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Length-weight relationships and condition factor of Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758) (Cichlidae) in Koka Reservoir, Ethiopia

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Abstract
A study was conducted to analyse the length-weight relationship and condition factor of Nile tilapia (Oreochromis niloticus) in Koka Reservoir, Ethiopia. A total of 132 fish samples were collected, measured and data analysed. The length and weight relationships of this fish species was found to be highly correlated (r = 0.964) and significant at the 0.01 level. The parameters 'a' and 'b' of the length – weight relationship were estimated using the formula $W=aL^b$, while the condition factor was calculated from the equation $K=W/L^3x100$. The 'b' values in the length-weight relationships were; males (3.210), females (2.868) and both sexes combined (3.170). Males and combined sexes exhibited positive allometric growth, while the females exhibited negative allometric growth pattern. The mean condition factor (K) of the specimen produced male, female and combined sex values of 1.64, 1.70, and 1.66, respectively. All the K values were found to be greater than 1, mathematically indicating a healthy status and general well-being of Oreochromis niloticus in Koka Reservoir. The length-weight relationship and condition factor study was found to be a useful method in assessing the well-being and growth performance of the fish species in the Reservoir.

Keywords: condition factor, length-weight relationships, Koka Reservoir, *Oreochromis niloticus*

Introduction

Nile tilapia (*Oreochromis niloticus*) is an important commercial fish species, distributed in all the rift valley lakes of Ethiopia [1]. According to [2], it is also found in some other Ethiopian high land lakes and rivers. It contributes more than 50% of total landings of fish catch per year in Ethiopia [3], and considered as the most edible fish species [4]. This species is found throughout the year in Koka Reservoir, economically contributing to the well-being of the nearby community. Length-weight relationship of a fish species can serve as a baseline information for the development of proper utilization and management schemes of fish resources of any water bodies, because it can assist in estimating the average weight of fishes at a given length. According to [5], length-weight relationship is used in estimating biomass from length data and condition factor. Length-weight relationship measurement is also a useful tool that provides important information concerning the structure and function of fish populations in any aquatic systems [6]. Biotic and abiotic environmental factors, genetic make-up of the fish species, and trophic status of a given aquatic ecosystem are considered as the main cause for the difference in length-weight values. The relationship between the length (L) and weight (W) of a fish is usually expressed by the equation $W=aL^b$, where 'a' is the intercept and 'b' is the allometry coefficient. Values of the exponent 'b' provide information on fish growth. When 'b' = 3, increase in weight is isometric. When the value of 'b' is other than 3, weight increase is allometric (positive if 'b' >3, negative if 'b' <3). This is a useful tool that provides important information concerning the structure and function of fish populations [6]. Condition factor (the coefficient of body condition) is a good parameter that shows the wellbeing of fishes in their natural habitats or in aquaculture, because it indicates different biological and ecological factors in relation to the fishes' feeding habits [7]. However, condition factor is also influenced by stress, sex, season, availability of food and the water quality in the environment in which the fishes live. Better body condition is correlated with high values of condition factor and poor body condition is obtained when the values of condition factor is less [8]. The health of water bodies, in relation to pollution, can also be detected with the mathematical approach of the length -weight relationship and condition factor (wellness) of the fishes as these variables are directly affected by any water polluting substances [9]. Condition factor has been generically described as the well-being or robustness of an individual fish [10] and has typically been estimated by comparing individual fish weight of a given length to a standard weight. Condition factor has also been estimated by directly measuring physiological parameters related to the energy stores such as tissue lipid content and reproductive status [11]. The study of length-weight relationship and condition factor of freshwater fish species is a base for the development of a successful management program on fish capture and culture in wild and controlled environments. Hence, the information is vital for management of the fish taken from their habitats, feeding habits and species interaction under culture systems [12]. This research is therefore planned to study the length-weight relationship and condition factor of tilapia (*Oreochromis niloticus*) fish species at Koka Reservoir, Ethiopia.

2. Materials and Methods

2.1 Description of the Study Area

Koka Reservoir (Latitude 08^{0}24'0"N and Longitude 39^{0}35'0"E) is formed as a result of damming of the Awash river for the purpose of hydropower in the late 1960's. The surface area of the Reservoir is 250km^2 with a maximum and mean depth of 14m and 9m, respectively [13]. It is located at an altitude of 1,590m above sea level and about 90km southeast of Addis Ababa (Figure 1). The region around Koka Reservoir has a total average annual rainfall of about 630mm and an average surface water temperature of 19^0C (averaged for the period between 1998 and 2009) [14].

