LENGTH WEIGHT RELATIONSHIP AND CONDITION FACTOR OF *Chrysichthys longidorsalis* IN THE SANAGA RIVER BASIN, CENTRAL REGION, CAMEROON.

Abstract

The huge demand - supply gap of fish in Cameroon can be closed through sustainable fisheries, aquaculture and the enhancement of native fish species for aquaculture development. Management of fish sizes, length-weight relationship (LWR) and condition factor are essential in the prediction of potential yield populations of fish living in certain feeding, density and climatic conditions. Given the lack of adequate information on morphometric characteristic of wild fish in Cameroon, the present research was carried out from November 2019 to October 2020 to analyse the LWR and Fulton's condition factor (K) of *Chrysichthys longidorsalis* in a bid to provide baseline information for its fishery management and aquaculture development. A total of 451 sampled *C. longidorsalis* fish captured in the Sanaga River basin of Centre region in Cameroon was identified and their lengths and weights measured to determine their length-weight relationships and condition factors. The results showed that the mean standard length (SL), total length (TL) and total weight (TW) of *C. longidorsalis* in the Sanaga River basin of Cameroon were 18.13 ± 7.32 cm, 23.91 ± 9.37 cm and 305.15 ± 315.66 g, respectively. Overall, the male fish were significantly ($p<0.05$) longer and heavier than the female fish. The high correlation coefficient (>0.9) and coefficient of determination ($R^2 = 0.8921$), and positive 'a' (intercept) values (0.0578 for combined sexes) revealed a strong positive relationship (>95%) between SL and TW of the fish. The growth coefficient (b) values, were all less than 3 (2.6116 for combined sexes) suggesting a negative allometric growth pattern. Though the condition factor was significantly higher ($p<0.05$) in males and during the dry season than in females and during the rainy season, the overall value was 5.85 ± 11.44 indicating that the fish had good adaptation to the conditions of the Sanaga River basin**.** The study serves as useful reference for sustainable management and conservation of fish resources in Cameroonian waters and for aquaculture development.

Keywords: Length - weight relationship, Fulton's condition factor, growth pattern, *Chrysichthys longidorsalis*, Sanaga River basin Cameroon.

Introduction

Fish is the preferred protein source of most underprivileged communities in Cameroon due its affordability and availability in small units for easy purchased (Kaktcham *et al*., 2015). However, Cameroon's natural fisheries stocks are rapidly deteriorating due to illegal and overfishing (FAO, 2009; FAO, 2017) and wild capture fisheries does not satisfy the national needs which increase annually in proportion to population growth (Pouomogne *et al*., 2008).

The huge demand - supply gap obliges the country to import frozen fish (over 100,000 tonnes of fish per year), leading to a deficit in fish products trade balance and escalating fish prices (Pouomogne *et al*., 2008, FAO, 2017). Closing this gap requires sustainable fisheries through application of appropriate and effective fishery management strategies, and sufficient annual recruitment through aquaculture to reduce pressure on capture fisheries (Sikoki *et al.*, 1999).

The World fish supply of 20 kg per capita is due to intensification and growth in aquaculture correlated with enhancement of native species in certain regions (FAO, 2016; Tiogue´ *et al*. 2020). Cameroon's biodiversity comprises many indigenous fish species such *Chrysichthys longidorsalis* (*C. longidorsalis*), *Labeobarbus batesii* and *Parachana obscura* amongst others, which could have great aquaculture potential and high commercial value in Cameroon (Pouomogne *et al*., 2008). Indigenous African carps and catfish including *Labeo parvus* (Montchowui *et al*., 2011a, b and c) in Benin, *Labeo coubie* in Nigeria (Ikpi and Okey, 2010) and *Clarias jaensis* (Zango *et al.*, 2016, 2017) have been shown to be profitable and adapting better to constraints of local aquaculture. This suggests that indigenous fish species in Cameroon can perform better in aquacultures in the country. Despite high biophysical potential for fish culture in Cameroon, with inland waters covering over 40,000 Km^2 and a growing increasing population, fish farming is poorly established and highly dependent on exotic species (*Clarias gariepinus*, *Oreochromis niloticus* and *Cyprinus carpio)* which are less adapted compared to indigenous species to the environment and whose fingerlings are rare and expensive (Pouomogne *et al*., 2008). In this regard, understanding the fishery and enhancing of the breeding of *C. longidorsalis,* which is a highly valued food fish endemic to the middle course of the Sanaga River basin (Brummett, 2008), through appropriate techniques to ensure adequate and regular supply of fish seeds for aquaculture development will improve fish yields by targeted communities in the country.

Length - weight relationship (LWR) and condition (K) factor are important tools for adequate management of fish species (Ndome *et al*., 2012). LWR is used to compute the K - factor which is important in determining the performance, survivorship and reproductive success in a fish population (Forseth *et al*., 1999). Also, the K - factor indicates the amount of energy available to an individual allocated to various life functions such as reproduction, foraging and survival (Al-Azizz *et al.*, 2017) and provides information when comparing two populations of fish living in certain feeding, density and climatic conditions (Idodo-Umeh, 2002). Though fish size and LWR is used to predict potential yield and size at capture for optimum yield, management parameters are directly related to length of fish for differentiating populations. However, there is dearth of information on the characteristic length - weight relationship and condition factor of wild fish in Cameroon and the influence of these relationships to sustainable development and intensification of fishery and aquaculture in Cameroon. Given the lack of information on morphometric characteristics of wild fish in Cameroon, the present research was carried out to analyse length-weight relationship and condition factor of *C. longidorsalis* in the Sanaga River basin to provide baseline information for its fishery management and aquaculture development.

Materials and Methods

Description of study area

This study was carried out at the River Sanaga basin in the Centre Region of Cameroon. The river flows for 918 km from the Adamawa Plateau to the mouth of the Atlantic Ocean. Fish samples were collected upstream of Ebebda, at the Mbam and Sanaga confluence zone (Latitudes 3°38′ and 7°22′ North and Longitude 9°38′ and 14°54′ East) (Figure 1). The area has two distinct rainy seasons (mid-March – mid-June and mid-September – mid-November) with an annual rainfall range of 1500 – 2000 mm, and two distinct dry seasons (mid-June to mid-September, mid-November to mid-March). The surrounding area is moderately populated (20 – 69 / km^2) with major activities being subsistence farming, fishing and sand extraction. The fishing gears frequently used include gillnets, seine nets, non-return valve and bamboo traps.

