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Length-Weight Relationship and Condition Factor of Three Cichlids from the Tono Dam, Ghana

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Abstract

The length-weight relationship (LWR) and condition factor of three Cichlids, namely, *Sarotherodon galilaeus*, *Coptodon zillii* and *Oreochromis niloticus* from the Tono dam in Ghana, were investigated. A total of 1,870 individuals of the target species were randomly collected from 20 artisanal fishermen using gill nets to fish from January to December 2015. Each species was sorted by sex, and each fish's total length (L) and body weight (W) were measured and recorded. Simple linear regression plots of weight against length were computed, and the slope of the regression line, 'b' and intercept of the regression line, 'a' of each species (male, female, and mixed sexes) were derived. Their condition factor (*K*) was estimated using the relationship, $K = 100W/L^3$. The total length and body weight of the three species ranged from 5.0 - 21.5 cm for *O. niloticus*, 2.1 - 19.5 cm for *S. galilaeus*, and 4.5 - 19.5 cm for *C. zillii*, while their body weight ranged from 08.0 - 282.0 g for *O. niloticus*, 10.0 - 270.0 g for *S. galilaeus* and 10.0 - 210.0 g for *C. zillii*. All three species exhibited a positive allometric growth pattern, except for females of *S. galilaeus*. The coefficient of determination values ranged between 0.954 and 0.972 in all three species, which showed a high degree of positive correlation between the L and W of all the fish. The monthly mean condition factor (K) estimated for each species ranged from 4.23 to 5.39 for *O. niloticus*, 4.21 to 5.32 for *S. galilaeus*, and 2.29 to 5.20 for *C. zillii*. The high condition factors (*K*) recorded in this study indicate that the fish stock is in excellent health, benefiting from good food availability, favorable environmental conditions, and low-stress levels. These findings suggest that the habitat provides optimal resources for growth and survival, contributing to the overall well-being of the fish.

Keywords: *Oreochromis niloticus*; Growth pattern; Allometric growth; coefficient of determination; population dynamics

Introduction

Fish live under a diversity of environmental conditions that affect their growth and well-being. The knowledge of some quantitative aspects of fish, such as the length-weight relationship (LWR), is an important tool in the biological study of fish ecology and stock management (Kunlapapuk et al. 2024, Chandran et al. 2023, Li et al. 2023, Baidoo et al. 2022, Alhassan et al. 2015, Imam et al. 2010, Yılmaz and Polat 2011, Sparre and Venema 1998). The LWR is a critical tool in fisheries biology and ecology, facilitating the assessment of fish stock health, population dynamics, and growth patterns. It provides insights into fish physiology and ecological conditions by estimating body condition and biomass, contributing to effective fisheries management (Kunlapapuk et al. 2024, Li et al. 2023). It also helps to monitor seasonal and environmental changes impacting fish populations and supports comparisons of growth rates and conditions across geographical regions (Li et al. 2023). Various factors such as habitat, food availability, and environmental stressors influence LWR, making it a valuable indicator of fish well-being (Kunlapapuk et al. 2024, Li et al. 2023).

Recent studies have shown how LWR is used to track changes in fish population dynamics and assess fisheries resource health in different environments (Kannan et al. 2021; Karuppasamy et al. 2019). Furthermore, the relationship assists in evaluating the condition and health of fish species and their environments, informing stock assessments and conservation efforts (Jisr et al. 2018, Gumanao et al. 2016). These values are important for the estimation of the number of fish landed at a particular time and the comparison of fish species populations caught from various places at similar or different times (Mat Isa et al. 2010, Sparre and Venema 1998). In addition, the LWR indicates the degree of stabilization of taxonomic characters in fish species and is very useful in the management and exploitation of fish populations (Chu et al. 2012, Pervin and Mortuza 2008).

