze reservoir.

Month	No. of males	FCF for males	No. of females	FCF for females
June (2015)	77	1.98 ±0.06	91	1.91±0.04
July	104	1.73±0.03	121	1.61±0.02
August	87	1.84±0.05	93	1.72±0.05
September	71	1.76±0.03	84	1.76±0.02
October	28	1.83±0.05	46	1.73±0.03
November	41	2.05±0.02	52	1.89±0.04
December	76	1.95±0.04	61	1.85±0.05
January (2016)	90	1.79±0.01	75	1.75±0.02
February	81	1.82±0.04	103	1.80±0.06
March	68	1.98±0.05	83	1.92±0.04
April	55	2.02±0.06	98	1.99±0.05
May	67	1.86±0.02	74	1.79±0.03
Total	845	1.91±0.04	981	1.82±0.03

(1.84). But comparatively higher value were reported for the same species from Lakes Hawassa (2.03) and Chamo (2.35) (Yirga and Demeke, 2002). The difference in CF value in different lakes might be attributed to the differences in food availability between water bodies. There was no significant difference in CF between females and males in Tekeze Reservoir ($p>0.05$). However, there was significant difference in CF values between months ($p<0.05$) indicating differences in the condition of the fish with seasons. Relatively, the lowest value was recorded in July and coincided with the main spawning period of the fish (Table 3).

Length – weight relationship

The relation between TL and TW of combined sexes were curvilinear. The slope of the equation calculated for both sexes was very close to the theoretical value of b=3, that was 2.92 (for male b=3.03 and for female b=2.91) (Figure 3). The poor condition of *O. niloticus* in Tekeze reservoir in July might be attributed to the stress resulting from intense breeding activities which cost high energy for the fish. The length- weight relationship of female and male of *O. niloticus* in Tekeze reservoir was described best by the following regression equations:

Male: $TW=0.0253TL^{3.03}$, $R^2= 0.9735$, n=845
Female= $TW=0.0203TL^{2.911}$ $R^2=0.9534$, n=981
For both sexes= $TW=0.047TL^{2.9169}$ $R^2=0.9529$, n=1826

This has also been confirmed in earlier studies from Lake Ziway, Tana and Turkana (Stewart, 1988; Zenebe, 1988). Other environmental factors such as availability of food

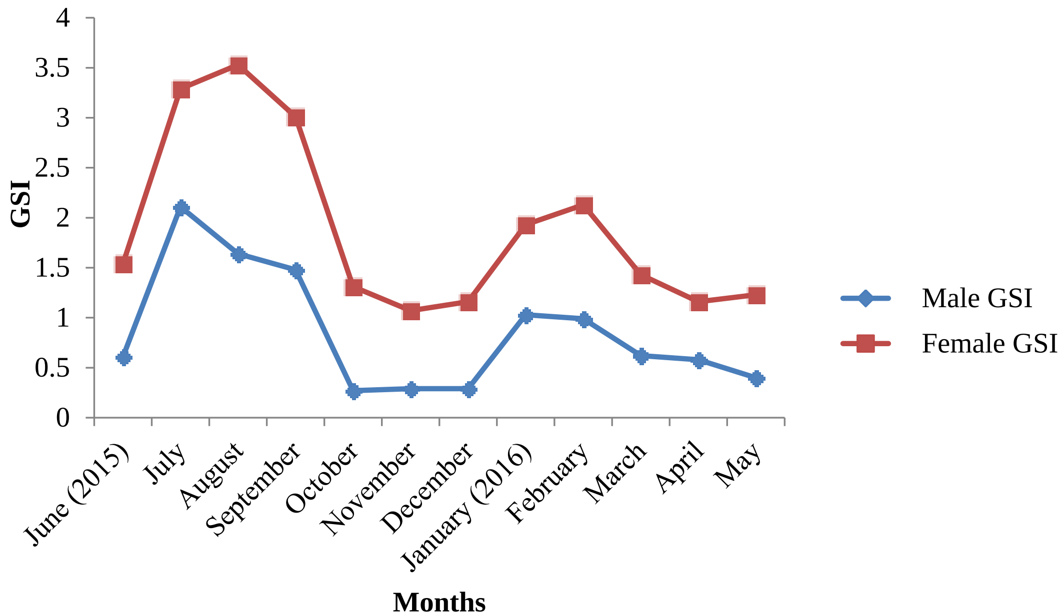

Figure 4. Monthly mean temporal variation in Gonado Somatic Index (G.S.I) of *O. niloticus* from Tekeze reservoir.

and food quality, feeding rate, degree of parasitism (Getachew, 1987; Teshima et al., 1987; stewart, 1988) and pollution have been reported to affect the condition factors of *O. niloticus* (Bakhoum, 1994; Khallaf *et al.,* 2003). Maternal mouth brooders like *O. niloticus* fast or take less food during the early stages and probably throughout the brooding period (Fryer and Iles, 1972) (Figure 1).

