Length-weight relationship, Fulton's condition factor and sex ratio of *Bagrus docmak* (Forsskål, 1775) in Lake Chamo, Ethiopia

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Abstract: *The objectives of the study were to determine the length-weight relationship, Fulton's condition factor, and sex ratio of Bagrus docmak in Lake Chamo. Total length (TL), total weight (TW), and sex data were collected from 469 fish samples (268 females and 201 males) for one year (January to December 2021) from the commercial fishery of Lake Chamo. The collected data were summarized by 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 the power function and obtained as* $TW = 0.0087*TL^{3.0272}$, $(R^2 = 0.8959)$, $TW = 0.0052*TL^{3.1412}$, $(R^2 = 0.9281)$ *and* $TW = 0.0063*TL^{3.0998}$, $(R^2 = 0.9152)$ *for females, males and combined sexes, respectively. The regression coefficient "b" was significantly different from the cubic value "3" (P < 0.05), implying that B. docmak of Lake Chamo followed a positive allometric growth pattern. There was a significant deviation in the sex ratio of male to female (1:1.33) from the hypothetical 1:1 ratio* ($\chi^2 = 4.79$; $P < 0.05$). *The average Fulton's condition factor for females, males, and combined sexes was 1.01, 0.97, and 0.99, respectively. The one-way ANOVA (P > 0.05) revealed that Fulton's condition factor between sexes was insignificant. But it was significantly different in the months of interaction (ANOVA, P < 0.05). The t-test also revealed a highly significant difference in a month's interaction (t-test, P = 0.000) indicating the seasonal variation in the mean monthly condition factor. The condition factor indicated that the health condition of B. docmak was not as good. Heavy fishing pressure and different agricultural practices were taking place around the lake which might disturb and break the chain of food availability in addition to other biotic and abiotic factors. Further investigations on water quality parameters and other biological aspects such as feeding habits and reproductive biology of B. docmak shall be undertaken for the management of the fish stocks in the lake.*

Keywords: Condition factor, Lake Chamo, fish sex, water quality

1. Introduction

Bagrus is a genus of Bagrid catfishes that are native to Africa and Asia (Nelson, 2006). *Bagrus docmak* is one of the commercially important fish species in Ethiopia. It occurs in the most southern rift valley lakes like Abaya and Chamo (Shibru, 1973), in the Segen River (Risch, 1986), and in the Nile system (Golubstov *et al*., 1995).

Fish length-weight relationships are useful for converting length observations into weight estimates to provide some measure of biomass (Froese, 1998). Length-weight relationships have been used frequently to estimate weight from length because direct weight measurements can be time-consuming in the field (Sinovcic *et al*., 2004). Knowledge of length-weight relationships and population dynamics of the fish is vital in fishery science and management (Lizama and Ambrosio, 2002; Ahmed *et al*., 2003). Also, knowledge of the sex ratio of fish is important to ensure proportional fishing of two sexes and provides information necessary for assessing the reproductive potential of a population (Vazzoler, 1996).

The condition factor is a method by which the physical condition and seasonal variation in the well-being of an individual fish could be known (King, 1995). The condition factor (K) is a quantitative parameter of the well-being, and state of the fish and reflects recent feeding conditions (LeCren, 1951). The growth of any fish is related to the prevailing environmental conditions. Many authors have 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 length-weight relationship is also very essential as it is possible to estimate the average weight of fish at a given length (Lawson *et al*., 2013; Ahmed *et al*., 2017; Getso *et al*., 2017; Kumar *et al.*, 2017; Melaku *et al*., 2017; Muchlisin *et al*., 2017). The well-being 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 fish's body condition (Gupta and Tripathi, 2017).

Bagrus docmak is one of the four commercially important fish species with 8% catch contribution in Lake Chamo fishery (Shishitu *et al*., 2021). It is highly regarded by local people as food fish because it has few intramuscular bones. The catch contribution and production of *B. docmak* was drastically declined in Lake Chamo fishery (Shishitu *et al*. 2021). Length-weight relationship and condition factor are very important tools of fishery management as it provides information about the growth of the fish, its general wellbeing, and fitness in a water body. Therefore, this study was aimed to determine some aspects of the length-weight relationship, sex ratio, and condition factor of *B. docmak* in the lake to provide the necessary scientific information for proper utilization and management of the stock.