The LWR can also be used to determine the coefficient of condition or condition factor (K), which is used to express the physiological state of the fish in numerical terms (Seher and Suleyman 2012). Pauly (1983) described condition factor (K) as the well-being of a certain species and its degree of fitness, which depends on the weight of the fish sampled. It is based on the hypothesis that heavier fish of a particular length are in a better physiological condition. It is also a useful index for monitoring feeding intensity, age, and growth rates in fish (Ujjania et al. 2012). Condition factor studies consider the health and general well-being of fish as related to their environment; hence, they represent how fairly deep-bodied or robust fishes are and the effects of environmental changes on fish species (Froese 2006, Reynold 1968). It has been reported that the condition factor measures various ecological and biological factors such as degree of fitness, gonad development, and the suitability of the environment with regard to the feeding condition. When the condition factor value is higher, it means that the fish has attained a better condition (Lizama and Ambrósio 2002, Mac Gregoer 1959). The condition factor of fish is affected by several factors such as stress, the state of sexual maturity, the degree of food sources availability, age and sex, season, and other water quality parameters (Kharat and Khillare 2020, Khallaf et al. 2003, Beyer 1987).

Fish growth is highly influenced by abiotic factors such as temperature, oxygen levels, and salinity, which can be exacerbated by global climate change. Changes in these factors lead to variability in fish size, especially in tropical and sub-tropical species, where warming temperatures can result in smaller body sizes and altered growth patterns (Canosa et al. 2022). Information about the type or pattern of fish growth (whether isometric or allometric) can be determined using the LWR (Ragheb 2023, Ricker 1975). The study of growth patterns in fish has been based principally on LWRs between sizes of scales or other calcified tissues and body length because of their importance in age and growth analyses (Adeyemi et al. 2009). Fish is said to exhibit isometric growth when length increases in equal proportion with body weight. The regression coefficient for isometric growth is ‘3’ and values greater than ‘3’ indicate allometric growth (Olurin and Aderibigbe 2006). Presently, limited studies have been done on freshwater fishes in Northern Ghana, especially on the LWR and condition factor. Therefore, this study assessed the LWR and condition factor (K) of three (3) Cichlids from the Tono Dam in the Upper East Region of Ghana.

Materials and Methods

Study area

The study site was the Tono Dam, located near Navrongo in the Kassena-Nankana Municipality of the Upper East Region of Ghana, is a critical multi-purpose water resource. Situated at coordinates 10°60ˈ N, 1°07ˈ W (Figure 1), and an altitude of 160 meters, its construction began in 1975 and was completed in 1985 by Tysec, a British Engineering Company. The dam features a catchment area of 650 km^2, a maximum surface area of 1,860 hectares, and a maximum storage capacity of 93×10^6 m^3, with live and dead storage volumes of 83×10^6 m^3 and 10×10^6 m^3, respectively. Its 3,471-meter-long crest makes it a significant infrastructure in the region. The Tono Dam plays a pivotal role in the local economy by supporting artisanal fisheries, with eight key fishing communities—Bonia, Wuru, Yigbania, Yogbania, Korania, Gaani, and Chuchuliga—depending on it for livelihoods. It is also crucial for irrigation, managed by the Irrigation Company of Upper Region (ICOUR) Ltd, which oversees its use in crop production, livestock rearing, aquaculture, and forestry resources. The dam provides water to small-scale farmers through organized irrigation schemes, enhancing agricultural productivity in the area. Additionally, the dam has five designated landing bays where fishermen offload their daily catches, further supporting the local fisheries sector. The ecosystem of the Tono Dam fosters a diverse aquatic environment that sustains various fish species and is integral to the socio-economic well-being of the region. Three main water tributaries, Chanabugu (Chiana area), Gaobugu (Pro area in Burkina Faso), and Songobugo (Nabio, Kajilo area), primarily supply the dam. The watershed communities of Wuru, Bonia, Yigbania, Korania Gaani, Biu, and Chuchuliga surround the Tono Dam. Two air masses‐ the southwestern trade winds (monsoon) and the northeast trade winds (harmattan)‐ have impacted the region's climate. November through April are the months when the harmattan wind is felt. During this time, daytime highs of 42 ºC and nighttime lows of 18 ºC are typical. The municipality is exposed to the south-western trade winds air mass from May through October. This results in an average of 950 mm of precipitation annually, which is sufficient for the cultivation of root crops as well as grains (Dinye and Ayitio 2013).

