Length-Weight Relationship and Fulton's Condition Factor of the Nile Tilapia (*Oreochromis niloticus* L., 1758*)* in Lake Chamo, Ethiopia

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Abstract: *The objectives of the study were to determine the length-weight relationship and Fulton's condition factor of O. niloticus in Lake Chamo, Southern region of Ethiopia. Data for total length (TL), total weight (TW) and sex were collected from 5,778 fish samples (3577 females and 2201 males) for nine months (February to October 2018) from commercial fishery of Lake Chamo. The collected data were summarized using descriptive statistics (graphs and tables) and analyzed with the application of Microsoft Excel 2010 and SPSS Software. The length-weight relationship was calculated using power function and obtained as* $TW = 0.0112*TL^{3.14}$, *(*$R^2 = 0.96$*),* $TW = 0.0102*TL^{3.19}$*, (*$R^2 = 0.98$*) and* $TW = 0.0102*TL^{3.18,}$ *(*$R^2 = 0.97$*) for male, female and pooled sexes, respectively. The b value in this study was greater than the cubic (*$b > 3$*) value and indicates that both males and females of O. niloticus in Lake Chamo followed positive allometric growth pattern. The average Fulton's condition factor (K) value for male, female and combined sex was 1.78, 1.96 and 1.85, respectively. The one-way ANOVA (*$P > 0.05$*) revealed that Fulton's condition factor by month's interaction was insignificant. But the condition factor of both sexes in Lake Chamo was significantly different (ANOVA,* $p < 0.05$*). There was highly significant differences between sexes interaction (t-test,* $P = 0.000$*) which indicates the presence of temporal variation between both sexes in Fulton's condition factor. All the values of Fulton's condition factors of male, female and combined sex of O. niloticus were above 1.6 and indicates that O. niloticus of Lake Chamo was in a very good condition throughout the study period. Future studies including other species of fish are also recommended.*

Keywords: ***Fulton's condition factor, Lake Chamo, Length-weight relationship***

1. Introduction

Nile tilapia (*Oreochromis niloticus* L., 1758) contributes more than 50% of the total landings of fish caught per year in Ethiopian water bodies (Tesfaye and Wolff, 2014). In addition to this, the Nile tilapia are the most important fish species in both tropical and subtropical freshwater bodies and often playing a significant role of commercial fisheries in various African countries (Mohammed and Uraguchi, 2013). This is most probably due to their high range of tolerance to environmental conditions and the ability to accept artificially formulated and naturally available food items that make them commercially feasible (Adeyemi, 2009). In Ethiopian context, *O. niloticus* is the most edible fish species (Wudneh, 1998; Mitike, 2014). The O. niloticus is widely found in the Rift valley lakes, Abay, Awash, Baro-Akobo, Omo-Gibe, Tekeze and Wabishebele-Genale basins (Golubtsov and Mina, 2003; Awoke, 2015). Furthermore, it is also found in some other Ethiopian highland lakes and rivers (Golubtsov and Mina, 2003).

Length-weight relationships data of fishes are useful tools for biologists in fishery assessment and proper management of fish population (Martin-Smith, 1996). In addition, the length-weight relationship is used to obtain information about the condition of fishes to determine whether somatic growth is isometric or allometric (Gurkan and Taskavak, 2007; Ujjania *et al*., 2012).

Condition factor (K) is an important biological parameter, which indicates the suitability of a specific water body for growth of fish and an index of species average size (Alam *et al*., 2014). Many authors have also explained the importance of condition factor as a useful tool for assessing fish growth rate, age and feeding intensity (Abowei, 2006; Kumolu-Johnson and Ndimele, 2010; Oribhabor *et al*., 2011; Onimisi and Ogbe, 2015; Abu and Agarin, 2016). The relationship is also very essential for proper fish exploitation and management schemes and it is possible to estimate the average weight of fish at a given length (Lawson *et al*., 2013; Assefa, 2014; Ahmed *et al*., 2017; Getso *et al*., 2017; Kumar *et al*., 2017; Melaku *et al*., 2017; Muchlisin *et al*., 2017). The wellbeing of the fish is considered as a good indicator of various water bodies' health in relation to water pollution due to its cheapest means of determining the stress of water pollution on the fishes' body condition (Gupta and Tripathi, 2017).