2. Materials and Methods

2.1. Description of the study area

Lake Chamo (5°50ꞌ59ꞌꞌ N; 37°33ꞌ54ꞌꞌ E) is located 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, 2006). 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 (a first from end-March to mid-June, a second from mid-September to late November) and two dry seasons (a first from December to mid-March, a 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 floodplains and the deltas of the lake are fertile and hence have been under extensive agricultural cultivation for the last three decades.

There are four commercially important fish species in Lake Chamo which are Nile tilapia (*Oreochromis niloticus*), African catfish (*Clarias gariepinus*), Nile perch (*Lates niloticus*) and *Bagrus docmak*. The fishery on Lake Chamo is almost exclusively conducted with a surface gillnet, although long–lines are also used to some extent for African catfish (*Clarias gariepinus*) and *Bagrus docmak*. The nets are prepared locally by fishers themselves or by some other people involved in fishing gear-making activity. Also, a monofilament gillnet is used and it is obtained from abroad illegally and it is dangerous as it causes overfishing.

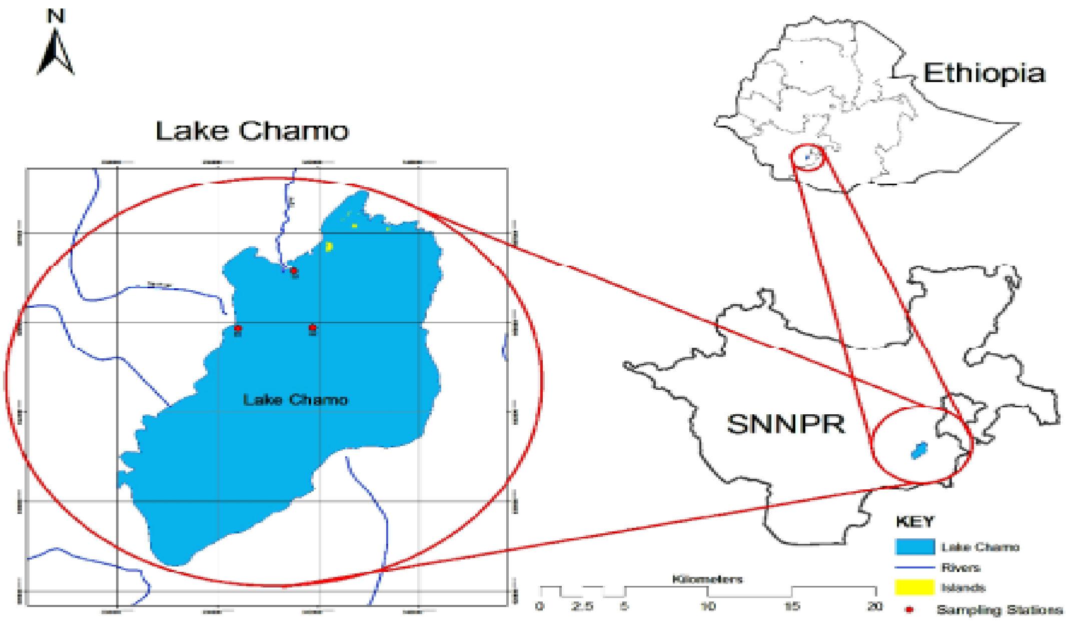

Figure 1: Location of onshore and offshore sampling stations at Lake Chamo, Southern Ethiopia (Utaile and Sulaiman, 2016)

2.2. Methods of sampling and data collection

Six legal cooperatives are organized on Lake Chamo fisheries and four cooperatives (Arba Minch, Chamo, Sego and Harura Boche) were selected for data collection. Out of the selected cooperatives, eight landing sites (Ganta fora, Bedena 1, Grawa, Wedeb, Bole, Ashewa, Chika, and Mehal) were selected and used as sampling sites. Samples of *B. docmak* were collected from the commercial fisheries of Lake Chamo randomly selected three days a week from January to December 2021. 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 a measuring board and sensitive electronic balance, respectively. Sex determination was distinguished manually based on external sexual characters. Males have two openings which are present just before the anal fin and females have three body openings. The length-weight relationship was calculated using the power function (Le Cren, 1951).

$$TW = aTL^b \quad [1]$$

Where

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

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 is indicated below.

$$K = \frac{TW}{TL^3} * 100 \quad [2]$$

Where

- TW = total weight of fish in grams (g)
- TL = total length of fish in centimeters (cm)

2.3. Data analysis

The data analyses were done using Microsoft Office Excel (2010) and SPSS (Version 16.0) software. A Chi-square test (χ^2 test) was employed to determine if the sex ratio varies between males and females *B. docmak*.