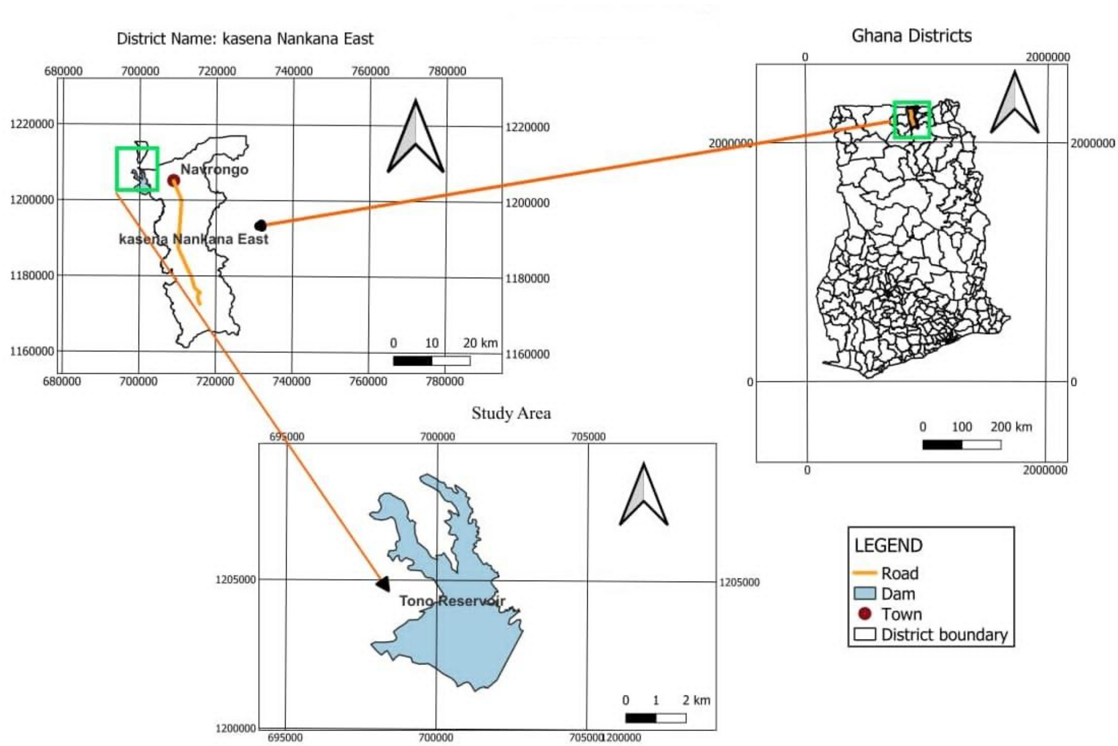

Figure 1: Map of Ghana showing the location of the Tono dam

Collection of fish samples and Measurement of length and weight of fish

A total of 1,870 individual samples of the target fish species *Oreochromis niloticus* (502), *Sarotherodon galilaeus* (840) and *Coptodon zillii* (528) were randomly collected from the catches of 20 artisanal fishermen monthly from January to December 2015. The fish were harvested using gill nets with mesh sizes ranging from 1.0 to 10.0 cm. The three Cichlid species were identified and sorted out from other catches using identification keys from Dankwa *et al*. (1999). The sex of each individual fish was determined and each species was grouped into males and females. The total length (L) of individual fish was measured on a measuring board, and their weights were measured using a spring balance. The total length of each fish was measured by placing it on a measuring board and taking the total length with a meter rule from the tip of the snout (with mouth closed) to the extended tip of the caudal fin. The total length and weight were recorded in centimeters (cm) and grams (g), respectively. Recordings were done separately for males and females for all three species.