O. niloticus is one of the edible fish species in Lake Chamo and is economically important with high acceptability by the consumers in Arba Minch as well as in the country. According to Shija *et al*. (2019), 93.1% of the total annual catch of *O. niloticus* was reported as immature and drastically reduced in yield. So, it is important to determine the growth pattern and conditions of fish in Lake Chamo. Therefore, the present study was aimed at determining the length-weight relationship and Fulton's condition factor of *O. niloticus* in Lake Chamo. The finding of this study would serve as an essential input for intervention in fish resource management and environmental conservation.

2. Materials and Methods

2.1. Description of the study area

Geographically Lake Chamo is located at 5°50ʹ59ʺ N and 37°33ʹ54ʺ E in Southern Nations Nationalities and People's Regional State of Ethiopia (Figure 1). The catchment and surface area of Lake Chamo is 1,109 km^2 and 329 km^2, respectively (Awulachew, 2006a, b). The catchment of the lake is characterized by a humid to hot semi-arid tropical climate with a bimodal rainfall pattern including two wet seasons (the first from end-March to mid-June, and the second from mid-September to late November) and two dry seasons (the first from December to mid-March, the second from end-June to mid-September) (Makin *et al*., 1975; Wagesho, 2014). Lake Chamo receives water from the rivers Kulfo, Sile and Elgo (Makin *et al*., 1975; Teklemariam, 2005). The flood plains and the deltas of the lake are fertile and hence have been under extensive agricultural cultivation since the last three decades (Fassil *et al*., 2018).

The fishery on Lake Chamo is almost exclusively conducted with a surface gillnet, although long–lines are also used to some extent to *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, monofilament is highly applicable in the fishery. The mesh size of gillnet used in the present study ranged from 3 to 8 cm.

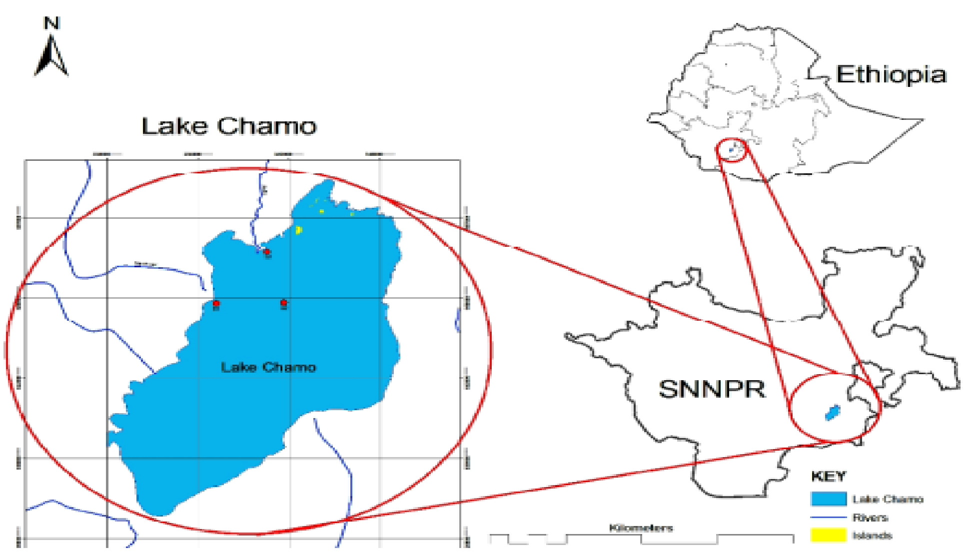

Figure 1: Location of Lake Chamo, Southern Ethiopia (Utaile and Sulaiman, 2016)

Table 1: Water quality parameters of Lake Chamo and recommended water quality limits for the protection of aquatic life