3. Results and Discussion

3.1. Length-weight relationship

The values of the regression coefficient "*b*" for females, males, and combined sexes obtained from the length-weight relationship by using the best-fit regression of power function gave 3.0272, 3.1412, and 3.0998, respectively. The relationship was presented in Fig. 2, 3, and 4, respectively. Analysis of variance (one-way ANOVA) showed significant differences between the regression coefficient "*b*" and the expected cubic relationship between length and weight for an ideal fish which maintains the same shape "*b"* (3) (Table 1; P<0.05). As indicated in Table 2, the t-test revealed the presence of a significant difference between the regression coefficient "*b*" in females, males and combined sexes (P < 0.05). According to the results of this study, the growth patterns of *B. docmak* were positive allometric and curvilinear in Lake Chamo.

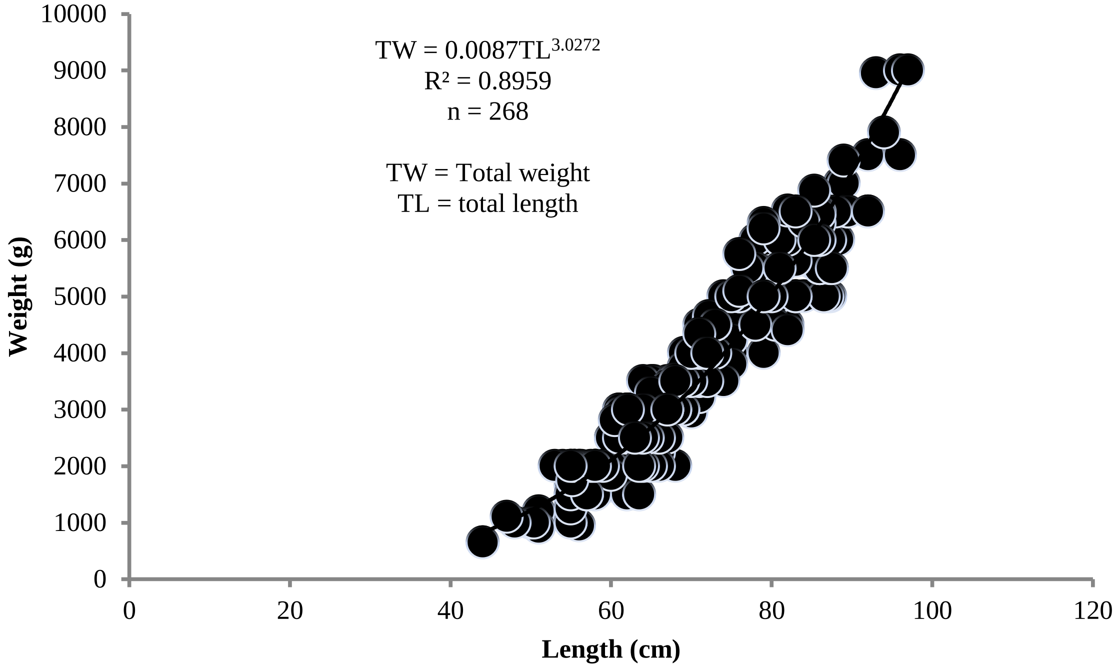

Figure 2: Length-weight relationship of female *B. docmak* from Lake Chamo

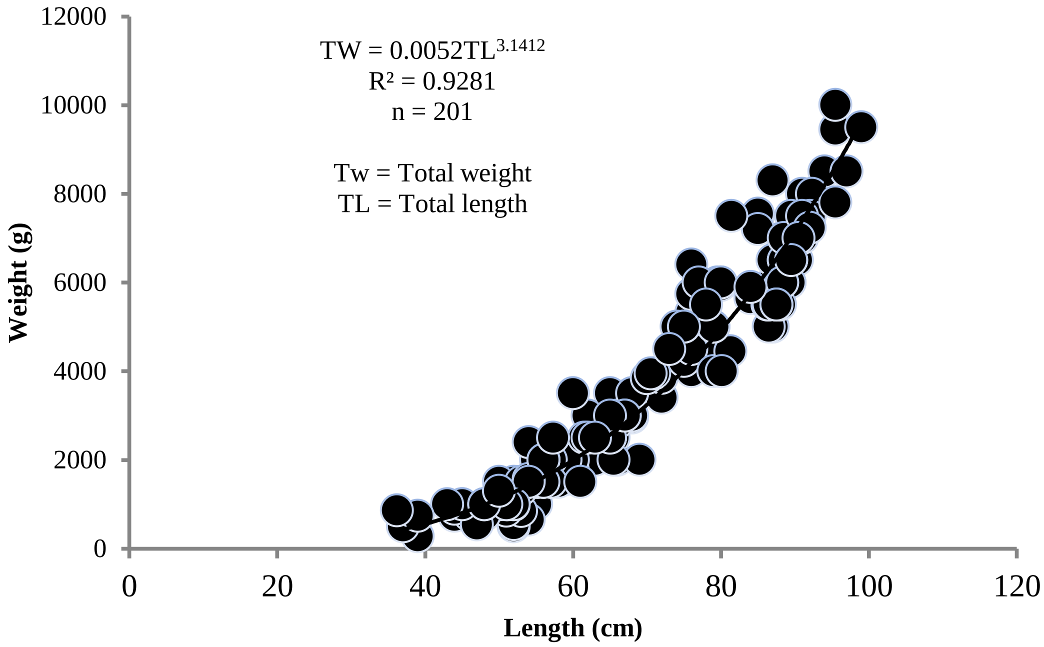

Figure 3: Length-weight relationship of male *B. docmak* from Lake Chamo

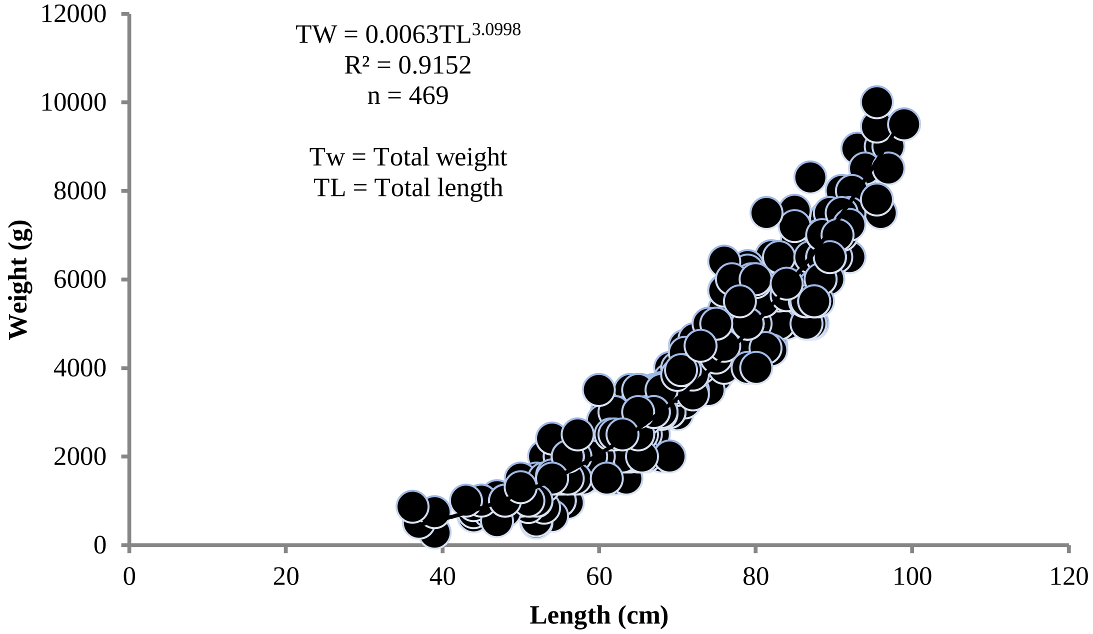

Figure 4: Length-weight relationship of combined sexes of *B. docmak* from Lake Chamo