Data Analysis

The relationship between the length and weight of the fish was determined by plotting simple linear regression using the XLSTAT 2015 computer software. A scatter plot of the Log of weight (W) against the Log of total length (L) was made for each species. This was done first for male and female groups and then for both sexes. The regression of weight against length was computed from the relationship by Rickter (1973): $W = aL^b$ (eq. 1). where 'W' is the observed total weight of fish in grams, 'L' is the observed total length of fish in cm, 'a' is the initial growth coefficient (intercept on length axis), and 'b' is the growth coefficient (regression coefficient). The values of constant 'a' and 'b' were estimated after logarithmic transformation of eq. 1 using the least square linear regression as described by Zar (1984) to give: $Log_{10} W = log_{10} a + b log_{10} L$ (eq. 2). The condition factor (K) was calculated from the relationship of Pauly (1983): $K = 100W/L^3$ (eq. 3), Where 'W' and 'L' are the mean body weight and mean total length, respectively. Condition factor (K) was estimated for male and female groups and for both sexes.

Results

The results of the measurements of the total lengths (L) and total body weights (W) of the three (3) Cichlid species examined are presented in Table 1. For the three species of tilapia, *Oreochromis niloticus* recorded a minimum and maximum L of 5.0 cm and 21.5 cm respectively, with a mean L of 15.3 cm, while *Sarotherodon galilaeus* recorded a minimum and maximum L of 4.5 cm and 19.5 cm respectively, with a mean L of 13.1 cm. *Coptodon zillii* recorded a minimum of 4.5 cm and a maximum L of 19.5 cm with 12.2 cm as the mean L. For weight (W), *O. niloticus* recorded a minimum and maximum of 8.00 g and 282 g respectively, with a mean W of 93.40 g. *S. galilaeus* recorded a minimum and a maximum value of 10.00 g and 270 g, respectively, with 100.50 g as the mean W. *C. zillii* recorded a minimum body weight of 10.00 g and a maximum body weight of 210 g with 64.01 g as the mean W. The females of all three species recorded relatively higher mean L and W than their male counterparts.

Table 1: Morphometric characteristics of three Cichlid species from the Tono dam, Ghana

Name of Species	Total Length (cm) Characteristics						Weight (g) Characteristics			
	Sex	**n**	**mean**	**SD**	**Min**	**Max**	**mean**	**SD**	**Min**	**Max**
O. niloticus	Males	282	14.7	7.3	9.0	21.5	67.6	37.1	8.0	175.0
	Females	220	15.7	6.7	5.0	21.5	126.5	35.7	60.0	282.0
	Mixed Sexes	502	15.3	7.0	5.0	21.5	93.4	46.8	08.0	282.0
S. galilaeus	Males	584	12.6	2.1	4.5	16.2	85.2	29.6	10.0	160.0
	Females	256	14.3	2.1	8.4	19.5	135.5	31.2	70.0	270.0
	Mixed Sexes	840	13.1	2.3	4.5	19.5	100.5	37.9	10.0	270.0
C. zillii	Males	243	11.0	2.8	4.5	16.6	52.4	37.8	10.0	200.0
	Females	285	13.7	2.4	7.7	19.5	73.6	47.9	10.0	210.0
	Mixed Sexes	528	12.2	2.9	4.5	19.5	64.0	44.8	10.0	210.0

[**n:** sample size; **SD:** standard deviation; **Min:** minimum; **Max:** maximum]

The values of the regression coefficients, 'a' and 'b' obtained are presented in Table 2. Values of 'a' obtained for the mixed sexes of the three species, *O. niloticus, S. galilaeus*, and *C. zillii*, were -1.978, -2.198, and -2.648, respectively, while the corresponding 'b' values were 3.193, 3.371 and 3.711, respectively.

The exponent, 'b' of all the species were each greater than 3. When 'b' is not equal to 3, then the fish's growth is an allometric pattern, which could either be positive if greater than 3 (>3) or negative if less than 3 (<3). Therefore, the three species exhibited a positive allometric growth pattern, except for females of *S. galilaeus*. The coefficient of determination values ranged between 0.954 and 0.972 in all three species. This showed a high degree of positive correlation between the L and W of all the fishes.