Figure 1: Map of Sanaga River basin showing point of collection of study samples

Selection and sampling of fish for the study

A cross-sectional study using stratified sampling procedure was carried out during the period of December 2018 to December 2019 to select fishermen and individual fish per fisherman's catch at the middle course (upstream of Ebebda) of the Sanaga River, at the Mbam and Sanaga confluence zone of Centre Region, Cameroon. For lack of previously reported data, a default rate of 50% was used to estimate the number of fish required for the study with a desired 95% confidence and precision of ≥ 5% (Thrusfield, 2007). The selection of fishermen during each visit was done by simple random-number generation method of the fishermen doing commerce at the study sites. The selection procedure took into consideration health status of the captured fish and fishermen's willingness to participate in the study. Eligible fishermen were numbered and chosen randomly without replacing the number. Selection of individual fish from the chosen fishermen was based on a calculated sampling fraction of five (every fifth fish was sampled) for use at each fisherman's catch. Briefly, the first fish was selected by picking a fish by random generation method from the first five fish being transferred to the temporal storage chain for commercial activities. Thereafter, every fifth fish (adding 5 to previous picked number) was chosen as sample. Thus, a total of 451 samples of

C. longidorsalis, identified as previously by Risch and Thys van den Audenaerde (1981) and Brumette (2008), and considered healthy on the basis of appearance and absence of obvious diseases, were randomly collected without bias of size, type and sex on monthly bases for 12 months (November 2019 to October 2020) from fishermen's commercial catch. Specialised and unspecialized fishing gears including gillnet, seine net, non-return valve and bamboo traps were used by the fishermen to capture the live fish samples. To preserve the maximum freshness, the collected samples were transported in an ice chest to the Research Center for Food, Food Security and Nutrition of the Institute for Medical Research and Medicinal Plants Studies (IMPM), Ministry of Scientific Research and Innovation (MINRESSI), Yaoundé, Cameroon, for dissection and further analyses. Manipulation and examination of all fish specimens was done within 12 hours after capture.

Morphometric Parameters: The length-weight relationship and Condition Factor (K)

The size (standard and total lengths (cm)) of the fish was measured using a calibrated measuring board while the weight of each fish was measured using an electronic balance (0.1g error margin) after blotting it dry with a clean towel (Johnson *et al*., 2013).

The Length Weight Relationship (LWR) was determined using the equation $W = aL^b$ (Le Cren, 1951, Froes, 2006 and Ezekiel, 2013).

Where: W = Fish weight (g), L = SL (cm), a = constant (intercept) and b =length exponent (slope of the log - transformed relation) and referred to as the growth constant.

Regression parameters 'a' and 'b' of the length - weight relationships were estimated by linear regression equation Log W = log a + b log L after logarithmic transformation of weight and length data respectively. The growth of the fish population, whether Isometric ($b = 3$), negative allometric ($b < 3$) or positive allometric ($b > 3$), was determined as previously described (Quarcoopome, 2017, Froese, Tsikliras and Stergiou, 2011). The degree of association between length and weight was expressed by a correlation coefficient "r" (ranging between -1 and +1) with a negative correlation corresponding to a negative value of 'b' and positive correlation corresponding to a positive value of b in regression analysis (Pauly, 1983).

The Fulton's condition factor was estimated using: $K = 100W/ L^b$. (Ricker, 1975); Where: W is the total weight of fish (g), L = standard length of the fish (cm), b = slope of log transformed length – weight plots corresponding to the coefficient of allometry considered equal to 3) (Akombo *et al*., 2013. Dekić *et al*., 2016). The Fulton's Condition Factor (K) assumes that the weight of the fish is proportional to the cube of the length and was used to assess the general health of the fishes, on individual and population level. The Fulton's condition factor was multiplied with 100 to get it close to 1, and the number 1 indicated a normal condition of the fish, greater than 1 indicated fat fish and less than 1 indicated skinny fish. This morphometric index assumes that the heavier a fish for a given length the better its condition.

Determination of the sex

The sex of each fish was determined by visual inspection and dissection to inspect the gonads using previously described procedures (Akombo *et al*., 2013' Mbakane *et al.*, 2010). Briefly, pressing the abdomen of some adult fish specimens caused the release of whitish milt for males and eggs for females. Upon dissection of some adult female samples, eggs were readily seen swollen in the paired ovaries, while the testes were typically flattened and elongated, whitish and non-granular in appearance in adult male samples. Also, the shape of the gonad was a guide to the sex for immature fish specimens. Otherwise, the gonads were excised and examined under the microscope for the presence of immature eggs (female) or milt (male) for immature fishes. Where gonads were not identified, the sex of the fish was recorded as undetermined (Quarcoopome, 2017).

Statistical Analysis

Microsoft office Excel 2013 was used for entering obtained data for descriptive statistics. The data was transferred to the Statistical Package for the Social Sciences (version 22, SPSS Inc., USA) for further statistical analysis (Thrusfield, 2007). Linear regression was used to estimate a, b and coefficient of correlation (r) and to ascertain the significance of the relationship derived from the length - weight analysis. The relationships between factors such as host sex, weight and length were obtained using analysis of variance (ANOVA) and significant level was set at $p < 0.05$ (Anderson and Neumann, 1996, Thrusfield, 2007).

Results

Size Distribution and Population Structure

Overall, 451 *C. longidorsalis* samples (136 males, 200 females and 115 undetermined) considered healthy on the basis of appearance and absence of obvious diseases were used in the study (Table 1). The standard length (SL), total length (TL) and total weight (W) of the fish ranged from 6.20 cm to 41.20 cm (mean: 18.13 ± 7.32 cm), 8.00 cm to 53.10 cm (mean: 23.91 ± 9.37 cm) and 25.00 g to 1605.00 g (mean: 305.15 ± 315.66 g) respectively. The male *C. longidorsalis* were significantly ($p<0.05$) longer and heavier than the female fish.