Variables	(Mean + SD)	Recommended limits	Sources	Explanations
Temperature (°C)	29.41+1.67	26-30	Boyd, 1990	The range for optimal growth of tropical fishes
pH	9.15+0.08	5-10	USEPA, 1986	Fishes may die if 5 <pH > 10
TSS (mg/L)	112.77+63.19	20-80	Alabaster and Lloyd, 1980	Suitable range for diverse fish species
DO (mg/L)	6.41+0.48	5	Akporhonor and Asia, 2007	The minimum concentration that allows survival of freshwater fishes
BOD (mg/L)	2.59+0.80	<5	US EPA 1997	Indicate the absence of biodegradable organic pollution
TDS (mg/L)	1232.80+13.04	1340	SETAC 2004	May cause adverse effects to fishes

Source: Utaile and Sulaiman (2016)

2.2. Methods of sampling and data collection

Samples of *O. niloticus* were collected monthly from February to October 2018 in randomly selected three days in a week from the fisheries of Lake Chamo. The trained fishermen were involved in data collection with regular following up by the researcher. The total length and total weight of fresh fish samples were measured to the nearest 1 mm and 1 g using measuring board and sensitive electronic balance, respectively. Length-weight relationship was calculated using power function (Le Cren, 1951).

$$TW = aTLb \qquad [1]$$

Logarithmic transformation of the formula indicated above [1] gives a linear equation as indicated below.

$$Ln\, TW = \ln a + b * \ln TL \qquad [2]$$

Where,

TW = total weight (g)
TL = total length (cm)
a = the intercept
b = the slope of length-weight regression

The confidence limit for the slope (b) was estimated using the formula described by King (1995), which is indicated below.

$$95\%\ confidence\ limit\ = b \pm t * Sb \qquad [3]$$

Where,

b = slope in length weight relationship
t = table value of t (t test at 95 % confidence)
Sb = the standard error of slope b

The Fulton's condition factor (K) is often used to reflect the nutritional status or well-being of an individual fish. It was calculated by using the formula described by Fulton (1904) which indicated below.

$$K = \left(\frac{\text{TW}}{\text{TL3}}\right) * 100 \qquad [4]$$

Where,

TW = total weight of fish in gram (g)
TL = total length of fish in centimeter (cm)

2.3. Data analysis

The data analyses were done using Microsoft Office Excel (2010) and SPSS software.

3. Results and Discussion

3.1. Length-weight relationship

A total of 5,778 fish samples comprising 3,577 females and 2,201 males were collected from the landing sites for the study. Based on the collected data, the length-weight relationship of *O. niloticus* in Lake Chamo was curvilinear. The relationship representing male, female and pooled (both sexes) are presented in Figure 2, 3 & 4, respectively. According to the results, the rate of increase in body weight was inversely proportional to length. It is the same relationship as has been reported by earlier authors for the same species in Lake Chamo (Teferi and Admassu, 2002), in Lake Hayq (Worie and Getahun, 2014), in Lakes Koka, Ziway and Langano (Tesfaye and Tadesse, 2008).

The 95% confidence limits for the slope (b) of length-weight relationship of male, female and pooled data were estimated following the formula in equation [3] and indicated below.

