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Length-Weight Relationship and Condition Factor of *Bagrus bayad* (Fabricius, 1775, Bagridae) from Lake Albert, DR Congo

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Abstract

This study provides information on the length-weight relationship and condition factor of *Bagrus bayad,* a fish species from Lake Albert. These variables were analysed from 520 samples collected from Lake Albert (DR Congo) between January and December 2020. The mean total length and total weight of *B. bayad*, (combined sexes) were 47.43 ± 7.81 (cm) and 495.34 ± 293.36 (g), respectively. The *b*-value of the weight-length relationship varied from 2.20 to 3.21. Males exhibited a negative allometric growth while females showed isometric growth. There was a strong positive correlation between length and weight, of *B. bayad* (*i.e.*, LnTW = 2.72LnTL − 1.88; R^2 = 0.875) and for females (*i.e.*, LnTW = 2.742LnTL − 1.95; R^2 = 0.739). The length-weight ratio for both sexes was (LnTW = 2.8812LnTL − 2.1686) with a correlation coefficient r^2 = 0.837. *B. bayad* exhibited negative allometric growth pattern. The result indicated that there was no significant difference between the mean condition factor of male and female of *B. bayad* (P > 0.05). The condition factor for both sexes of *B. bayad* observed in rainy seasons (females K = 0.78 ± 0.134 and males K = 0.825 ± 0.127) were significantly in dry season than the mean values of males (females K = 0.76 ± 0.286 and males K = 0.829 ± 0.128). The overall condition factor was 0.80 ± 0.12 for males and females combined, but individually this factor was higher in males than in females during both seasons. This study provides baseline information about *B. bayad* from Lake Albert that is needed to develop strategies for the protection and sustainable exploitation of this species.

Subject Areas

Hydrology

Keywords

Length-Weight Relationship, Condition Factor, Growth Pattern, *B. bayad*, Lake Albert

1. Introduction

Bagrus fishes are also known as naked catfishes belong to the family Bagridae that is constituted of 30 genera and over 200 species. Like other catfishes, the Bagrids have four pairs of well-developed barbels that are covered with a layer of taste bud-enriched epithelium (Zhang *et al.*, 2006) [1]. Bagrid catfishes are ecologically and economically important because they play silent roles in determining the dynamics and structure of the aquatic ecosystem and serve as food for humans. Moreover, some species serve as ornamental aquarium fishes (Nelson, 2006) [2]. *Bagrus bayad* is widely spread in African rivers and lakes, in Benin, Democratic Republic of Congo, Egypt, Mali, Ghana, Guinea, Kenya, Sudan, Nigeria, Tanzania, and Uganda (Froese and Pauly, 2009) [3]. The species has been recorded in the Nile River, Niger, Senegal, Congo, Volta Lake, and Chad Basins. The general ecology of bagrids in some aquatic ecosystems has been studied (Fagade, 1980 [4]; Ogbe and Fagade, 2002 [5]; Ogbe *et al.*, 2003 [6]; Ogbe *et al.*, 2006 [7]), however, detailed studies such as reproduction biology, diet, and growth patterns of this fish species remain very limited in most of the Nile Basin water bodies and into the Lake Albert in particular.

Length-weight relationship parameters (a, b) are important in stock-assessment studies (Moutopoulos and Stergiou, 2002) [8] because they are often used to infer fish biomass status (Froese, 1998) [9]. These parameters are also used to compare growth of fish species (Petrakis and Stergiou, 1995) [10], and serve as a practical index for fish condition (Barros *et al.*, 2001) [11]. *a* and *b* parameters from the length-weight relationship can also be used to compare populations of the same species living in similar or different ecosystems (Stergiou and Moutopoulos, 2001 [12]; Thomas *et al.*, 2003 [13]; Odat, 2003 [14]). Fish living in the tropical and sub-tropical water system experience growth fluctuations due to changes in food composition, environmental variability and spawning conditions. Length-weight data provide important information that is used to monitor fish structure and functions of populations (Anderson and Neumann, 1996) [15]. Indeed, knowledge of the morphological parameters, such as the length-weight relationship and condition factor are parameters that define the well-being of fish, and reflect the feeding conditions of exploited species that are essential for sustainable management of their stocks (Le Cren, 1951 [16]; Hailu, *et al.* 2001 [17] and Konan, 2021 [18]). Unfortunately, few studies (if anything) have been conducted on the Congolese side of Lake Albert to elucidate the morphological parameters of *B. bayad*. Like on lakes Kivu, Edward, and Victoria, most studies on lake Albert have explored feeding behaviour and fish diets (Greenwood, 1956 [19]; Verbeke, 1959 [20]), socioeconomics of artisanal fishing (Chikwanine, 2020) [21] and the value chain of *Bagrus spp* (Matunguru *et al.*, 2020) [22]. Little is known about biological parameters of this species. The only available data on morphometric variation among *B. docmac* populations exists on the Ugandan side (Mwanja *et al.*, 2014) [23]. Therefore, this study examined the morphometric characteristics mainly length-weight relationship and condition factor of *B. bayad* populations on the Congolese side of Lake Albert to inform better management of the species. Therefore, this knowledge is mandatory for considering priority options regarding the management and conservation of *B. bayad* in Lake Albert. Therefore, this paper sets out to document the growth aspects (length-weight relationship and condition factor) in Lake Albert to provide the necessary scientific information for proper utilization and management of the stock.