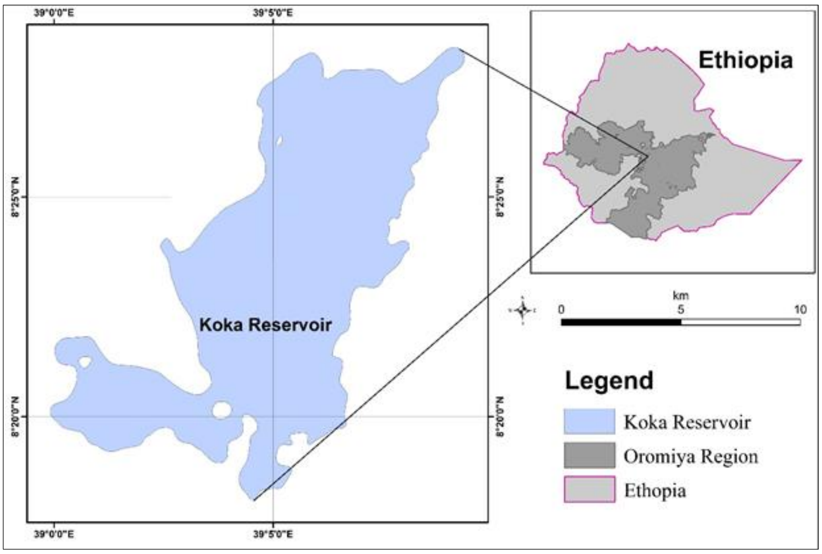

Fig 1: Map of the study area

2.2 Fish sampling and measurement

A total of 132 Nile tilapia (*Oreochromis niloticus*) fish samples caught by fishermen were purchased on their arrival at the landing site and immediately taken to the nearby laboratory of the Batu Fish and Other Aquatic Life Research Centre. The length of fish was measured with centimetre scale to the nearest centimetre and body weights were measured using a digital balance to the nearest gram. Sex of the fishes was identified by dissection. The fish maturity stages were determined by visual examination of the gonads and using a five point maturity scale [16]. The species was then categorized into three groups vis., group I males (N=82), group II females (N=50), and group III combined sexes (N= 132) for convenience of interpretation. An equation in the form of $W = aL^b$ (which was transformed to logarithm of the form Log W = Log a + b Log L), where W is the body weight of fish in grams, L is the total length in centimetres, 'a' is the intercept and 'b' is the slope of the regression line was used to calculate the relationship between length (L) and weight (W) of fish [17]. The Condition factor (K) was estimated using the formula $K=W/L^3x100$ [18], where K is the condition factor, W is the body weight of fish in grams, and L is the total length in centimetres.

2.3 Data Analysis

Data were analysed using the statistical package [19, 20]. Means were expressed as $\pm$ SD and compared using t-test. The length-weight relationship were carried out using regression analysis. The parameters 'a' and 'b' of the length-weight relationship was obtained using the linear regression based on logarithmic transformation of the formula ($W=aL^b$). Values were significant at $P \leq 0.05$. The condition factor was calculated using Microsoft Excel [20] from the equation $K=W/L^3x100$, where K is the condition factor, W is the body weight of fish in grams, and L is the total length in centimetres.

3. Results

A total of 132 specimens of *Oreochromis niloticus* were collected for this study. The length-weight frequency distribution of the fishes in Koka Reservoir is shown in Table 1. There were significant difference in length ($t_{0.05,}$ 130 = -3.402, P = 0.001) and weight ($t_{0.05,}$ 130 = -3.317, P = 0.001) between males and females, the females being taller and heavier.

Table 1: Length and weight frequency distribution and gonad maturity stages of *Oreochromis niloticus* in Koka Reservoir

Variables	**Total Length (cm)**				**Weight (gm.)**		
Sex:	**N**	**Minimum**	**Maximum**	**Mean ± SD**	**Minimum**	**Maximum**	**Mean ± SD**
Male	82	16.03	29.94	22.09±2.56	62.75	492.03	185.29±71.78
Female	50	20.04	29.01	23.53±1.98	134.37	389.63	225.30±58.90
Combined sex	132	16.03	29.94	22.63±2.45	62.75	492.03	200.44±69.73
Gonad Maturity Stages:	I	II	III	IV	V		
Frequency of Gonad Maturity:	32	56	19	23	2		

Note: Stage I = Immature or virgin, Stage II = Developing virgin or recovering spent, Stage III = Maturing or ripening, Stage IV = Ripe and running, Stage V = Spent.

The frequency of male and female gonad maturity stages of the sampled fishes was depicted in Figure 2. Fifty percent of males with a gonad maturity stage of I and II, and females with a gonad maturity stage of II, III and V were observed in the sampled fishes.