Table 2: Estimated parameters of the length-weight relationship of three Cichlids from the Tono dam, Ghana

Name of Species	Sex	a	b	*SE*	R^2	Growth Pattern
O. nilotucus	Males	-2.003	3.214	0.029	0.965	PA
	Females	-1.973	3.190	0.046	0.946	PA
	Mixed Sexes	-1.978	3.193	0.025	0.959	PA
S. galilaeus	Males	-2.159	3.335	0.025	0.976	PA
	Females	-1.440	2.717	0.092	0.966	NA
	Mixed Sexes	-2.198	3.371	0.018	0.972	PA
C. zillii	Males	-2.676	3.737	0.056	0.960	PA
	Females	-3.537	4.465	0.099	0.931	PA
	Mixed Sexes	-2.648	3.711	0.042	0.954	PA

[**SE**: Standard error; **a:** Intercept of regression line; **b:** slope of regression line (regression coefficient); $\mathbf{R^2}$**:** coefficient of determination; NA: negative allometric; PA: positive allometric]

The condition factor (K)

Figures 1, 2 and 3 show the variation in the mean monthly condition factors of *O. niloticus, S. galilaeus* and *C. zillii* respectively from the Tono dam from January to December, 2015. The condition factor of mixed sexes of *O. niloticus* ranged from 4.23 to 5.39; those of *S. galilaeus* varied from 4.21 to 5.32 and *C. zillii* ranged from 2.29 to 5.20. These values indicated that all the three species were in their good condition during the period of study.

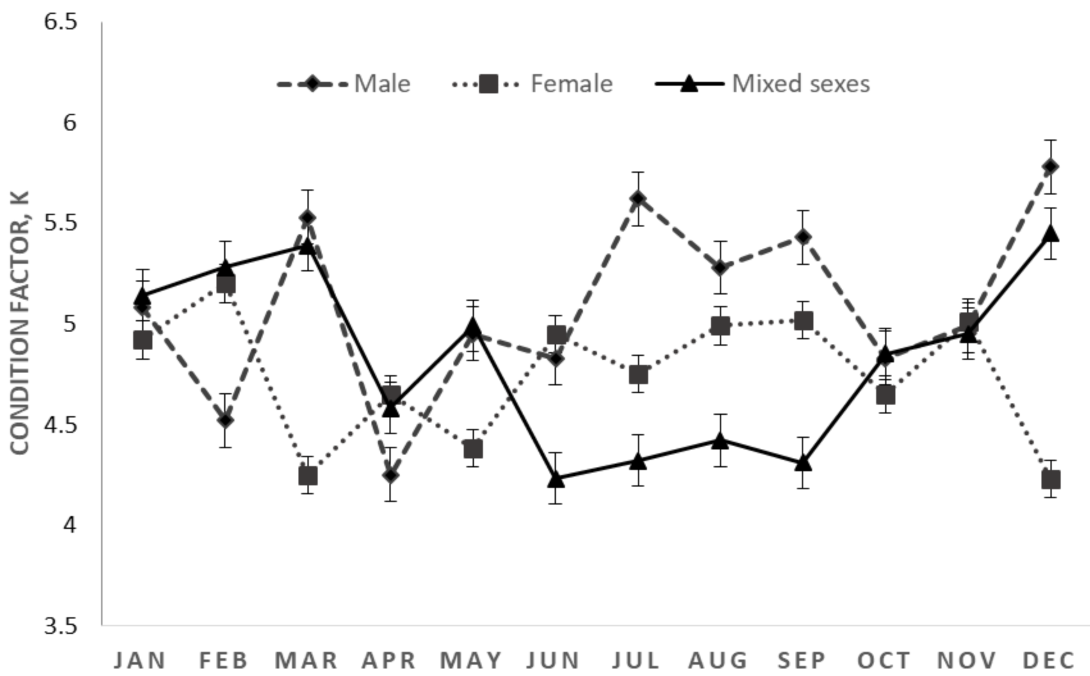

Figure 2: Mean monthly variation in condition factor of *Oreochromis niloticus* from the Tono dam during the study period in Ghana