2. Materials and Methods

2.1. Study Area

Lake Albert (**Figure 1**), formerly known as Lake Mobutu Sese Seko, is shared between Uganda (54%) and the Democratic Republic of the Congo-DRC (46%) and is situated at the northern tip of the Western Arm of the African Great Rift Valley (coordinates 1˚0'N 30˚5'E). Compared to other large African Great Lakes (AGL), Lake Albert is relatively shallow and comparatively small, with an average depth of 25 meters and a surface area of 5300 km^2. Its outlet, at the northern most tip, is the Albert Nile, also known as the White Nile, which joins the Blue Nile in South Sudan to form the famous River Nile that flows through Egypt to the Mediterranean Sea. The lake's annual average water temperatures range between 17 and 29 degrees Celsius (Matunguru *et al.*, 2022) [24].

2.2. Materials

We used specimens of the *B. bayad* species as biological material. For the site location, we used a GPS (Geographic Position System) device to collect the geographical coordinates, which led to the location map of the sampling sites.

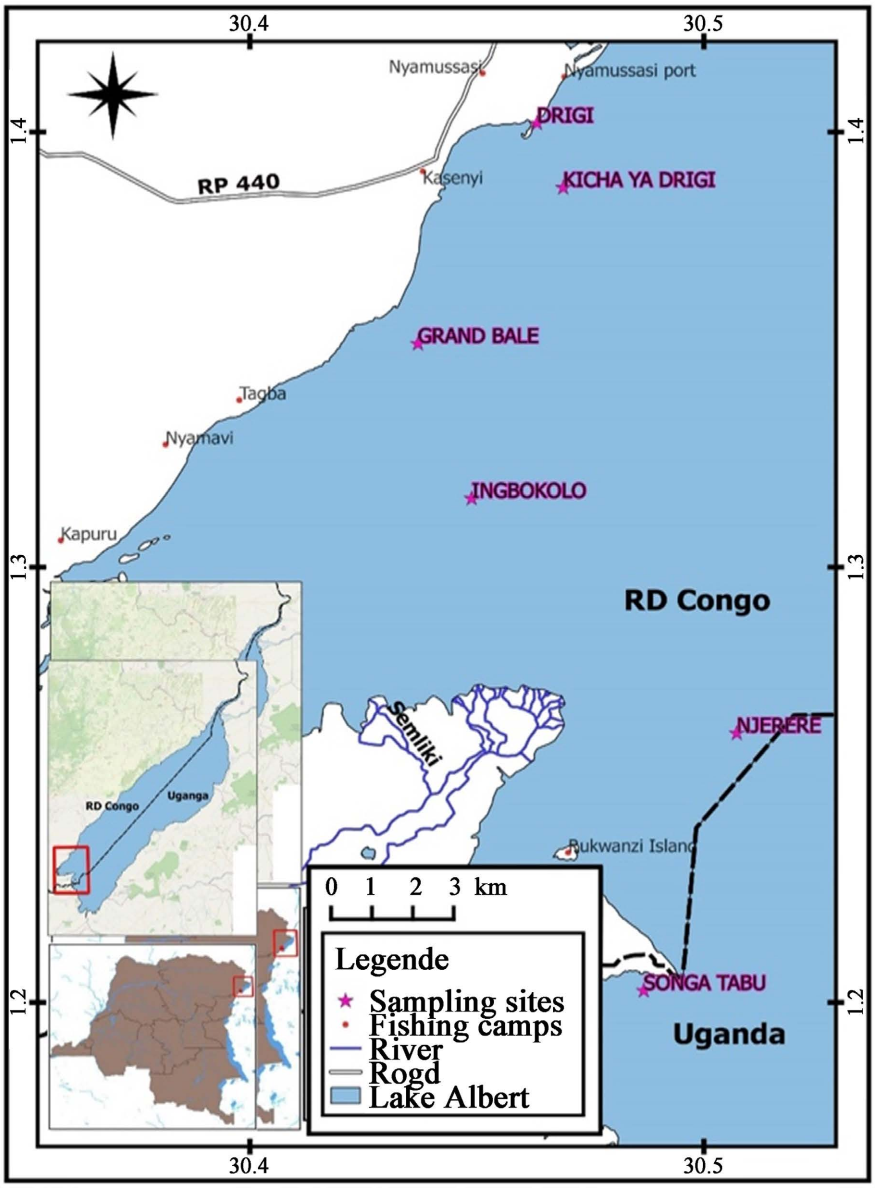

Figure 1. Sampling sites localization in Lake Albert in DR Congo side.

Specimens were obtained from fishermen operating on Lake Albert. Fishermen used various fishing gears that included hand nets, cast nets, and gill nets of various mesh sizes (20.2; 25.4; and 30; 5 mm). Total weight (TW) and gutted weight (GW) were measured to the nearest 0.01 g using a sensitive Mettler electronic scale. For each fish specimen, the total length (TL) and standard length (SL) were measured at landing site to the nearest 1 mm using ichthyometer.

2.3. Methods

2.3.1. Sampling Procedure and Sample Size

A total of 520 specimens of *B. bayad* were obtained monthly from six sampling sites (Drigi, Kicha ya drigi, Grand Bale, Ingbokolo, Njerere, Songa Tabu) in the south-western sector of Lake Albert (**Figure 1**) for a period of one year (December 2019 to December 2020). Samples were usually collected in the mornings between 7.00 am-9.00 am and in the evenings between 4:30 pm-6:30 pm.

The total length and standard length were measured according to Olatunde (1977) [25] with an Ichtyometer placed on measuring board graduated at 1 cm interval. The sex and maturity of each fish specimen were determined by visual examination of the urogenital opening (Holden and Raitt, 1974) [26] where the females had a circular scaleless area around their urogenital opening, while males' scaleless area was more oblong.

2.3.2. Data processing

1) Relationship between Total length (TL) and Standard length (SL)

The relationship between total length and standard length was established by least squares regression. In a situation of accidental loss of the caudal fin, Equation (1) was used to estimate the total length.

$$\mathrm{TL} = a + b\,\mathrm{SL} \tag{1}$$

where a represents the ordinate at the origin and b the slope of the regression line.