Male: 3.11 – 3.16
Female: 3.17 – 3.20
Pooled: 3.16 – 3.19

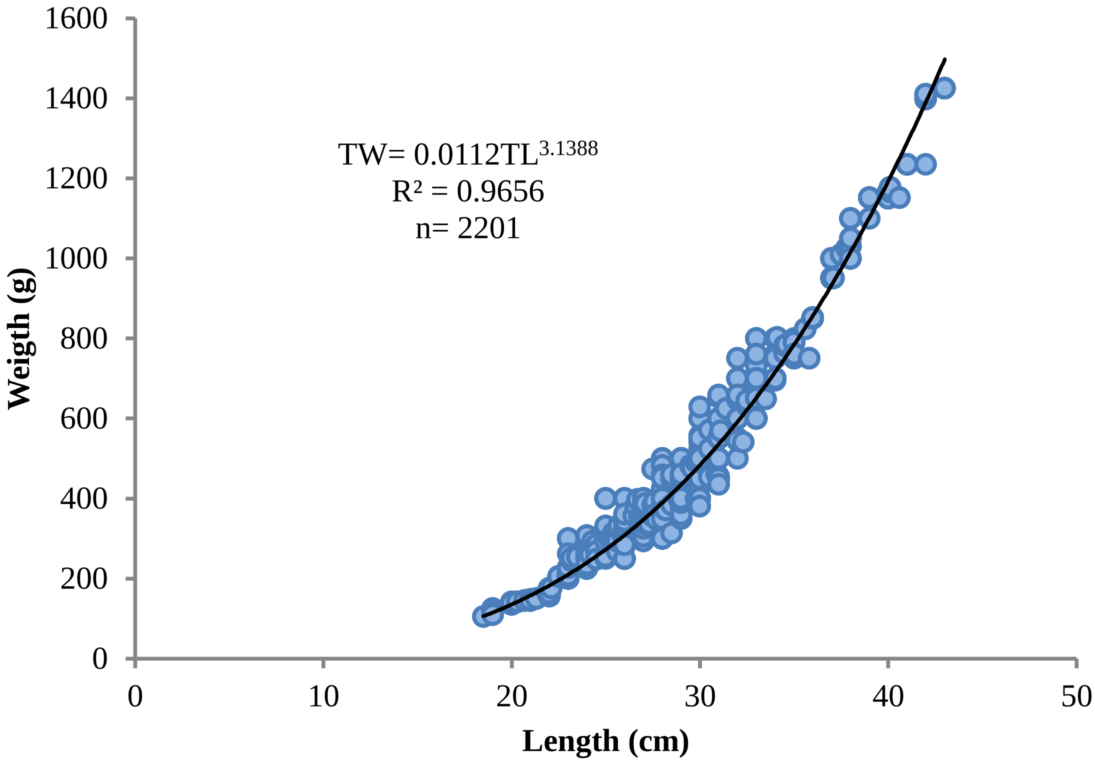

Figure 2: Length-weight relationship of male *O. niloticus* in Lake Chamo
TW = total weight; R^2 = coefficient of determination; n = number of sample