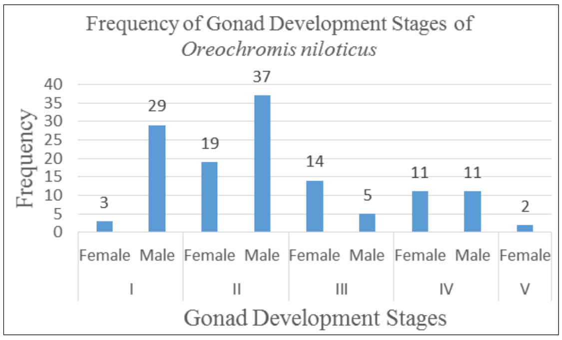

Fig 2: Frequency of gonad development stages of *Oreochromis niloticus* in Koka Reservoir

3.1 Length-weight relationships

Length-weight relationship of the specimen of males, females and combined sexes of tilapia (*Oreochromis niloticus*) were calculated based on the logarithmic transformation of the data, and the regression graph of the total length and weight relationship of the species is shown in Figures 3 to 5. When sexes were separated, male (Figure 4) and female (Figure 5) *Oreochromis niloticus* had different allometry coefficient values of 3.210 and 2.868, respectively. When both sexes are combined (Figure 3), the regression slope was 3.170 indicating that the fish had positive allometric growth. The exponent of (b) value of the females is less than 3, indicating that they exhibit negative allometric growth, i.e., increase in length was not balanced by the weight gain or the weight gain was slower than length gain. The length-weight relationship equations and their parameters were given in Table 2.

Table 2: Equations of the length-weight relationship and their parameters

Sex	Equations	'b'	Coefficient of determination (r^2)
Male	Log W=3.2095LogTL-2.0698	3.2095	0.9678
Female	Log W=2.868LogTL-1.5919	2.868	0.8991
Combined sexes	Log W=3.1703LogTL-2.0131	3.1703	0.9561

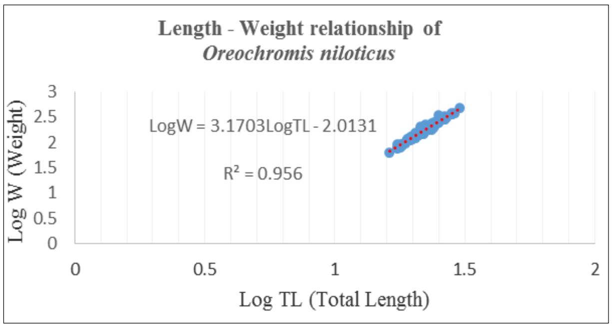

Fig 3: Length–weight relationship of *Oreochromis niloticus* at Koka Reservoir (Both sexes considered)

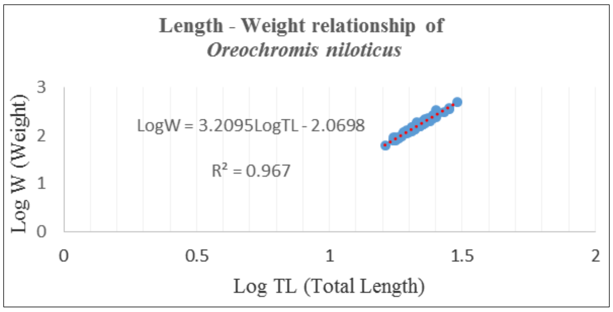

Fig 4: Length-weight relationship of *Oreochromis niloticus* at Koka Reservoir (Only males)

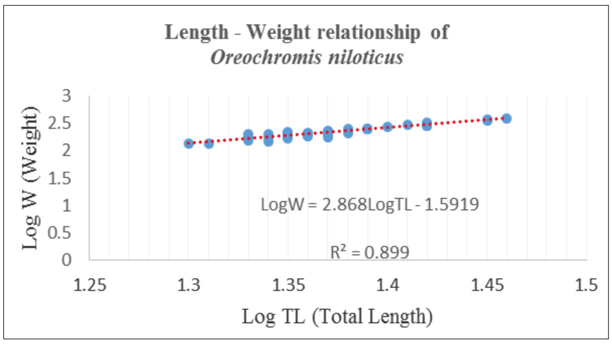

Fig 5: Length –Weight relationship of *Oreochromis niloticus* at Koka Reservoir (Only females)

3.2 Fish Condition Factor

A sign of overall fish condition was employed to compare length and body weight with the assessment of overall fitness and outputs of a particular specimen or individual [21]. The Fulton condition factor (K) of male fish ranged from 1.41 to 2.19, with an average value of 1.64±0.12, while the K value of female fish ranged from 1.39 to 2.14 with an average value of 1.70±0.13. In addition, the K value of combined sexes (male and female) ranged from 1.39 to 2.19, with an average value of 1.66±0.13 (Figure 6). The result indicated that female fishes had higher average K value suggesting that they are well adapted to the environmental conditions in Koka Reservoir than males. The t-test also indicated that there was significant difference ($t_{0.05}$, 130 = -2.650, P = 0.009) in condition factor between male and female fishes, females were being in a good condition during the study period.