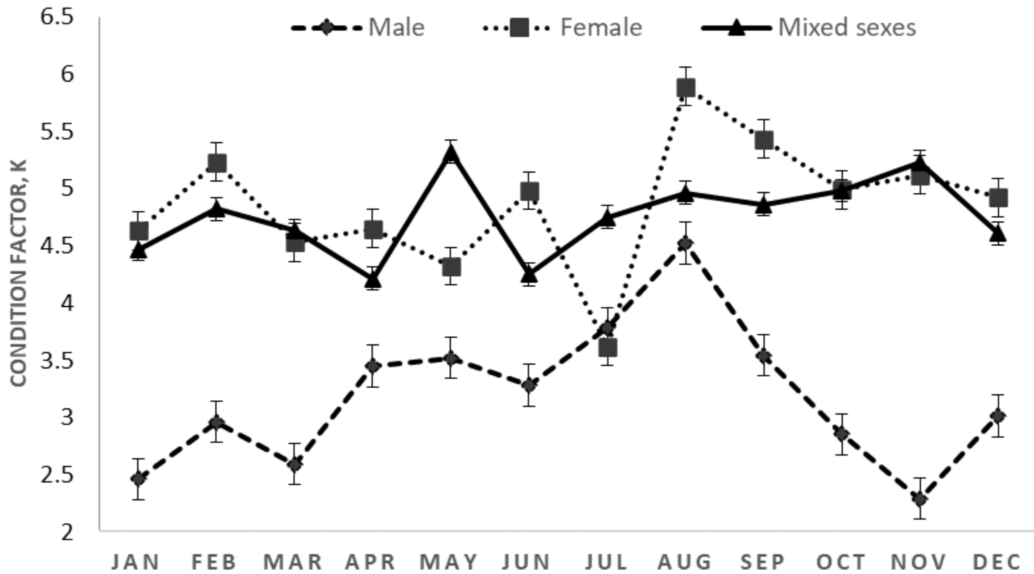

Figure 3: Mean monthly variation in condition factor of *Sarotherodon galilaeus* from the Tono dam during the study period in Ghana

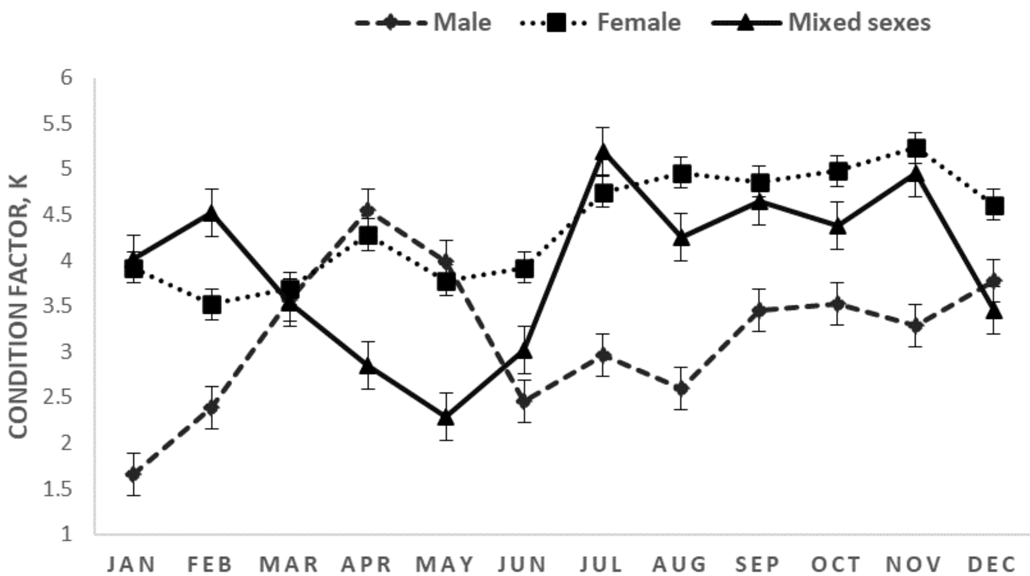

Figure 4: Mean monthly variation in condition factor of *Coptodon zillii* from the Tono dam during the study period in Ghana