2) Relationship between total weight and total body length

The relationship between total length and total weight of fishes is, in general, a power function (Le Cren, 1951) [16].

$$\mathrm{PT} = a\,\mathrm{LT}^{b} \tag{2}$$

This equation is linear in the following form

$$\ln \mathrm{PT} = \ln a + b \ln \mathrm{LT} \tag{3}$$

where;

Ln is the natural logarithm, PT *is* the body weight in g, LT is the total length in cm, a *is* the regression constant and b is the allometric coefficient

This transformation makes it possible to reduce the variability and to homogenize the two variables TL and TW (Chikou, 2006) [27]. The constants a and b are respectively characteristic factors of the environment of the species. The coefficient b varies between 2 and 4, but it is often close to 3. When it is statistically equal to 3, the growth is said to be isometric. When it is different from 3, the growth is said to be allometric. A coefficient b greater than 3 (positive allometry) indicates better growth in weight than in length and vice versa when b is less than 3 (negative allometry) (Ricker, 1980) [28].

3) Condition Factor (K) calculation

The condition factor K expresses the ratio between the weight and the length of the fish according to Bagenal and Tesch (1978) [29]. The condition factor, (K) was determined using the equation:

$$K = \frac{\mathrm{PT}}{\mathrm{LT}^{b}} \times 100 \tag{4}$$

with TW and TL the variables used to establish the weight-length relationship of the species, b being the allometric coefficient obtained.

4) Statistical analyses

Data were analysed using Statistical software for data science: STATA software (Version 14). One-way Analysis of variance (ANOVA) was used to analyse data to extract the morphometric variables, to generate the frequencies of the length distributions. This software helped as well to establish morphometric relationships of the regression equations for the *B. bayad* species. Student's t-test and Wilcoxon's -test was used to compare their *b* values to 3 in the weight-length relationship in individuals of the same species. Student's t-test and Wilcoxon's test were used to test the equality of the different parameters while the F-test was used in the comparison of b-values to 3 in the total weight-length relationship. The Shapiro test was used to test data normality. All the tests were carried out at the 95% significance level.

3. Results

3.1. Morphometric Variables

Table 1 presents the mean, median, minimum, maximum values and the standard deviation of the total length, standard length, total and eviscerated body weights of 520 specimens of *Bagrus bajad* from Lake Albert. In general, the highest total length and total body weight of both sexes combined were recorded at TL 79.4 cm - 2115 g, respectively. The recorded values for females were TL 79.4 cm and TW 2115 g, while that of males were TL 61.4 cm and TW 1630 g respectively. The average lengths and total weight were 47.43 cm and 495.34 g for females and 49.50 cm and 577.17g for males. The smallest length and body weight values recorded for both sexes were 30.4 cm and 10 g respectively. Results in Table 1 show that males of *B. Bayad* were moderately smaller than females.

3.2. General Structure by Size

Figures 2-4 present the different length frequency distributions of *B. bayad*

Table 1. Morphometric variables of *B. bayad* from Lake Albert.

Season	Male		Female		Combined (N = 520)
	Rainy (n = 118)	Dry (n = 120)	Rainy (n = 137)	Dry (n = 145)	
TL avg	45.45 ± 5.58	44.50 ± 5.49	49.55 ± 9.97	49.45 ± 7.55	47.43 ± 7.81
TLmin-max	33 - 61.4	30.4 - 57.3	32 - 79.4	35 - 77	30.4 - 79.4
SL avg	37.02 ± 4.58	36.45 ± 4.79	39.99 ± 8.10	40.41 ±	38.62 ± 6.52
SL min-max	29.5 - 54.5	25.5 - 49.5	26 - 65	27.3 - 66	25.5 - 66
TW avg	405.60 ± 152.65	391.95 ± 192.82	588.61 ± 400.37	566.28 ± 283.32	495.34 ± 293.36
TW min-max	210 - 1215	10 - 1630	105 - 2065	145 - 2115	10 - 2115
GW avg	259.55 ± 97.67	250.82 ± 123.40	376.69 ± 256.25	362.38 ± 181.34	316.98 ± 187.75
GW min-max	134.4 - 777.6	6.4 - 1043.2	67.2 - 1321.6	92.8 - 1353.6	6.4 - 1353.6

N = number of individuals, TL = total length in cm, SL = standard length in cm, TW = total weight in g, GW = gutted weight in g, Max = maximum, Min = minimum, Avg: average, Med = medium.