Table 1: Distribution of *C. longidorsalis* from Sanaga River according to Length and Weight

Parameter	Variable	Number sampled (%)	Standard length (cm) Mean ± SD (Min – max)	Total length (cm) Mean ± SD (Min – max)	Weight (g) Mean ± SD (Min – max)
Rainy season	Female	109	18.86 ± 7.72a (6.2 – 39.3)	24.90 ± 9.94a (8.0 – 47.4)	168.11 ± 233.20a (15 – 980)
	Male	65	17.07 ± 5.92a (10.1 – 41.2)	22.59 ± 7.52a (13 – 51.4)	246.51 ± 259.51b (25 – 1605)
	Sex not determined	85	24.01 ± 8.72 (10.1 – 40.9)	31.37 ± 10.87 (17.9 – 50.8)	81.94 ± 143.57 (20 – 1060)
	Total	259	20.10 ± 8.15A (6.20 – 41.2)	26.44 ± 10.33A (8.00 – 51.4)	159.51 ± 223.83A (15 – 1605)
Dry season	Female	91	16.23 ± 5.73a (10 – 40.3)	21.65 ± 7.44a (12 – 19.4)	136.87 ± 197.38a (25.0 – 1310)
	Male	71	14.62 ± 4.47a (9.6 – 36.5)	19.17 ± 5.89a (11.0 – 46.4)-	358.83 ± 352.81b (40 – 1240)
	Sex not determined	30	15.15 ± 2.13 (10 – 20.3)	20.17 ± 3.96 (11.8 – 26.8)	73.07 ± 85.77 (20 – 500)
	Total	192	15.47 ± 4.90B (6.2 – 41.2)	20.50 ± 6.52B (11.0 – 46.4)	208.98 ± 280.75B (20 – 1310)
Overall	Female	200 (44.34)	17.66 ± 6.99a (6.20 – 40.30)	23.42 ± 9.02a (8.00 – 49.40)	153.90 ± 217.66a (15.00 – 1310.00)
	Male	136 (30.15)	15.79 ± 5.34b (10.00 - 41.20)	20.81 ± 6.91b (8.40 – 53.10)	305.15 ± 315.66b (25.00 – 1605.00)
	Sex not determined	115 (25.50)	21.69 ± 8.51 (9.60 – 36.50)	28.45 ± 10.75 (11.00 – 46.40)	79.63 ± 130.67 (20.00 – 1060.00)
	Total	451 (100)	18.13 ± 7.32 (6.20 – 41.20)	23.91 ± 9.37 (8.00 – 53.10)	180.57 ± 250.56 (15.00 – 1605.00)

a, b: same letters on a category (parameter) in a column are not significantly different ($p>0.05$)

A, B: same letters in a column are not significantly different ($p>0.05$)

Length - Length Relationship

The correlation coefficient and coefficient of determination revealed a strong relationship (>95%) between standard and total lengths of *C. longidorsalis* from the Sanaga River basin (figures 2, 3 and 4). The observed standard length - total length relationships of the samples are shown by the following linear regression equations:

For males: SL = 0.7894 TL - 0.9351(n = 136, R^2 = 0.9717);

For females: SL = 0.7379 TL + 0.2911 (n = 200, R^2 = 0.9589);

For both sexes: SL = 0.7596 TL - 0.0888 (n = 451, R^2 = 0.9708).

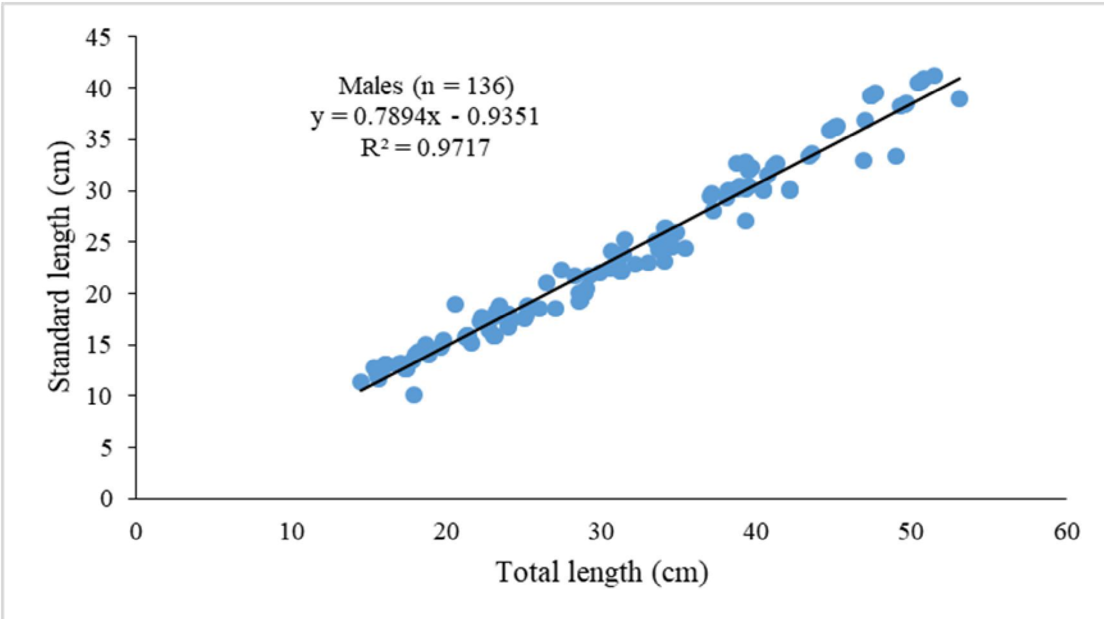

Figure 2: Standard length - total length relationship of males *C. longidorsalis* from the Sanaga River basin of Cameroon.