Discussion

The sizes of *Oreochromis niloticus* examined in this study were relatively larger than those of *Sarotherodon galilaeus* and *Coptodon zillii* judging from the values of total length and body weight recorded. The bigger sizes of *O. niloticus* sampled could probably be attributed to their faster growth rates and intense feeding habits. *O. niloticus* is voracious and omnivorous, while *S. galilaeus* shows a preference for phytoplankton over zooplankton (Osunwale 2014). Idodo-Umeh (2005) and Abowei and Hart (2009) attributed bigger sizes of fish to faster growth rate and intensity of feeding. Oni et al. (1983) earlier indicated that feeding and reproductive phenomena were the main factors responsible for the size of fish. It is conceivable that the *O. niloticus* sampled were adults, probably with full-laden stomachs or matured reproductive organs.

All three species of fish investigated in the current study showed positive allometric growth patterns with regression co-efficient, 'b' values greater than 3. Alhassan et al. (2015) reported negative allometric growth for *S. galilaeus*, and *C. zillii* but isometric growth for *O. niloticus* from Golinga Dam in the Northern Region of Ghana. The Golinga Dam and the Tono Dam are located within the same ecological zone in the Northern sector of Ghana. These outcomes could have resulted from differences in the two dams' physical, chemical, and biological conditions due to the various anthrophonic activities around the dams and within their catchment areas. The result did not agree with the findings of Fagade (1983) on related species, which showed isometric growth in a man-made lake in Ibadan, South-west Nigeria. In contrast, Olurin and Sotubo (1989) reported allometric growth in three Cichlids in the Owa stream, South-west Nigeria. Variations within the same species in terms of growth could be due to different stages in the ontogenetic development, differences in sex, and the differences in geographical location with the associated environmental conditions (Alhassan et al. 2015, Froese 2006, Kraljevic et al. 1996).

According to Adeyemi et al. (2009), the allometric growth pattern in fish implies that the weight of the fish increases at a lesser rate than the cube of the body length or vice versa. Except for *C. zillii*, the 'b' values recorded from this study were within the ranges of 2.5 and 3.5, which Gayanilo and Pauly (1997) suggested as the recommended values for 'b'. Ricker (1975) recommended 3 as the normal length-weight ratio for 'b'. With reference to Reynold (1968), the condition factor (K) recorded for the three species in this study showed that they were all in good condition during the study period. Reynold (1968) explained that the higher the values, the better the physiological condition of the species, which was the case in this study. The variations in the mean monthly condition factors for all three species could be attributed to the season of sampling and sample size and the prevailing ecological conditions in the Tono dam. Alhassan et al. (2015) attributed monthly fluctuations in condition factors to be influenced by gonadal development, availability of food, and gastral activity. Dadzie et al. (2000) indicated that changes in the condition factor of fishes could be used to interpret various biological features such as fatness, food availability, reproductive activities, and environmental health.

The coefficient of determination (R^2) of the fishes, which ranged from 0.954 to 0.972, indicated a strong positive correlation between their total length (L) and total body weight (W). The implication is that the body weights of the fish increased with the increase in body length at almost the same rate. In this study, the fish were not sorted by state of maturity and state of stomach fullness, and the effects of these factors were not evaluated in this study.

Conclusion

This study revealed that the three Cichlids (*Oreochromis niloticus*, *Sarotherodon galilaeus*, and *Tilapia zillii*) from the Tono dam in the Upper East Region of Ghana exhibited positive allometric growth patterns. The coefficient of determination (R^2) of the LWRs also indicated a strong positive correlation between their length and body weight. The condition factors (*K*) recorded in this study indicate that the fish stock is in excellent health, benefiting from good food availability, favorable environmental conditions, and low-stress levels. These findings suggest that the habitat provides optimal resources for growth and survival, contributing to the overall well-being of these cichlid species.

Conflict of interest

The authors have no relevant financial or non-financial interests to disclose.

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