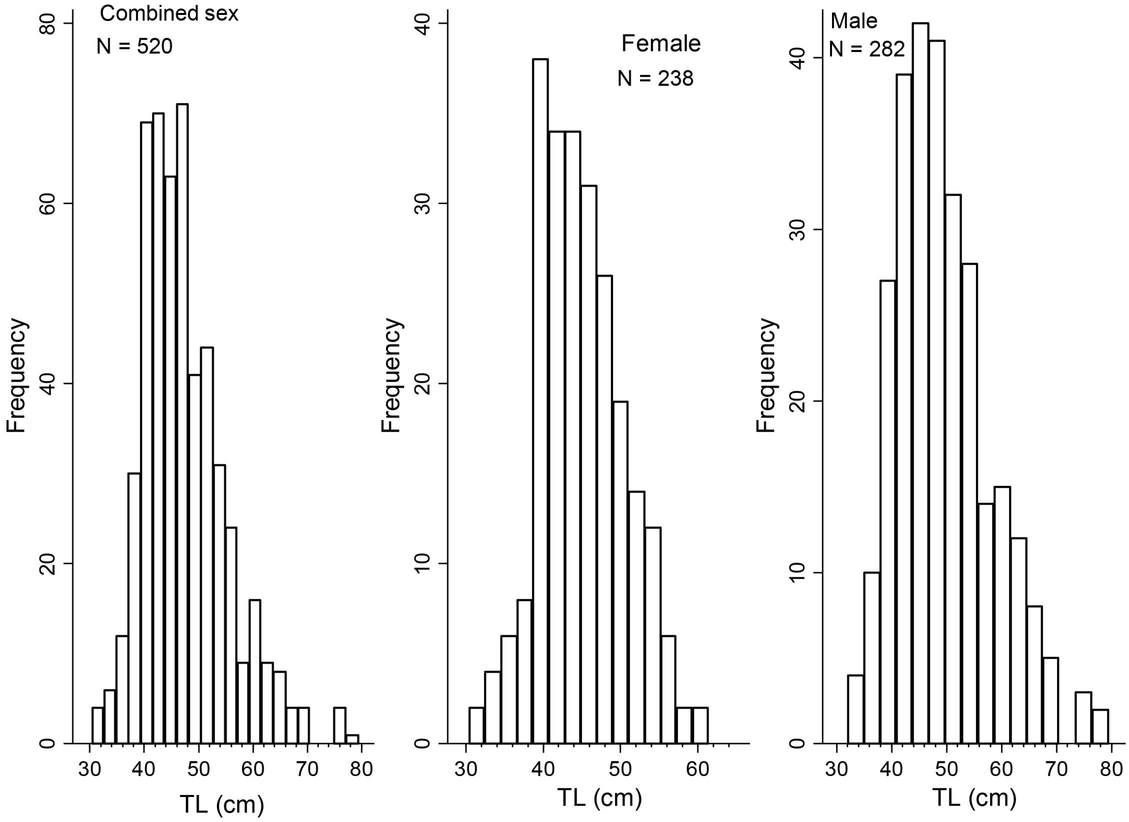

Figure 2. Frequency distribution of the total length according to Sex of *B. bayad* from Lake Albert, DR Congo.

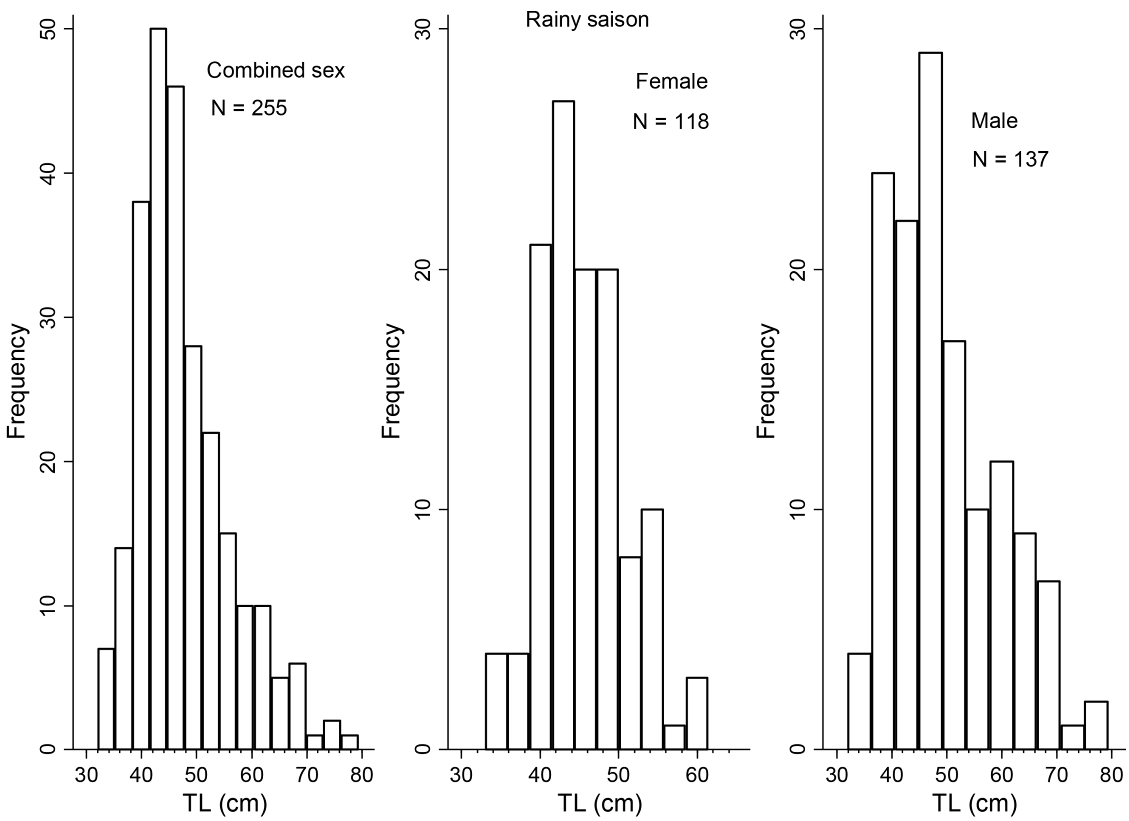

Figure 3. Frequency distribution of the total length according to sex and season of *B. bayad* from Lake Albert, DR Congo.