Table 1: Analysis of variance (ANOVA) of length-weight relationship of *B. docmak* from Lake Chamo

Source of Variation	SS	df	MS	F	P-value	F-critical
Between Groups	0.0144	1	0.0144	36	0.027	18.513
Within Groups	0.0008	2	0.0004			
Total	0.0152	3				

Table 2: Regression static parameters of female, male and combined sexes

Parameters	Females	Males	Combined sexes
a value	0.0087	0.0052	0.0063
b value	3.0272	3.1412	3.0998
Std. Error (S_b)	0.063	0.062	0.043
R^2	0.8959	0.9281	0.9152
t-calculated	48.33	50.45	71.29
t-critical (5%)	1.962	1.962	1.962
No of observation	268	201	469
Significance	0.0000	0.0000	0.0000

A similar relationship has been reported by earlier studies for *B. docmak* (Anja *et al*., 2009). According to the reports of some authors, the growth patterns of *B. docmak* were negative allometric (Ikongbeh *et al*., 2012; Edwin and Simon, 2021). Fish can attain an isometric, negative or positive allometric growth pattern. The positive allometric growth implies that the fish becomes relatively broader and fatter as its length increases (Riedel *et al*., 2007). Based on the findings of this study, the growth pattern of *B. docmak* in Lake Chamo became relatively stouter and deep-bodied as they increase in length.

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 (Bagenal and Tesch, 1978; Froese, 2006; Yilmaz *et al*., 2012 and Ali *et al*., 2016). Furthermore, variations in fish growth patterns could also be related to the condition of the species itself, its phenotype, specific geographic location, and its environment (Tsoumani *et al*., 2006). However, these factors were not specifically considered in the present study, it was not possible to clarify which factors among those described above influenced these study results. It should also be noted that the growth process can differ in the same fish species on the basis of dwelling in diverse locations influenced by numerous biotic and abiotic factors.

3.2. Fulton's condition factor (K)

The analysis showed that there was no significant difference between the mean condition factor of males and females *B. docmak* (P > 0.05; Table 3). But the mean condition factor by month's interaction in Lake Chamo was significantly different (P < 0.05; Table 4). The seasonal variation in the mean monthly condition factor was highly significant in the months' interaction (t-test, P = 0.000).

The monthly mean Fulton's condition factor ranged from 0.92 to 1.2 for females, 0.8 to 1.1 for males, and 0.88 to 1.15 for combined sexes (Table 5). The average K value for females, males, and combined sexes was 1.01, 0.97, and 0.99, respectively. The lowest condition factor for females (0.92) was recorded in January, and the highest (1.2) was in November. For males, the lowest value (0.8) was recorded in March and the highest value (1.1) was in August. For combined sexes, the lowest value (0.88) was recorded in March and the highest (1.15) in November.

According to Anja *et al*. (2009), the condition factor of *B. docmak* in Lake Chamo ranged from 0.436 to 0.489 for males and from 0.449 to 0.489 for females. The condition factor (K) of the fish species in this study was not in agreement with the condition factors of the same fish species as reported by Ikongbeh *et al*. (2012); 1.61, 1.62, and 1.62 for male, female and combined sexes, respectively, in Lake Akata. Variations in condition factors are influenced by many biotic and abiotic factors such as phytoplankton abundance, predation, water temperature, and dissolved oxygen concentrations (Ahmed *et al*., 2011). The condition factor of fish can vary on the basis of the species type, prevailing environmental conditions, and food availability in their occupied habitats (Okach and Dadzie 1988; Wanyanga *et al*., 2016). The condition factor of fish can also be affected by season, reproductive cycles, and water quality parameters (Khallaf *et al*., 2003). When the condition factor K value is equal to or greater than one, it means the fish have attained a better condition (LeCren, 1951). Ayoade (2011) also suggests that a condition factor higher than one is a good fish health condition.