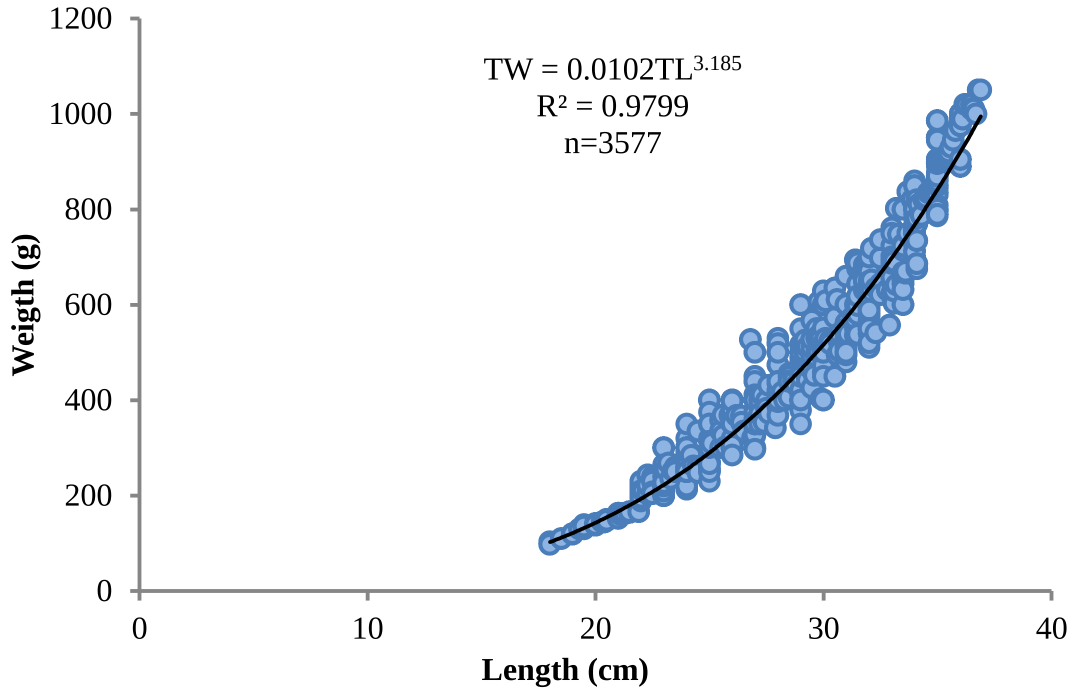

Figure 3: Length-weight relationship of female *O. niloticus* in Lake Chamo
TW = total weight; R^2 = coefficient of determination; n = number of sample

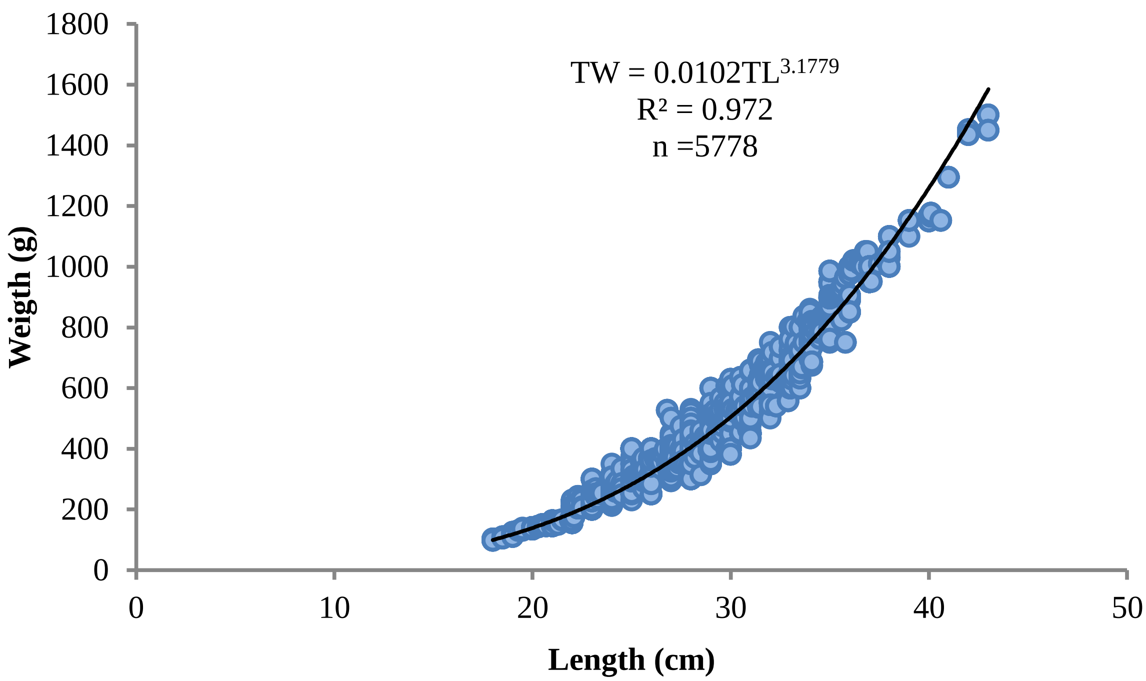

Figure 4: Length-weight relationship in both sexes (pooled) of *O. niloticus* in Lake Chamo
TW = total weight; R^2 = coefficient of determination; n = number of sample