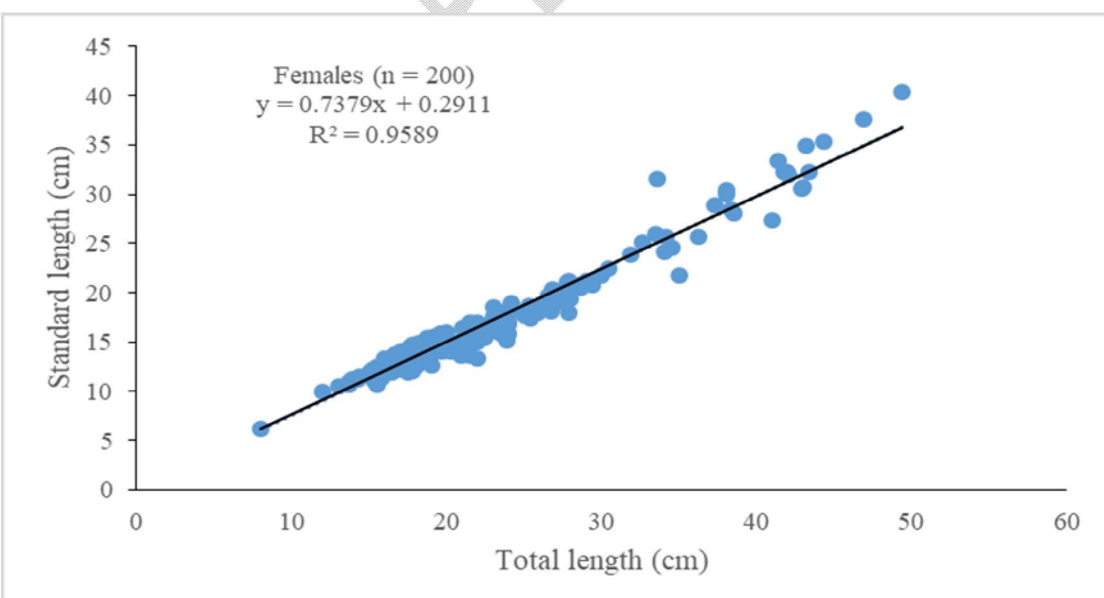

Figure 3: Standard length - total length relationship for females *C. longidorsalis* from the Sanaga River basin of Cameroon.

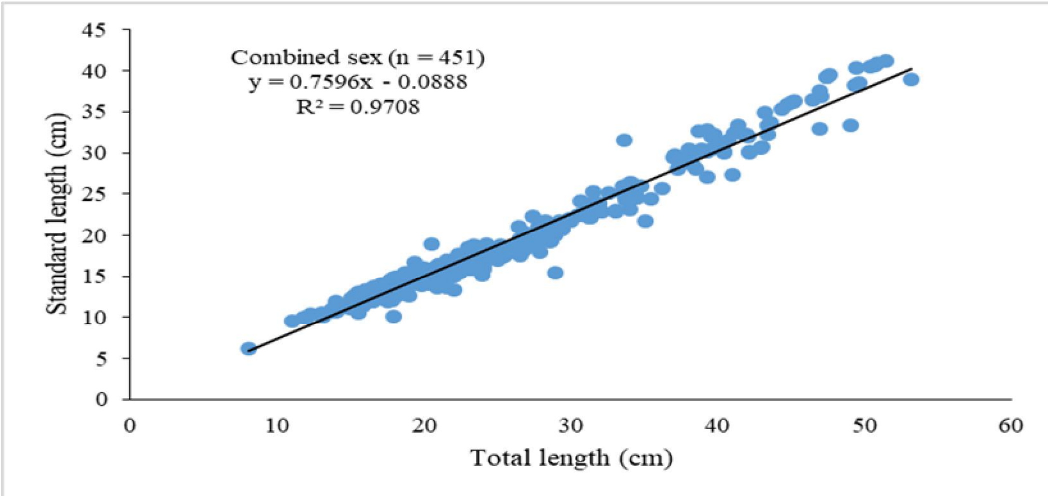

Figure 4: Standard length - total length relationship for combined sex *C. longidorsalis* from the Sanaga River basin of Cameroon.

Length - Weight Relationship

Also, the correlation coefficient and coefficient of determination revealed a strong relationship (>95%) between standard length and weight of *C. longidorsalis* from the Sanaga River. (figures 5, 6 and 7). The observed standard length - weight relationships are shown by the following linear regression equations with the estimated values for "a", "b" and "R^2":

For males: $W = 0.0788\ SL^{2.5255}$ (n = 136, $R^2 = 0.8855$);

For females: $W = 0.0532\ SL^{2.6353}$ (n = 200, $R^2 = 0.8303$);

For both sexes: $W = 0.0578\ SL^{2.6116}$ (n = 451, $R^2 = 0.8921$);

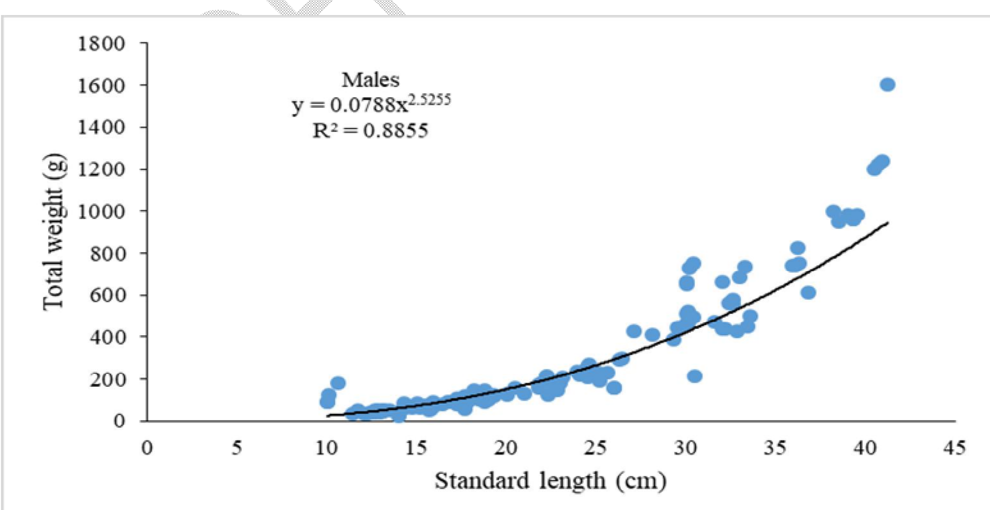

Figure 5: Length - weight relationship for males *C. longidorsalis* from the Sanaga River basin of Cameroon

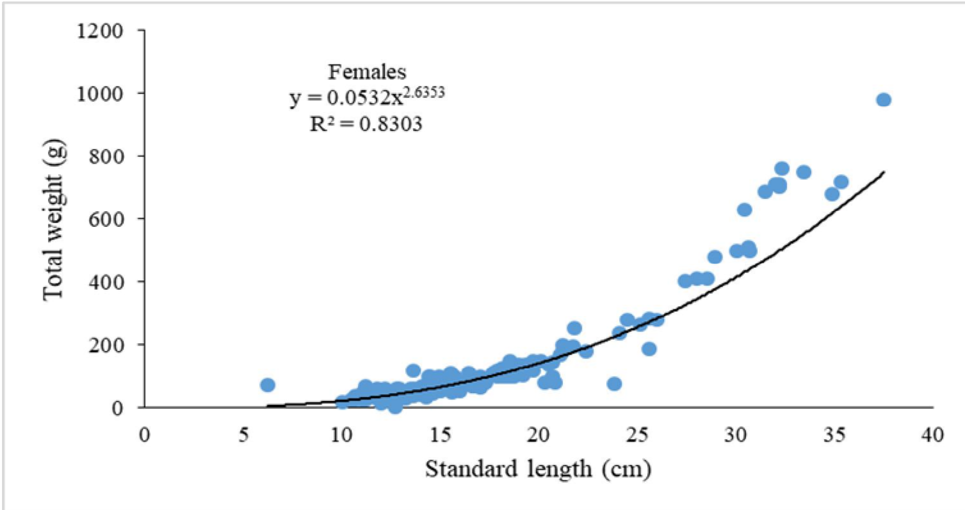

Figure 6: Length - weight relationship for females *C. longidorsalis* from the Sanaga River basin of Cameroon