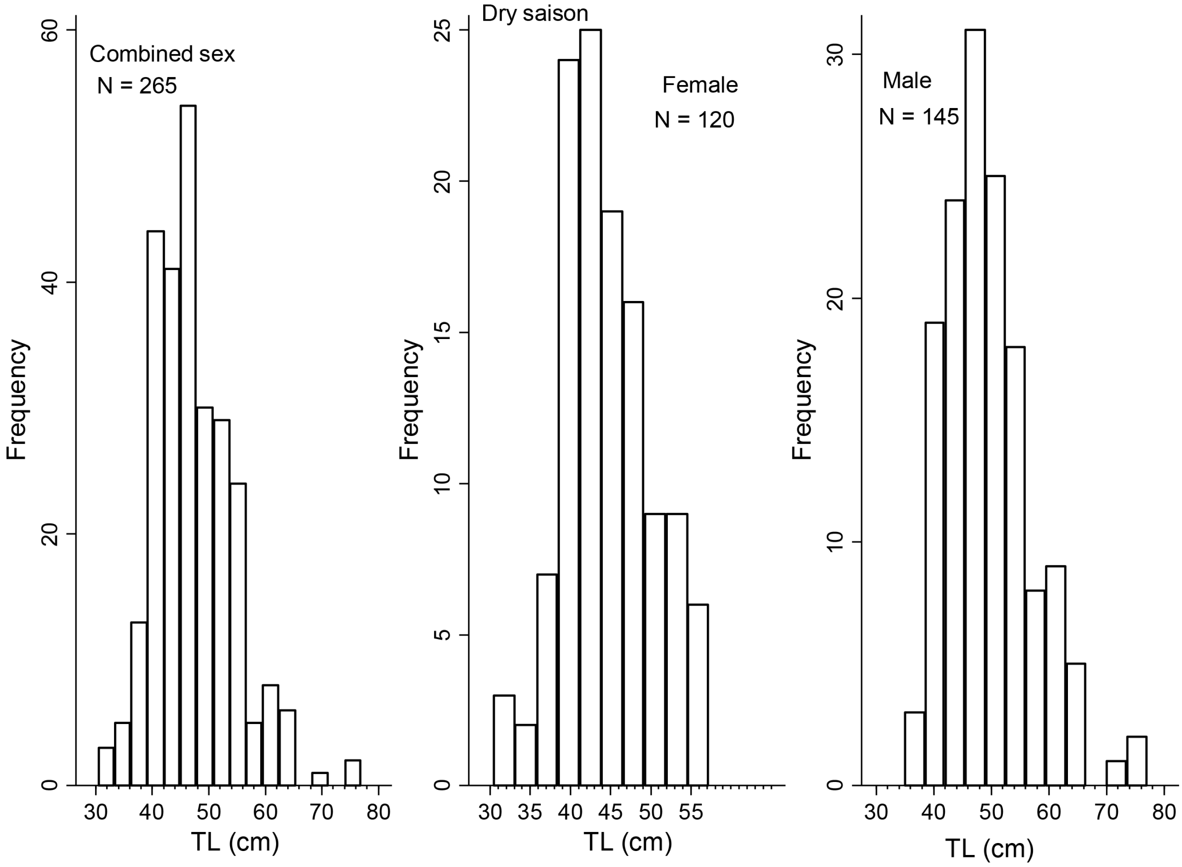

Figure 4. Frequency distribution of the total length according to sex and season of *B. bayad* from Lake Albert, DR Congo.

from Lake Albert. All individuals of these species exhibited a unimodal distribution. Most of the females are close to the modal size unlike the males.

3.3. Morphometric Relationships

Table 2 presents the relationships between total length and standard length, the relationships between these two lengths and total body weight, the regression *Equations* between total length, standard length and total weight, as well as the coefficient of determination r^2 according to sex. The correlation is positive, r^2 varying from 0.739 (Females) to 0.949 (Males). The relationship between TW and TL reflects negative allometric growth (H1: $b < 3$, $p < 0.05$) for both sexes combined. For females, overall growth is isometric (H0: $b = 3$, $p = 0.11$); it is positive allometric in the dry season and negative in the rainy season. For males, allometric growth is negative in the rainy season and positive allometric in the dry season. Table 3 and Table 4 show the statistical description of *Bagrus bajad*.

3.4. Condition Factor (*K*) and Variation of Values *a*, *b* and r^2

The coefficient values of the relationship between total length and total weight was 0.138 for both sexes combined. They varied from 0.142 for females to 0.164 for males. Regarding the season, the factor *a* varied from 0.064 in the dry season for females to 0.181 in the rainy season for males. As for the average condition factor (*K*), the value is 0.80 for all sexes combined. However, it varied from 0.77 for females to 0.83 for males. The lowest mean value of *K* was observed in the

Table 2. Morphometric relationships and Growth Types of *B. bayad* (from samples of 520 specimens) from the Lac Albert, DR Congo.

Season	Females			Males			Combined
	Combined	Rainy	Dry	Combined	Rainy	Dry	
N	238	118	120	282	137	145	520
TL = *a* + *b*SL	7.22 + 1.03-SL	9.17 + 0.98SL	5.65 + 1.07SL	4.49 + 1.12SL	3.45 + 1.15SL	5.99 + 1.08SL	4.52 + 1.11SL
ES(*b*)	0.038	0.067	0.039	0.024	0.037	0.30	0.020
r^2	0.869	0.805	0.930	0.941	0.937	0.949	0.928
LnTW = ln*a* + *b*LnSL	−1.959 + 2.896LnSL	0.473 + 1.781LnSL	−2.602 + 3.300LnSL	−1.746 + 2.785LnSL	−1.787 + 2.810LnSL	−1.522 + 2.645LnSL	−1.89 + 2.864LnSL
ES(*b*)	0.144	0.114	0.248	0.071	0.092	0.113	0.068
r^2	0.794	0.889	0.774	0.919	0.934	0.890	0.882
LnTW = ln*a* + *b*LnTL	−1.953 + 2.737Ln**TL**	−1.060 + 2.203Ln**TL**	−2.743 + 3.212Ln**TL**	−1.806 + 2.670Ln**TL**	−1.709 + 2.608Ln**TL**	−1.983 + 2.778Ln**TL**	−1.978 + 2.763Ln**TL**
a	0.142	0.35	0.064	0.164	0.181	0.137	0.138
ES(*b*)	0.162	0.134	0.286	0.090	0.127	0.128	0.079
r^2	0.739	0.836	0.719	0.875	0.870	0.877	0.840
Kavg	0.77	0.78	0.76	0.83	0.825	0.829	0.80
K_{min}	0.03	0.35	0.03	0.11	0.108	0.109	0.03
K_{max}	1.85	1.32	1.85	1.53	1.30	1.53	1.85
GT	**I**	**A-**	**A+**	**A-**	**A-**	**I**	**A-**