Fisheries of Lake Chamo are under heavy fishing pressure related to recruitment and growth overfishing with increased effort and reduced mesh size. There are also different agricultural practices taking place around the lake which might disturb and break the chain of food availability for the fish (Shishitu, 2020). In the present study, the average condition factor of *B. docmak* in Lake Chamo did not lie in the range of a good health condition. Even if, factors affecting the wellbeing of *B. docmak* in Lake Chamo were not specifically considered, it might be due to heavy fishing pressure, changes in the environmental conditions of the lake, and thereby changes in the nutritional status of the fish.

Table 3: One-way ANOVA of Fulton's condition factor by sex

Source of variation	SS	df	MS	F	P-value	F-critical
Between groups	0.012	1	0.012	1.667	0.210	4.301
Within groups	0.160	22	0.007			
Total	0.172	23				

Table 4: One-way ANOVA of Fulton's condition factor by months

Source of variation	SS	df	MS	F	F-critical	Sig.
Between groups	0.136	11	0.012	4.077	2.717	0.011
Within groups	0036	12	0.003			
Total	0.172	23				

Table 5: The mean monthly condition factor of females, males and combined sexes of *B. docmak* in Lake Chamo

Moths	Females	Males	Combined sexes
January	0.92	0.89	0.91
February	0.96	0.94	0.95
March	0.94	0.8	0.88
April	0.99	0.95	0.95
May	0.97	0.88	0.94
June	0.93	0.92	0.91
July	0.99	0.99	0.97
August	1.01	1.1	1.04
September	1.03	0.95	1
October	1.11	1.07	1.1
November	1.2	1.04	1.15
December	1.07	1.05	1.06
Average	1.01	0.97	0.99

3.3. Sex ratio

About 469 samples of *B. docmak* were collected. Among these samples 268 (57.14%) were females and 201 (42.86%) were males (Table 6). The monthly sex ratio (M:F) was statistically insignificant between males and females except for April and May. But the total sex ratio (M:F) was 1:1.33 and statistically highly significant (χ^2 = 4.79; P<0.05). The finding indicates that there was a deviation from the expected sex ratio of one male to one female and reveals that females were more numerous than males in Lake Chamo. The sex disparity could be a result of the differential survival to certain environmental conditions and is described as a mechanism for regulation in fishes.

Contrarily to the present study, the sex ratio of males to females of *B. docmak* was not significantly different Anja *et al*., (2009) sex ratio (1.0:1.07), Ikongbeh *et al*., (2012) sex ratio (1.0:1.08) and Edwin and Simon, (2021) sex ratio (1.0:1.26) in Lake Chamo, Lake Akata (Nigeria) and Lake Victoria (Kenya), respectively. In the present study, females were more numerous than males in Lake Chamo. The general bias towards females might be due to a potential mechanism to produce more offspring in situations wherein the populations are under some stress and as a result, allocations of resources to increase biomass.

Table 6: Sex ratio of *B. docmak* from Lake Chamo

Months	Female	Male	Total	Expected frequency	Sex ratio (M:F)	Chi-square (χ^2)	P-value
January	21	11	32	16	1:1.91	1.56	0.08
February	12	17	29	14.5	1:0.70	0.43	0.35
March	25	16	41	20.5	1:1.56	0.99	0.16
April	28	14	42	21	1:2	2.33	0.03*
May	20	9	29	14.5	1:2.22	2.09	0.04*
June	21	24	45	22.5	1:0.88	0.10	0.65
July	25	22	47	23.5	1:1.14	0.10	0.66
August	21	25	46	23	1:0.84	0.17	0.56
September	27	18	45	22.5	1:1.5	0.90	0.18
October	26	17	43	21.5	1:1.53	0.94	0.17
November	18	8	26	13	1:2.25	1.92	0.05
December	24	20	44	22	1:1.2	0.18	0.55
Total	268	201	469	234.5	1:1.33	4.79	0.00*

***Significant value**

4. Conclusion and Recommendations

The length-weight relationship of *B. docmak* in Lake Chamo followed a positive allometric growth pattern. The body condition of *B. docmak* showed seasonal variability in the monthly condition factor and its health condition was not as such good. The sex ratio of *B. docmak* deviated from the expected sex ratio of one male to one female where females were more numerous than males in Lake Chamo. Further study on water quality parameters and biological aspects of *B. docmak* and other fish species are recommended for better management of the fish species in the lake.

Conflict of interest

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

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