There is high significant difference between *b* and the cubic value (b^3) in both sexes and pooled data (Table 2). The calculated t-value was much higher from the tabulated t-value, which justifies that the *b* value calculated based on length-weight data of *O. niloticus* was significant. The exponential value of all cases was tested against '3' and was found to be significantly different at the 5% confidence interval level. When the value of *b* was smaller, equal and larger than 3, it indicates negative allometry, isometry and positive allometry, respectively (Nehemia *et al*., 2012). Fish can attain an isometric, negative or positive allometric growth pattern. In isometric growth, the fish does not change the shape of its body as it continues to grow while negative allometric growth shows the fish becomes thinner as its body weight increases as opposed to a positive allometric growth that implies the fish becomes relatively broader and fatter as its length increases (Riedel *et al*., 2007). As the *b* value in this study was greater than the cubic value, both males and females of *O. niloticus* in Lake Chamo follows positive allometric growth pattern. The *b* value (3.18) obtained in the present study was higher than the values obtained in the earlier studies for the same species in some lakes of Ethiopia.

The earlier studies showed that the *O. niloticus* in Lake Chamo, Ziway, Hawassa, and Tana was found to have *b* values of 2.98 (Teferi and Admassu, 2002), 3.03 (Tadesse, 1988), 2.90 (Admassu, 1990), and 2.74 (Tadesse, 1997), respectively, which indicate negative allometric growth pattern except for Lake Ziway. The *b* value in this study opposes the value in the previous study in Lake Chamo and the variation in growth pattern could be due to different ecological parameters during the study periods which comprises of several biotic and abiotic interactions depending on seasonality. According to Bagenal and Tesch (1978) and Froese (2006), the variation in the value of *b* takes place due to season, habitat, gonad maturity, sex, diet, stomach fullness, health, preservation techniques and annual differences in environmental conditions.

The *b* value in the present study was comparable to that of Lake Victoria (3.20) (Njiru *et al*., 2006), 3.16 (Steve and Okeyo, 2019**).** The R^2 values estimated in the present study was very close to 1 that shows the accuracy of data and methodology followed for the estimation of relationship.

Parameters	**Male**	**Female**	**Pooled**
a value	0.0112	0.0102	0.0102
b value	3.1388	3.185	3.1779
Std. error (S_b)	0.013	0.008	0.007
r^2	0.9656	0.9799	0.972
t value (calculated)	10.68	23.13	25.41
t critical at 5%	1.96	1.96	1.96
Number of observations	2201	3577	5778
Significance	Highly significant	Highly significant	Highly significant

The analysis of variance of the regression coefficient (ANOVA) for testing regression coefficient of length and weight of *O. nilotcus* were presented in Table 3.

Table 3: ANOVA table of regression analysis

	Regression			Residual			Total		
	Male	Female	Combined	Male	Female	Combined	Male	Female	combined
SS	663.92	1215.86	1934.10	23.68	26.67	55.74	687.61	1242.53	1989.84
DF	1	1	1	2199	3575	5777	2200	3576	5778
MS	663.92	1215.86	1934.10	0.011	0.007	0.01			
F	61639.66	162993.58	200446.74						
Sig.	0.000	0.000	0.000						

The calculated value of the coefficient of correlation (r) along with the coefficient of determination (r^2), adjusted r^2 and Standard Error of the estimate is presented in Table 4. The result shows that there is a high degree of correlation between r and r^2 parameters which justifies the fact that there was a strong significant relationship between length and weight.

Table 4: Calculated values of correlation (r) and determination (r^2) coefficient, adjusted r^2 and Std. error

Sex	R	r^2	Adjusted	Std. error
Male	0.983[a]	0.966	0.966	0.104
Female	0.989[a]	0.979	0.979	0.086
Combined	0.986[a]	0.972	0.972	0.098

3.2. Fulton's condition factor

Monthly mean Fulton's condition factor (K) values ranged from 1.75 to 1.79 for males, 1.85 to 1.97 for females and 1.81 to 1.90 for combined sex (Table 5). The average K value for male, female and combined sex was 1.78, 1.92 and 1.87, respectively. Unlike the present study, Teferi and Admassu, (2002) reported a high value of K (2.35) in Lake Chamo. The average K value of O. niloticus in this study was lower than the values reported for the same fish species from Lakes Koka (1.87) (Tesfaye and Tadesse, 2008), Hawassa (2.03) (Abebe and Tefera, 1992).

The variation in the K value might 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.