Gonado Somatic index (GSI)

Monthly variations in GSI of *O. niloticus* revealed that both sexes followed nearly the same trend; however, males had higher mean values in July whereas females have higher value in August (Figure 4). In females, two peaks of GSI values were observed during February and August (Figure 4). This means that females could breed more than once in a year.

Fecundity

Fecundity was estimated for 30 females ranging from 14 to 37 cm TL and 78.8 g to 711 g TW. The total number of ripe eggs ranged between 399 to 2129. The fecundity ranged between 104 to 709 eggs corresponding to fish length of 12.5 to 20.9 cm with an egg diameter of 1.0 to 3.0 mm (Gomez-Márquez et al., 2003). Pena – Mendoza et al. (2005) found that fecundity ranged from 243 to 847 eggs per fish (*O. niloticus*) in Zapata dam, Mexico with egg diameter from 3.00 to 3.70 mm. 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 (Kjesbu et al., 1989) and has been shown to be proportional to fish size (and hence, age) and condition. Thus, fish size and condition are key parameters to properly assess fecundity at the population level (Murua et al., 2003). In addition, the variation in fecundity may be attributed to differential abundance of food within the members of the population. Siddiqui et al. (1997) pointed out that fecundity increased with increased feeding levels. Moyle and Cech (2000) mentioned that in mouth brooding cichlids, the fecundity is considerably low because the parents assure the survival of the offspring, Fecundity was positively correlated with total weight (r=0.86), total length (r=0.77) and ovary weight (r=0.72) (Figure 5).

Conclusion

O. niloticus breed throughout the year however; August and February are the major breeding seasons. The length - weight relationship of female and male of *O. niloticus* in Tekeze Reservoir shows isometric growth pattern, indicating the well-being of the fish. However, the condition of the fish was found to be vary between months but not between sexes. Fecundity was more correlated with total weight than ovary weight. The physico-chemical parameters of Tekeze reservoir are generally optimal for the survival, growth and reproduction of *O. niloticus*. The fishing activities occurred during the

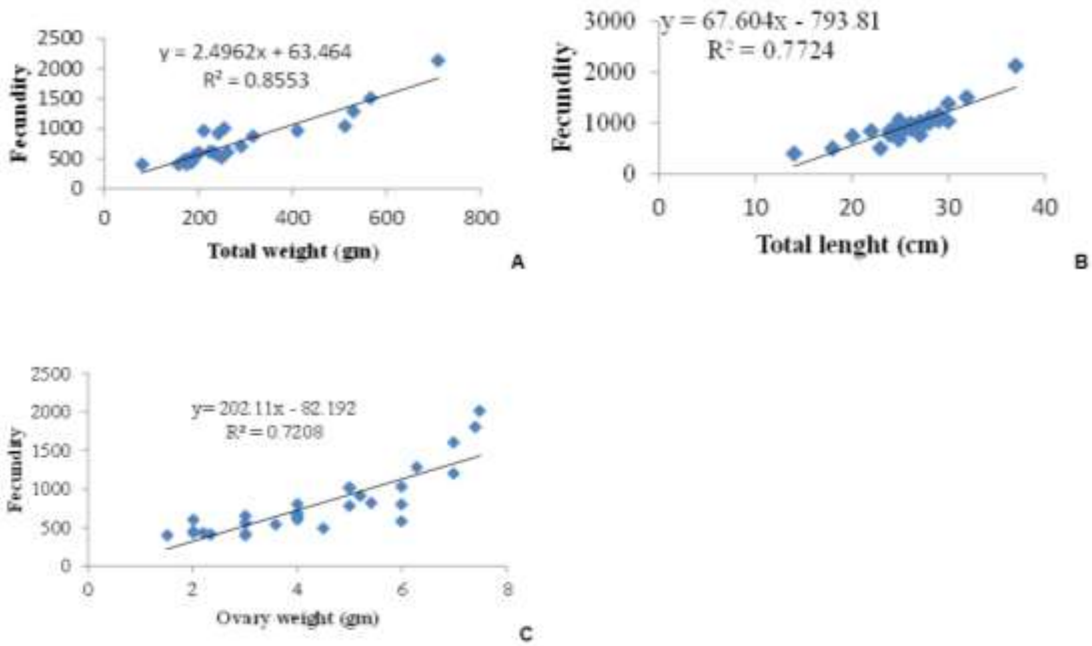

Figure 5. Relation between (a) fecundity and total weight (b) fecundity and total length (c) fecundity and ovary weight of *O. niloticus* from Tekze Reservoir

spawning period the major peak of breeding (July to September) should be regulated since that is the period of reproductive activities for Nile tilapia species (*O. niloticus)* at the reservoir. Therefore, the management option for the species should aim at protecting immature males and females so that they can reach breeding size and produce eggs to replenish the stock.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Abdel-Tawwab M, Mousa MA, Ahmad MH, Sakr SF (2007). The use of calcium pre-exposure as a protective agent against environmental copper toxicity for juvenile Nile tilapia, *Oreochromis niloticus* (L.). Aquaculture 264(1-4):236-246.