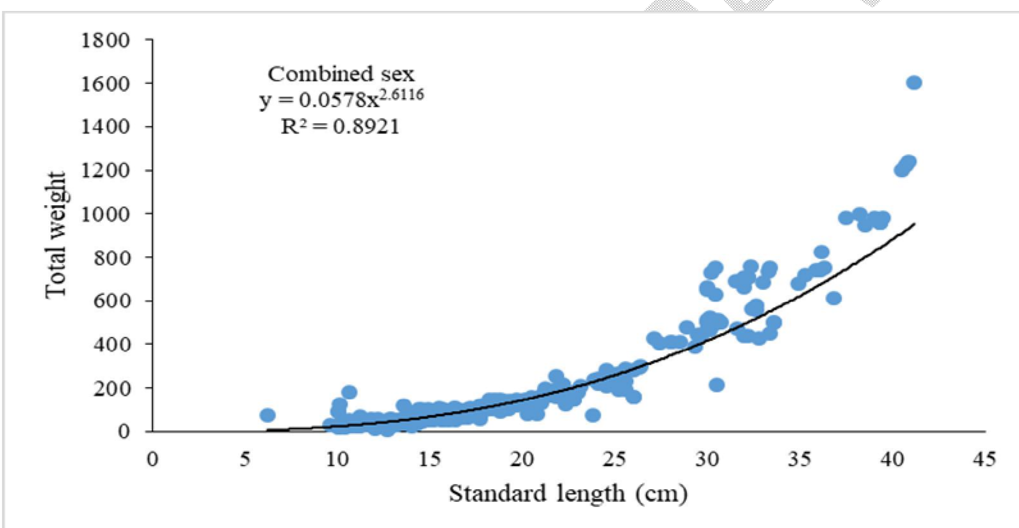

Figure 7: Length - weight relationship for combined sex *C. longidorsalis* from the Sanaga River basin of Cameroon

The fish exhibited negative allometric growth pattern ($b < 3$). The b - values for males (2.5255), females (2.6353) and both sexes combined (2.6116) were less than 3. There was strong positive correlation between the length and weight as shown by the positive “a” values for males (0.0788), females (0.0532) and both sexes combined (0.0578), and high correlation coefficients (>0.9) that approximated to 1. The length - weight relationship with respect to seasons is linear and represented as follows (figures 8,9,10 and 11): for long dry season: R^2 is 0.763, r = 0.8735, a = - 1.1392 and b = 2.5339; short rainy season : R^2 = 0.8112, r = 0.9006, a

= - 1.2821 and b = 2.6543; short dry season, R^2 is 0.9213, r = 0.9598, a = - 1.2545 and b = 2.6538 and long rainy season, R^2 = 0.694, r = 0.833, a = - 0.8514 and b = 2.3418.

The Length - weight regression for *C. longidorsalis* from the Sanaga River basin according to sex and season revealed a strong ($P<0.001$) positive correlation with the coefficients (R^2) ranging from 0.69 to 0.92 and slope (b) from 2.34 to 2.65.

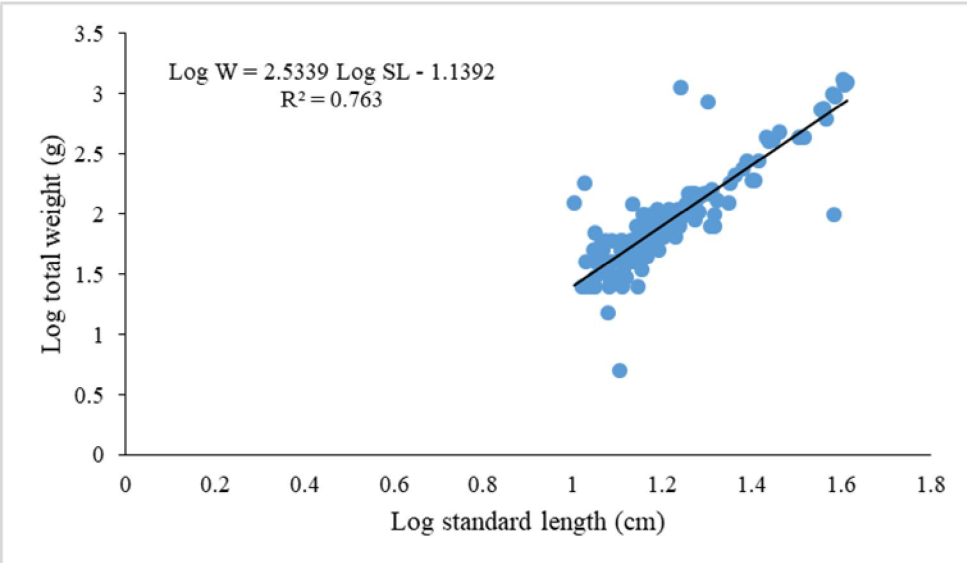

Figure 8: Length - weight relationship of *C. longidorsalis* from the Sanaga River basin for the long dry season.