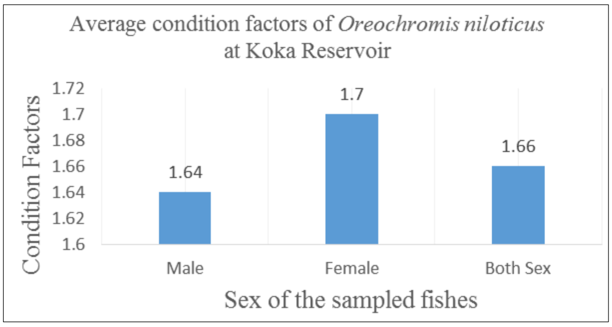

Fig 6: Condition Factors of *Oreochromis niloticus* at Koka Reservoir

4. Discussion

The Length-weight relationship provides important information concerning the structure and function of fish populations. If several weight-length relationships are available for a species, then plot of log 'a' over 'b' will form straight line and helps in detection of outliers [22]. In this study, the length and weight relationship of *Oreochromis niloticus* was very high (r = 0.964) and significant at the 0.01 level. The calculated high correlation coefficient value (r) shows that the model used (linear regression) for the analysis was reliable and fitted the data very well. Besides, it indicated that body weight of this species increases as the total length increase. According to [23], concept of cube law hypothetically suggested that the value of ‘b’ for an ideal fish needs to be 3.0, which represents an isometric growth and it was used in the present study for the comparison purposes. The value of regression coefficient ‘b’ ranged from 2.868 to 3.210, with no fish population exhibiting an isomeric (b=3) relative growth, which doesn’t maintain their specific body shape throughout their life. Fish undergoing positive allometric growth is an indication of stoutness of the body with increase in length. *Oreochromis niloticus* at Koka Reservoir had both negative and positive allometric growth pattern as the value of regression coefficient ‘b’ was less than 3 for females, and greater than 3 for males and combined sexes. Thus, for females the rate of weight gain is less than the increase in length, probably due to the timing of the batch where females empties their gonad loosing energy for egg production, hence less weight in relation to their length, and for males and combined sexes, the weight of fish was higher as compared to the cube of its length. This negative allometric growth of female fishes in a way tells that the environment is not suitable for isometric fish growth and reproduction. The same negative allometric growth pattern had been reported for different fish species in different water bodies. According to [24], a negative allometric growth can be caused by environmental factors such as overfishing, food competition and trophic potential of rivers and ponds. Koka Reservoir is a water body that is affected by pollution (e.g., tannery effluents and horticultural industry wastes), uncontrolled human interactions with ecosystem (e.g., illegal fishing with inappropriate mesh size), and lack of transparent and efficient regulatory institution [25]. The ongoing pollution and misuse of resources in this Reservoir directly or indirectly affect the growth of the fish.

Gonad maturity is correlated with the age of a fish. The sampled fishes indicated that 50% of male fishes were with gonad development stage I (immature or virgin) and II (developing virgin or recovering spent), clearly indicating that they were harvested even before they reach at a reproductive age. The same was true for the females whereby 16.67% fishes were at stages I and II of the gonad development (developing virgin or recovering spent). Besides, 20% of fishes at stage III (maturing or ripening) and V (ripe and running) were also caught, threatening the continuity of this species.

Condition factor is an index which indicates the physiological state of the fish with regard to feeding, spawning and other aspects related to the wellbeing of the fish. High condition factor values indicates favourable environmental conditions (such as: habitat and prey availability), and low values indicate less favourable environmental conditions [10]. There are several factors which affect the condition factor like sorting into classes, sex, stages of maturity and state of stomach. In the present study, the value of condition factor of the female *Oreochromis niloticus* was higher than the other two i.e., males, and combined sexes (males and females) during the study period. This increased condition factor of females is due to the sexual maturation of the sampled female fishes, which relatively included more fishes at a gonad development stage of III, IV and V. According to [26], the condition factor usually increases when sexual maturation approaches. Values higher than 1 for intensively fed female Nile tilapia in aquaculture ponds was recorded in USA [27], where by higher values for females than for males under the same feeding program was reported, which agrees with the result of this study. In the same manner, values between 1.5 and 1.8 were recorded in Lake Nyamusingiri and Lake Kyasanduka in Uganda [28].

5. Conclusions

The total length and weight of *Oreochromis niloticus* at Koka Reservoir is highly correlated to each other (r= 0.964). The regression coefficient ‘b’ shows positive allometric growth (b>3) for males and combined sexes (male and female), and negative allometric growth pattern for females showing that the rate of weight gain is less than the increase in length in females. The values of condition factor for both males, females and combined sexes (males and females) were >1.0 indicating that *Oreochromis niloticus* fish species in Koka Reservoir are in a good condition and wellbeing. The length-weight relationship and condition factor study was found to be a useful method in assessing the well-being and growth performance of the fish species in the Reservoir.

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