American Public Health Association (APHA) (1995). Standard methods for the examination of water and wastewater. 17th ed., American Public Health Association, New York, USA.

American Public Health Association (APHA) (2005). Standard methods for examination of water and waste water, 21st ed., American Public Health Association, New York, USA.

Babiker MM, Ibrahim H (1979). Studies on the biology of reproduction in the cichlid *Tilapia nilotica* (L): gonadal maturation and fecundity. Journal of Fish Biology 14:437-448.

Britton JR, Harper DM (2008). Juvenile growth of two tilapia species in Lakes Naivasha and Baringo, Kenya. Ecology of Freshwater Fish 17:481-488.

De Graaf GJ, Galemoni F, Huisman EA (1999). Reproductive biology of pond reared Nile tilapia, *Oreochromis niloticus* L. Aquaculture Research 30:25-33.

Fryer G, Iles TD (1972). The Cichlid Fishes of the Great Lakes of Africa: Their Biology and Evolution. Oliver and Boyd, Edinburgh, Scotland. P 641.

Gomez-Márquez JL, Peña- Mendoza B, Salgado-Ugarte IH, Guzmán-Arroyo M (2003). Reproductive aspects of *Oreochromis niloticus*. (perciformes: Cichlidae) at Coatetelco lake, Morelos,Mexico. Revista de Biología Tropical 51:221-228.

Humason GL (1972). Animal tissue technique. 3rd ed., San Franceisco, W.H. Freeman Co.

Kjesbu OS, Withames PR, Solemdal P, Greer MW (1989). Temporal variations in the fecundity of Arcto-Norwegian cod (*Gadus morhua)* in response to natural changes in food and temperature. Journal of Sea Research 40:303-332.

Kraus G, Tomkiewicz J, Kõster FW (2002). Egg production of Baltic cod in relation to variable sex ratio, maturity and fecundity. Canadian Journal of Fisheries and Aquatic Sciences 59:1908-1920.

Mehanna SF (2007). Stock assessment and management of the Egyptian Sole *Solea aegyptiaca* Chabanaud, 1927 (Osteichthyes: Soleidae), in the Southeastern Mediterranean, Egypt. Turkish Journal of Zoology 31:379-388.

Morales DA (1991). La Tilapia en México. Biología, Cultivo y Pesquerías. A G Editor, México, D.F. P 190.

Moyle BP, Cech JJ Jr. (2000). Fishes: An Introduction to Ichthyology. Prentice Hall, New Jersey, USA. pp. 123-144.

Murua H, Kraus G, Saborido-Rey F, Witthames PR, Thorsen A, Junquera S (2003). Procedures to estimate fecundity of marine fish species in relation to their reproductive strategy. Journal of Northwest Atlantic Fisheries Science 33:33-54.

Njiru M, Ojuok JE, Okeyo-Owuor JB, Muchiri M, Ntiba MJ, Cowx IG (2006). Some biological aspects and life history strategies of Nile tilapia *Oreochromis niloticus* (L.) in Lake Victoria, Kenya. African Journal of Ecology 44:30-37.

Pena-Mendoza B, Gómez-Márquez JL, Salgado-Ugarte IH, Ramirez-Noguera D (2005). Reproductive biology of *Oreochromis niloticus* (Perciformes: Cichlidae) at Emiliano Zapata dam, Morelos, Mexico. Revista de Biologia Tropical *53*(3-4):515-522.

Siddiqui AQ, Al-Harbi AH, Al-Hafedh YS (1997). Effects of food supply on size at first maturity fecundity and growth of hybrid tilapia, *Oreochromis niloticus* (L) × *Oreochromis aureus* (Steindachner), in outdoor concrete tanks in Saudia Arabia. Aquatic Research 28:341-349.

Tsegay T, Natarajan P, Zelealem Ty (2016a). Assessment of fishery activities for enhanced management and improved fish production in Tekeze reservoir, Ethiopia. International Journal of Fauna and Biological Studies 3(1):105-113.

Tsegay T, Natarajan P, Zelealem T (2016b). Analysis of Diet and Biochemical Composition of Nile Tilapia (*O. niloticus*) from Tekeze Reservoir and Lake Hashenge, Ethiopia. Journal of Fisheries and Livestock Production 4:172.

Witthames PR, Greer MW, Dinis MT, Whiting CL (1995). The geographical variation in the potential annual fecundity of dover sole, *Solea solea,* from European shelf waters during 1991. The Netherland Journal of Sea Research 34:45-58.