The study of condition assumes that heavier fish of a given length is in a better condition. The indices have been used by fishery biologists as indicators of the general "well-being" or "fitness" of the population under consideration (Jones *et al*., 1999). The condition factor is used to evaluate the sensitivity and healthy condition of fish (Jin *et al*., 2015). The values of condition factor depend on physiological features of fish especially maturity, spawning, life cycle, environmental factors and food availability in a water body (Ujjania *et al*., 2012; Dan-Kishiya, 2013). Morton and Routledge (2006) divided the K values into five categories as follows: very bad (0.8–1.0), bad (1.0–1.2), balance (1.2–1.4), good (1.4–1.6) and very good (> 1.6). On the other hand, Ayoade (2011) suggests that the condition factor higher than one is a good fish health condition. Thus, all the values of Fulton's condition factors of male, female and combined sex of *O. niloticus* were above 1.6 and indicates that *O. niloticus* of Lake Chamo was in a very good condition throughout the study period. Variations in the condition factor of many fishes is believed to be related to their reproductive cycle (Narejo *et al*., 2002), feeding rhythms, physio-chemical factors of environment, age, physiological state of fish or some other unknown factors (Dar *et al*., 2012).

Table 5: K values of male and female *O. niloticus* in Lake Chamo sampled from February 2018 to October 2018

Months	Male	Female	Combined
February	1.78	1.96	1.89
March	1.78	1.97	1.89
April	1.78	1.94	1.88
May	1.79	1.96	1.90
June	1.79	1.93	1.89
July	1.75	1.94	1.88
August	1.75	1.89	1.84
September	1.75	1.85	1.81
October	1.76	1.86	1.82

The K values by month's interaction was insignificant (one-way ANOVA, $P > 0.05$; Table 6) but the condition factor of both sexes in Lake Chamo was significantly different (ANOVA, $p < 0.05$; Table 7). The t-test also revealed high significant difference between sexes interaction (t-test, $P = 0.000$) indicating that K temporal variation of both sexes was different in the present study.

Table 6: One-way ANOVA table of K by months

K	Sum of squares	df	Mean square	F	Sig.
Between groups	0.013	8	0.002	0.139	0.995
Within groups	0.109	9	0.12		
Total	0.123	17			

Table 7: One-way ANOVA of K by sex

K	Sum of squares	df	Mean square	F	Sig.
Between groups	0.104	1	0.104	90.891	0.000
Within groups	0.018	16	0.001		
Total	0.123	17			

The condition of fish can be affected by several factors such as the environment, availability of food, stress, food quality, feeding rate, degree of parasitism and reproductive activity (Tefera, 1987; Stewart, 1988; Tadesse, 1997). It is also a useful index for monitoring feeding intensity, age, and growth rates in fish (Ujjania *et al*., 2012). Maternal mouthbrooders like *O. niliticus* take less food during the early stages and probably throughout the brooding period (Fryer and Iles, 1972). The males are also busy in building and guarding nests and fertilizing many females (Tadesse, 1997).

In general, the K values of females were higher than males in all the studied period and it might be due to the higher gonad weight of females than males which 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.

4. Conclusion

The *O. niloticus* of Lake Chamo followed positive allometric growth pattern which implies that the fish became relatively broader and fatter as its length increased. The body condition of the fish was found to be insignificantly different between months but significantly different between sexes and indicates that the FCF temporal variation of both sexes was different. The values of Fulton's condition factors of male, female and combined sex of *O. niloticus* were above 1.6 and indicates that *O. niloticus* of Lake Chamo was in a very good condition throughout the study period. Even if the K value of *O. niloticus* in Lake Chamo was in a better condition, it was lower than the values from earlier studies conducted on the same fish species in the same study area. As the differences in the K value indicate the changes in the general conditions of the lake, it is advised to undertake conservation and rehabilitation of the buffer zone of the Lake. Moreover, considering other species of fishes of Lake Chamo is also recommended in future research.

Conflicts of Interest

The author declares that there is no conflict of interest in publishing the manuscript in this journal.

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