TL = Total length; SL = Standard length; TW = Total weight; KAvg = K average; K_{min} = K minimum; K_{max} = K maximum; GT = Growth Type.

Table 3. Statistical description obtained for *Bagrus bajad* in different fishing stations of Lake Albert.

Station	Total Length (cm)		Total Weight (g)		*K*	
	Min.-Max	Moy ± SD	Min.-Max.	Moy. ± SD	Min.-Max	Moy. ± SD
DRIG	37 - 79.4	51.4 ± 10.5	105 - 2065	641.6 ± 519.5	0.04 - 0.6	0.3 ± 0.12
GREBA	33 - 77	47.9 ± 8.04	72 - 4000	565.0 - 365.02	0.05 - 1.0	0.4 ± 0.09
ING	32 - 70	47.1 ± 7.1	155 - 1745	492.8 ± 259.3	0.3 - 2.7	0.6 ± 0.2
JUSK	40.2 - 48.5	44.5 ± 2.7	250 - 560	357.8 ± 77.4	0.3 - 0.5	0.4 ± 0.04
NJE	40.5 - 51	46.4 ± 4.2	315 - 550	410.8 ± 90.3	0.3 - 0.5	0.4 ± 0.04
SOTA	39 - 64.4	47.3 ± 7.6	250 - 1065	497.4 ± 259.9	0.3 - 0.7	0.5 ± 0.08

Min: minimum; Max: maximum; SD: Standard Deviation; M: Mean; K: Condition Coefficient; DRIG: Drigi, GREBA: Grand Bale, ING: Ingbokolo; JUSK: Ju ya skul.

dry season (0.76) for females and the highest in the rainy season (0.78). The Shapiro Wilk test showed that the condition factor was not normal (n = 520, W = 0.843, p = 0.00). The average value of the correlation coefficient (r^2) was 0.84 for both combined sexes. The minimal value was 0.739 for females and 0.875 for males.

4. Discussion

The results of this study showed that the maximum total lengths and total body weights values of both sexes combined were in accordance with some previous investigations in some african water bodies (**Table 5**). El-Sedfy (1976) [30], Hashem (1977) [31], El-Badavy (1991) [32], Mohamed (2005) [33], Kantoussan *et al.* (2005) [34], El-Drawany (2015) [35] had found different results for the same species in different water bodies.

The length-weight regression coefficient (2.79) was close to the cube of the length as found by Vakily (1989) [36] for *B. docmac* in River Congo (Zaire and for *B. docmac* in Lake Chamo-Ethiopia (Hailu *et al.* (2001) [17].

Entsua *et al.* (1995) [37] working on *B. bayad* from the tributaries of the Volta River (Ghana) and Alimoso (1989) [38] studying *Bagrus meridionalis* in Lake Malawi have respectively reported negative allometric growth regression coefficients

Table 4. Statistical description of Bagrus bajad by sex in Lake Albert.

Sex	Total Length (cm)		Total Weight (g)		*K*	
	Min.-Max	Moy ± SD	Min.-Max.	Moy. ± SD	Min.-Max	M. ± SD
F	30.4 - 61.4	44.9 ± 5.5	10.0 - 1630	308.7 ± 173.8	0.01 - 1.0	0.4 ± 0.09
M	32.0 - 79.4	49.5 ± 8.8	105 - 4000	589 ± 400.1	0.04 -2.7	0.4 ± 0.1
Chi²		34.319		47.234		12.701
Signification		***		***		ND

(Min: Minimum; Max: Maximum; SD: Standard Deviation; M: Mean; K: Condition Coefficient; DRIG: Drigi, GREBA: Grand Bale, ING: Ingbokolo; JUSK: Ju ya skul, ***: Significant difference at p < 0.001), ND: Not Significant Difference).

Table 5. Previous results of maximum length (cm) and maximum weight (g) of *B. bayad* in various water bodies.

Authors	Lake/River	Maximum length (cm)		Maximum Weight (g)	
		Male	Female	Male	Female
El-Sedfy (1976) [30]	River Nile (Ethipia)	63.14	78.02		
Hashem (1977) [31]	Nozhahydrodrom (Ethiopia)	75	85	3668	5057
El-Badawy 1991 [32]	River Nile High Dame (Egypt)			2789	
Mohamed (2005) [33]	Beni-Suef (Ethiopia)	64.6		1788	
Kantoussan et. al. (2009) [34]	River Nile (Egypt)	75.6			
El-Drawany (2015) [35]	River Nile (Egypt)	87		89	
Present Study 2020 in Lake Albert DRC	Lake Albert (DRC)	61.4	77	2115	2115

very close to the cube. In the present study, the *b* value indicates that *B. bayad* in lake Albert has allometric growth pattern where the fish becomes more round in shape as it increases in length (Bagenal and Tesch, 1978) [39]. Condition factor for both males and females remained relatively constant during most of the sampling seasons, except in dry season where females had lower conditions factors than males. This suggests that the fat reserves are not seriously depleted during gonad development. In fact, condition of fish slightly improved.