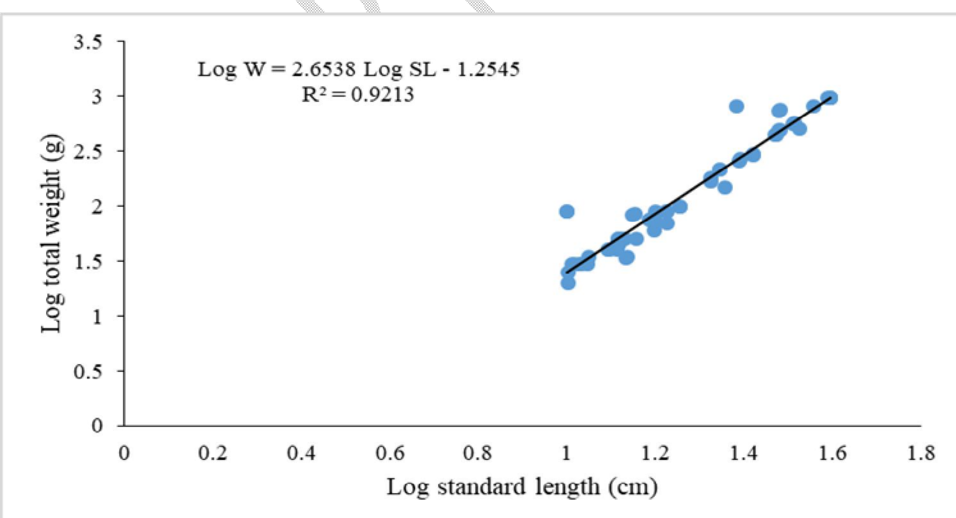

Figure 9: Length - weight relationship of *C. longidorsalis* from the Sanaga River basin for the short dry season.

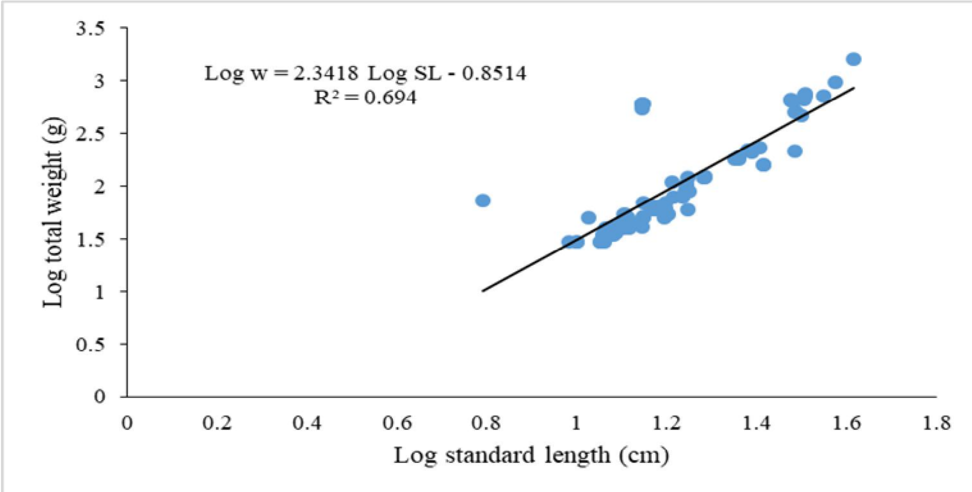

Figure 10: Length - weight relationship of *C. longidorsalis* from the Sanaga River basin for the long rainy season.

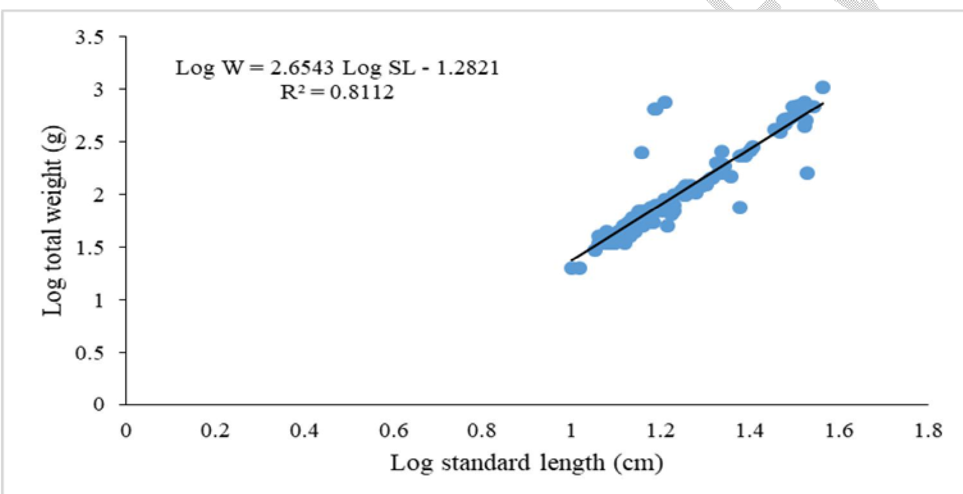

Figure 11: Length - weight relationship of *C. longidorsalis* from the Sanaga River basin for the short rainy season.

Condition factor

The condition factor (k) for *C. longidorsalis* from Sanaga River basin according to sex, size, month and season of the year are presented in Table 2. Overall, the mean K factor was significantly higher ($p<0.05$) in males and during the dry season than in females and during the rainy season. Also, the K factor was highest in July (17.09 ± 17.09) and December (15.47 ± 19.72) and lowest in March (1.57 ± 2.21) and April (1.75 ± 3.17). Table 3 shows the variation of condition factor with standard length and weight. The results showed that the k values generally decreased with fish standard length and increased with weight of the fish

Table 2: Condition factor of *C. longidorsalis* from river Sanaga basin Cameroon according month of month and season