From our findings, it revealed that the *b* et *K* values (b = 2.79 and K = 0.837) observed for *B. bayad* in Lake Albert are similar to those respectively reported by Kaningini (1995) [40] on the *Limnothrissa miodon* (b = 2.7; and K = 0.8) in Lake Kivu, Bukavu basin (DR Congo) and close to Mahy (1981) [41] who found *b* values between 2.11 and 3.42 for *L. miodon* in the northern sector of the same waterbody. The annual variation of *b* values and the condition factors justify influence differently expressed by abiotic environment on the considered sizes categories (Kaningini, 1995) [40].

In the Ouémé delta in Benin, Chikou (2006) [27] also observed a negative allometric growth for *C. gariepinus* (b = 2.845). As from our study (b = 3.12 in dry season and b = 2.55 in rainy season), the same growth type (b = 2.560 in rainy season and b = 2.980 in dry season) have been reported for *Clarias gariepinus* into the Boalin reservoir, in Burkina Faso (Ouedraogo *et al.*, 2015) [42]. This growth type is mainly dependant on the high growth potentials in length for this species.

Otherwise, this study also showed that *B. bayad* growth for both combined sexes was allometric positive in the dry season and negative in the rainy season. The *b*-value of the lenght-weight relationship varied from 2.20 to 3.20. Negative to isometric allometric growth was observed in females, while growth in males was negative allometric. There is a positive correlation between leight and weight. All regressions (**Figures 2-4**) show regardless of sex and season were significantly different with the correlation coefficient (r^2) varying from 0.719 to 0.869. Overexploitation of fish and unfavourable environmental conditions are the cause of low growth. Several authors have reported isometric and allometric growth patterns for different fish species from various water bodies. This agrees with the "*b*" values of 2.911 and 2.794 recorded for *Clarias gariepinus* (African sharptooth catfish) by (King, 1996a) [43]. Ogbé *et al.* (2006) [7] reported a positive allometric growth pattern for *B. bayad* from the Lower Benue River. In a related study, Ogbe and Ataguba (2008) [44] also reported an isometric growth pattern for *Malapterurus electricus* in the Lower Benue River. The *"b"* value obtained for *B. bayad* in this study falls within the range (2.20 - 3.13) reported for Bagrids from the Volta River (Entsua-Mensah *et al.*, 1995) [37]. King (1991) reported an allometric growth pattern for Tilapia species from Lake Umuoseriche. The graph of the logarithmic transformation shows that the weight increases faster at lower lengths than at higher lengths.

Ikongbeh *et al.* (2012) [45] found that the mean condition factor for *B. doc-*

mac had values of "1" and above in Lake Akata in Nigeria, indicating that the fish species are doing well in this lake. The condition factor obtained in this study for *B. bajad* is lower compared to the condition factors of different species of tropical fish studied and reported by Saliu (2001) [46] and Lizama *et al.* (2002) [47]. This may be due to reduced food and prey availability. This behaviour could be due to the fact that the *B. bayad* changed its feeding habits from insectivorous (entomophagy-hematophagy, deep entomophagy) mostly composed of Povilla, Chironomidae, Shrimps, Algae, animal and vegetation materials composed as primary dite while various invertebrates like Trichoptera, Odonates, Corixidae, Ostracods, young fish, molluscs, mud constituted the accessory diet (Verbeke, 1959 [20] and Greedwood, 1959 [19]) to omnivorous feeding mainly as piscivorous (eggs, larva and juveniles of *Orheocrhomis spp* and *Haplochromis spp*) and insectivorous (Masirika et. al., 2022) [48]. Therefore, the study on food composition and feeding habits of *B. Bayad* on Lake Albert showed that the fish species adapted its diet and feeding habits according to variation of food resources availability for its survival within a lake whose habitats and breeding areas facing degradation of habitats due to anthropogenic activities within the lake, as well as its catchment.

The overall condition factor was 0.80 ± 0.12 for males and females combined, but individually this factor was higher in the males (0.83) than in the females (0.76). Both sexes exhibited a negative allometric growth pattern. These results indicate that there is a significant difference between the mean of condition factor per season ($p > 0.05$) unlike *B. nurse* (Saliu, 2001) [46]. This study is in agreement with values reported for various cichlid fishes in Nigeria (King, 1991) [49].

Seasonal comparison of growth values for *B. bayad* showed that there were significant differences in condition factor between dry and rainy seasons ($p > 0.05$). This indicates that seasonal variations did affect the overall condition of this fish during this study. Seasonal variation in fish condition factor has been reported for *Leuciscus lepidus* and *Brycinus nurse* (Karabatak, 1997 [50]; Saliu, 2001 [46]). Despite these differences (Oni *et al.*, 1983) [51] noted that the condition factor is not constant for a species or population over a time interval and can be influenced by biotic and abiotic factors such as diet and the state of gonadal development (Saliu, 2001) [46]. Gomiero and Braga (2005) [52] reported that the better condition during the wet season was due to food availability and improved gonad development. Le Cren (1951) [16] also added that during the dry season the condition of the females is very generally related to the seasons and the seasonal evolution of the condition factor which is very often makes it possible to determine the spawning period of a species because the ovaries whose weight can represent up to 20% of the total weight of the individual emptied at this time, which causes the condition factor to drop. It is also suggested (Samat, *et al.*, 2008) [53] that the condition of fish can be influenced by some extrinsic factors such as changes in temperature and photoperiod. Masirika *et al.* (2022)

[48], showed that although the physico-chemical and nutriments parameters from lake Albert are within the limits of aquatic life in lake Albert (pH = 7.2; Temperature (T˚C) = 28.8˚C; Electronic Conductivity (EC) = 96.9; Ms/cm; Turbity (T) = 27.25 mg/L; Total Dissolved Solids (TDS) = 48.46 mg/L; Total Hardness (TH) = 54.8 mg/L; Dissolved oxygen(DO) = 7.63 mg/L; phosphates (PO_4) = 1.4 mg/L and nitrites(NO_2) = 0.25 mg/L), the results suggests that they are subject to strong variations over time. Changes in land use and land cover around the basin and pollution from lake Albert's tributary rivers may be fatal to the life of biodiversity in the long term.