Parameter	Variable	Females		Males		Undetermined		Total	
		N	**K ± SD**	**N**	**K ± SD**	**N**	**K ± SD**	**N**	**K ± SD**
Month	January	42	6.72 ± 14.62	8	4.36 ± 3.47	/	/	50	6.34 ± 13.47
	February	40	5.22 ± 14.92	10	6.73 ± 10.34	/	/	50	5.53 ± 14.12
	March	42	1.58 ± 2.28	3	3.31 ± 2.30	5	0.38 ± 0.17	50	1.57 ± 2.21
	April	10	4.60 ± 5.79	/	/	41	1.05 ± 1.57	51	1.75 ± 3.17
	May	21	4.29 ± 7.52	2	13.40 ± 16.60	17	0.41 ± 0.49	40	3.10 ± 6.75
	June	10	2.84 ± 2.51	22	8.31 ± 9.09	1	25.27	33	7.17 ± 8.55
	July	/	/	19	24.10 ± 17.02	10	16.54 ± 16.33	29	17.09 ± 17.09
	August	8	2.65 ± 1.68	21	4.71 ± 3.87	5	1.17 ± 0.45	34	3.70 ± 3.40
	September	9	11.30 ± 10.92	17	3.35 ± 2.45	/	/	26	6.10 ± 7.54
	October	10	7.05 ± 11.25	7	13.66 ± 24.37	10	1.76 ± 0.96	27	6.81 ± 14.27
	November	7	5.05 ± 4.79	14	4.33 ± 2.88	11	0.81 ± 0.89	32	3.28 ± 3.40
	December	1	2.01	13	32.34 ± 18.65	15	1.75 ±0.76	29	15.47 ± 19.72
Duration and type of season	Short rainy season	83	2.78 ± 4.74aA	27	8.13 ± 9.09bA	64	1.21 ± 3.33A	174	3.03 ± 5.69A
	Long rainy season	26	7.98 ± 9.80aB	38	5.61 ± 10.82aA	21	1.26 ± 1.02B	85	5.26 ±9.31B
	Short dry season	8	2.65 ± 1.68aC	40	13.92 ± 15.41bB	15	2.89 ± 4.41C	**63**	9.86 ± 13.54C
	Long dry season	83	5.94 ± 14.61aD	31	16.86 ± 18.90bB	15	1.75 ± 0.76D	**129**	8.08 ± 15.71C
Combined durations of the season	Whole rainy season	109	4.02 ± 6.65aE	65	6.66 ± 10.14bC	85	1.22 ± 2.92E	259	3.77 ± 7.15D
	Whole dry season	91	5.65 ± 13.98aF	71	15.20 ± 16.96bD	30	2.32 ± 3.17F	192	8.66 ± 15.02E
Total		**200**	4.77 ± 10.64a	**136**	11.12 ± 14.70b	**115**	1.51 ± 3.01	**451**	5.85 ± 11.44

a, b : Different letter in a category (parameter) in a row are significantly different (p<0.05)

A, B, C, D, E, F: Different letters in a category (parameter) in a column are significantly different (p<0.05)

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Table 3: Condition factor of *C. longidorsalis* from River Sanaga according to standard length and weight

Parameter	Variable	Female		Male		Undetermined		Total	
		N	K	N	K	N	K	N	K
Standard length (cm)	< 10	4	10.67 ± 8.01A	1	5.65	2	3.00 ± 0.00	7	7.76 ± 6.79A
	[10 – 20[	146	5.89 ± 12.09aA	119	12.41 ± 15.27bA	63	2.40 ± 3.82A	328	7.58 ±12.91A
	[20 – 30[	29	1.40 ± 1.72aB	11	2.47 ± 2.17aB	24	0.40 ± 0.18B	64	1.21 ± 1.62B
	> 30	21	0.49 ± 0.63aC	5	0.53 ± 0.38aB	26	0.26 ± 0.40B	52	0.38 ± 0.51C
Total weight (g)	< 200	169	2.54 ± 2.71aA	76	3.23 ± 2.29aA	110	1.09 ± 1.12	355	2.24 ± 2.38A
	[200 – 400[	6	3.21 ± 2.92aA	17	7.23 ± 3.38bB	1	7.41	24	6.24 ± 3.60B
	[400 – 600[	9	15.57 ± 13.12aB	20	19.03 ± 12.68aC	2	21.85 ± 4.99	31	14.13 ± 12.33C
	[600 – 800[	12	9.94 ± 9.86aB	11	18.66 ± 12.10aC	1	1.62	24	13.59 ± 11.65C
	[800 – 1000[	2	34.35 ± 30.46aC	8	42.65 ± 12.98aD	/	/	10	40.99 ± 15.69D
	> 1000	2	87.93 ± 7.51aC	4	54.18 ± 15.03bD	1	1.60	7	56.31 ± 30.95D
Total		200	4.77 ± 10.64a	136	11.12 ± 14.70b	115	1.51 ± 3.01	451	5.85 ± 11.44

a, b : Different letter in a category (parameter) in a row are significantly different (p<0.05)

A, B, C, D : Different letters in a category (Parameter) in a column are significantly different (p<0.05)

Discussion

The standard length (SL), total length (TL) and total weight (W) of *C. longidorsalis* from the Sanaga River basin ranged from 6.20 cm to 41.20 cm (mean: 18.13 ± 7.32 cm), 8.00 cm to 53.10 cm (Mean: 23.91 ± 9.37 cm) and 25.00 g to 1605.00 g (mean: 305.15 ± 315.66 g), respectively and the males were significantly longer and heavier than the females. The maximum SL encountered in the present study (41.20 cm) was more than 31.2cm previously reported by Risch and Thys van den Audenaerde (1981). However, the different sizes in fishes are influenced by location (King, 1994), harvesting season and techniques, genetic and environmental variations, and temperature (Sikoki *et al*., 1998; Tu *et al*., 2018; Arranz *et al.*, 2021).

The length-weight relationship (LWR) is an important tool that provides information on growth patterns and growth of fish species (Ighwela *et al*., 2011) with the b value in length-weight regression equation indicating the growth pattern. The growth patterns are isometric growth (b=3) when there is no change in body shape with increase in length, negative allometric growth (b<3) when the body becomes slender with increase in length and positive allometric growth (b>3) when the body shape increases with length (Alam *et al*., 2014). Negative allometry suggests poor environmental factors such poor water quality and unavailability of food while positive allometric growth indicates good environmental factors such as high level of dissolved oxygen, optimum temperature, and abundant food. The growth pattern or b value is affected by many factors including gonad maturity, sex, diet, stomach fullness, health, and preservation techniques and may vary with season, time (example: day, week, and month) and habitat (Mon *et al*., 2020).

Overall, the values of the growth coefficient (b) obtained in the present study was less than 3 which portrayed negative allometric growth patterns (Moreau, 1979). The fish became tinnier or slender (seeming longer) as they increased in weight suggesting unfavourable growth conditions (Laurat *et al*., 2019) of C. *longidorsalis* in the Sanaga River basin. This could be attributable to a myriad of ecosystem changes that impaired a three-dimensional growth of the fish (Isa *et al.*, 2010). The ecosystem changes of the Sanaga River basin included water level changes caused by the 2018 Nachtigal dam construction project upstream, which prompted imbalance in the water physicochemistry. Negative allometric growth pattern of other *Chrysicththys* species have been reported in some African waters including: *Chrysicthys longidorsalis* in New Calabar River (b = 1.93) by Elewuo (2012) and in kpong reservoir

Ghana (b = 2.79 for females and 2.91 for males) by (Quarcoopome, 2017), *Chrysichthys auratus* (b = 2.92 females) in River Nile in Egypt by Ragheb (2014) and *C. walkeri* (b = 2.88, females) from the Epe lagoon in Nigeria by Fafioye (2005). The length-weight relationship can vary significantly even within the same species given that the length-weight relationship can be affected by many factors such as sex, seasonal variability, growth phases, stomach contents, food availability, gonadal development, sample size, habitat suitability, temperature and salinity of the environment, fishing activities, individual metabolism, age, maturity and health status of the fish (Laurat *et al.*, 2019; Ahmed *et al.*, 2018; Hossain, 2010; Bayhan *et al.*, 2008; Henderson, 2005).

The correlation coefficient and coefficient of determination showed strong relationships between standard and total lengths of *C. longidorsalis* in the Sanaga River basin and indicated fitting regression equations for the standard length (Ezenwaji and Godfrey, 2004; Ragheb, 2014). Also, the high coefficient of determination (R^2 = 0.8921) and correlation coefficient (>0.9) approximating to 1, revealed strong relationships between standard length (SL) and weight (W) of *C. longidorsalis* from the Sanaga River basin of Cameroon. Hence the body weights of the fish species could be accurately estimated based on their standard lengths (Ahmed *et al.*, 2011; Ezenwaji *et al.*, 2009). Positive values were obtained for the intercepts (a) of the LWR curves of *C. longidorsalis* in this study affirming on the strong positive correlation between the standard length and weight of the fish. Therefore, in agreement with previous observations on different fish species from various water bodies (Konan *et al.*, 2007; Tah *et al.*, 2012; Koffi *et al.*, 2014),the weight increased with length of the fish.

The condition factor (K) describes the state of well-being or condition of fatness of a fish (Shinkafi *et al.*, 2013, Solomon *et al.*, 2017) based on fatness - length and physiological condition relationship in the fish (Laurat *et al.*, 2019). The K factor provides information on the physiological state of the fish in relation to environmental changes and conditions and is an indicator for monitoring feeding intensity and growth rates in fishes (Oniye *et al.*, 2006, Laurat *et al.*,2019) Desirable k factor values should be greater than 1 (Omitoyin *et al.*, 2013). The condition factor may vary for given species and between species and populations (Kartas and Quignard, 1984; Koné, 2000) due to the feeding mechanisms of the fishes (Kamaruzzaman *et al.*, 2010 ; Ahmed *et al.*, 2018) and the quantity and quality of feed available in the different environments (Soedarto & Tembalang, 2019).

In this study, the overall mean monthly condition factor for both sexes of C. *longidorsalis* from the Sanaga River basin was 5.85 ± 11.44, being lowest (1.57 ± 2.21) in March and highest (15.47 ± 19.72) in December. Given that the K factor values obtained in the present study were greater than 1, the C. *longidorsalis* was in good physiological and environmental (habitat) conditions and in satisfying states of wellbeing in the River Sanaga basin during the entire study period (Omitoyin *et al*., 2013). The higher mean K factor observed in males and during the dry season than in females and during the rainy season suggest indicate that the wellbeing of the fish in that river was affected by sex and reproductive activities which negatively affected the female more than the male C. *longidorsalis* (Laurat *et al*., 2019). The higher condition factors during the dry seasons compared to the rainy seasons were associated to the absence or reduction of wash-down water pollutants from the environment that adversely affects the fish physiological and health status. Overall, the k values in this study decreased with standard length and increased with weight of the fish in accordance with previously described reference situations (Waly *et al*., 2015).

The K factors obtained in this study could be compared favourably with reports for different fish species in water bodies in parts of Africa including Cameroon. Lower K factor values were obtained for Alien Fish Species (0.70 ± 0.40) in the Mbô Floodplain Rivers in Cameroon (Tiogué *et al*., 2018),' *Chrysichthys nigrodigitatus* (1.07 ± 0.09) in the Nkam River, Littoral Cameroon (Tiogué *et al*., 2020), *C. auratus* (1.0 to 2.9) in River Benin Nigeria (Ikomi and Odum, 1998); *Chrysichthys auratus auratus* (1.136 and 1.066) and *C. auratus longifilis* (1.137 and 1.016) in El-Nozha Hydrodrome (Bakhoum and Sayed-Ahmed, 2003), male *C. auratus* (1.87 ± 0.08) in Aiba Reservoir, Nigeria (Atobatele and Ugwumba, 2011) and *Coptodon zillii* (1.32), *Synodontis schall* (1.63) and *Chrysichthys nigrodigitatus* (0.97) in Lake Taabo (Aliko *et al*., 2010). However, higher or comparable K factor values were observed for 22 fresh water fish species (0.884±0.085 to 8.968±1.818) in the Solomougou Dam Lake, Korhogo, Côte d'Ivoire (Kouassi *et al*., 2019).

The months with the lowest mean monthly K factor value (March: 1.57 ± 2.21 and April: 1.75 ± 3.17) suggested the spawning season of *C. longidorsalis* in the River (Atobatele and Ugwumba, 2011).

Condition factor of fish are affected by Regional water variations due to environmental conditions and availability of feeds as well as the strain, species, stress and sex of the fish

(Tiogué *et al.*, 2020, Laurat *et al.*, 2019, Omitoyin *et al.*, 2013, Atobatele and Ugwumba, 2011, Khallaf *et al.*, 2003). Also, the physicochemical parameters of water may influence the vertical and horizontal migration of fishes in aquatic ecosystem, their distribution, feeding patterns and wellbeing (Haruna & Bichi., 2005). These factors could have contributed to the differences observed in the present study and previous reports.

Conclusion

This study revealed a strong positive correlation between standard lengths and total weights with b values < 3 indicating a negative allometric growth and suggesting unfavourable growth conditions of *C. longidorsalis* in the Sanaga River. The negative allometric growth can be attributed to ecological differences and changes in water quality caused by the dam construction upstream, reduction of body size to escape predation, overfishing, fish mortality and pollution. However, the condition factors of *C. longidorsalis* in the Sanaga River basin was good, indicating that the river basin is suitable for its habitat. Further investigation on environmental parameters is essential to understand the cause and nature of the allometric growth pattern of *C. longidorsalis* at the Sanaga River basin to aid fisheries managers in their quest for legislation of sustainable management and conservation of fish resources in Cameroonian waters.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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