Regarding the stations, the results in **Table 3** show that in the samples, both juvenile and adult individuals were considered for all 6 stations surveyed in the present study. The size of Bagrus bajad specimens caught at different stations varied from 32 to 79.4 cm in total length with a weight ranging from 72 to 2065 g. The smallest individual was observed at the Ingbokolo station (ING) and the largest at the Drigi station (DRIG). These two stations are located in the coastal and pelagic areas of Lake Albert respectively. According to Petrakis and Stergiou (1995) [10], when samples do not include a wide variation in size of individuals, including both juveniles and adults, the use of Weight-Length relationships can only be limited to the size range applied in the estimation of the linear regression parameters. With regard to season, the results show a significant difference between the size of males and females with larger values for males in the wet season.

The linear regressions were non-significant between male and female *Bagrus bajad* ($p > 0.05$) for all the stations considered, with the coefficients of determination $r^2 > 0.70$ for all the stations except for the Drigi ya Griki (DRGI) station which showed a coefficient of determination less than 0.50. The growth patterns by sex and station are recorded in **Table 3** and **Table 4**. In general, Bagrus bajad showed negative allometric growth ($b < 3$; $p < 0.05$) for both sexes and at almost all stations except Songa Tabu (SOTA) and Grand Bale (GREBA) where males showed isometric growth and at Juu ya Skul (JUSK) station for females.

The slope of the regression line b expresses the relative body shape of a fish (Le Cren, 1951 [16], Kareem *et al.*, 2015 [54]; Froese *et al.*, 2014 [55]). The values of b can indeed be influenced by sex, growth phase, stomach contents, level of gonad development (Hossain *et al.*, 2006) [56] and environmental conditions (Baby *et al.*, 2011) [57]. However, as with some authors (Lalèyè, 2006 [58]; Muzzalifah *et al.*, 2015 [59]; Lederou *et al.*, 2016 [60]; Mikembi *et al.*, 2019 [61]), in this study these parameters were not specifically taken into account during data processing.

The values of the Bagrus bajad condition factors (*K*) of all the stations studied are recorded in **Table 3** and **Table 4**. Overall, *K* varies between 0.04 and 2.7 with the lowest average obtained at Drigi ya Griki (0.04 - 0.06 (0.3 ± 0.12) and the highest at Ingbokolo station (ING) 0.3 - 2.7 (0.6 ± 0.2). According to Bagenal and Tesch (1978) [29], values between 2.9 and 4.8 are consistent for freshwater fish. In the present study, only 9.2% of Bagrus bajad individuals have mean K values within the range of Bagenal and Tesch (1978) [29], 90.8% have lower values and 0% have higher values. According to Lévêque (2017) [62], hydrological variability resulting from the seasonal distribution of rainfall or interannual variability of precipitation have important consequences on the biology and dynamics of fish populations.

In addition, seasonal changes in water level with the creation of flood plains of varying duration have an impact on the functioning of tropical hydrosystems (Lowe-MacConnell, 1988) [63]. Periodic flood-storm alternations favour the creation of a great diversity of habitats (Lévêque and Paugy, 2017) [62] and have a major impact on the biology, physiology and ecology of fish populations (Bolognini *et al.*, 2013) [64]. In Lake Albert, seasonal water level variations are not significant and floodplains are non-existent. A non-significant difference ($p < 0.05$) in water level was observed between the dry and rainy seasons in all sampled stations. This may explain the low values obtained.

A similar situation was reported by Ibala Zamba (2010) [65] in the Lefini river basin in the Republic of Congo; by Lederou *et al.* (2016) [60] in the Mono river basin in Benin and by Mikembi *et al.* (2019) [61] in the Dzoumouna river in the Democratic Republic of Congo.

5. Conclusion

The study on the length-weight relationship and the condition factor of *Bagrus bajad* from Lake Albert shows that the variable *b* of the weight-length relationship of this fish species displays a negative or isometric allometric growth during the dry season in all sexes. The analysis of the condition factor shows that the values are different between the two seasons but these values remain significantly lower for females than for males. These results contribute to the knowledge of the sustainable management and conservation of this species in Lake Albert. Fisheries decision-makers are therefore recommended to regularly monitor and control anthropogenic activities both on lake and the catchment to limit their impacts on various habitats, fish breeding areas, and littoral and pelagic zones for the fish species' welfare.

Authors' Contributions

Joseph M. Matunguru was involved in all phases of the study. These are the design of the study, the data, the tabulation, the data processing and analysis and the writing of this manuscript; Gabriel M. Okito was involved in the study design, tabulation, data processing and analysis and writing of this manuscript. Godfrey K. Kubiriza, Gaston T. Hamulonge and Jonas J. Uvon intervened in the data collection, counting, processing and analysis of the data. Mbalassa Mulongaibalu, Venant M. Nshombo, Peter Akoll, Godfrey K. Kubiriza, Richard Rugadya, Herbert Nakiyende, Jean-Claude Micha, Gaspard Ntakimazi reviewed and corrected the English in the manuscript.

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Conflicts of Interest

The authors declare no conflicts of interest.

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