Original Research Paper

Impact of some ectoparasites on length-weight ratio and condition factor of cultured Fish Species in the West region of Cameroon

ABSTRACT

Aims: This study aims to analyse the effect of ectoparasite infections on length-weight relationships and condition factor of cultured fishes in the West region of Cameroon.

Study Design: A stratified cross-sectional study was used to select fish farms and individual fish per farm.

Place and duration of study: Fish farms in the West region of Cameroon between December 2018 and December 2019.

Methodology: Sampled fishes were identified and examined from ectoparasites and pathologies according to standard procedures. Their lengths and weights were measured to determine their length-weight relationships and condition factors. A total of 2254 fishes (692 *Clarias gariepinus*, 969 *Oreochromis nilotichus,* 593 *Cyprinus carpio)* were sampled.

Results: Overall, 34.87% of the sampled fishes were infected with ectoparasites (*O. niloticus* (34.37%)*, C. carpio* (37.10%) and *C. gariepinus* (33.67%)). The prevalence rates were significantly influenced by size (P=0.001, X^2=10.59) and weight (P<0.0001, X^2=32.24) and negative allometric growth patterns (b < 2) were observed irrespective of the parasitic status of the fishes. Though the mean condition factor ranged from 1.07 to 3.01 throughout in the study according to species, sex and season and ectoparasite status of the fish, significantly higher (P<0.05) condition factors were observed for male fishes, fishes harvested during the dry season and uninfected fishes compared to female fishes, fishes harvested during the rainy season and infected fishes. Among the infected fished, the highest (p<0.05) condition was recorded in *O. niloticus* followed by *C. carpio* and *C. gariepinus*.

Conclusion: The study revealed that ectoparasite infection significantly influence length-weight relationships and condition factor of cultured fishes in the west region of Cameroon. Irrespective of parasitic status, there was relationship between body weight and length of fish. The control of

ectoparasite infection of cultured fishes is vital for improved conditions, health and production yields in fishery sectors in Cameroon.

Keywords: Allometric growth, Length-Weight relationship, Condition factor, cultured fish, external parasites, West region Cameroon

1. INTRODUCTION

Protein deficiency is a major global challenge especially in developing countries [1]. Fish serves as a good source of animal protein for man and livestock and accounts for over 40% of the protein diet of two – third of the global population [1, 2] and poverty alleviation in many communities in developing countries [2-7]. However, an increased fish production implies intensifying production, which has been associated with risks of parasite proliferation and compromised water quality [1]. Parasitic diseases are common among fish species and it is one of the key threats to the production of the industry which leads to major losses in the production thus reduces the profit of the industry [8]. Parasites cause mechanical damage (fusion of gill lamellae, tissue replacement), physiological damage (cell proliferation, immune-modulation, altered growth, detrimental behavioural responses) and reproductive damage on fish species [9-11]. Ectoparasites, compared to endoparasites, are very damaging and have been responsible for high mortality in culturing fish species [12].

For adequate management length-weight and length-length relationships, condition factor and growth are important tools for fish species [13]. Length-weight relationship helps to determine the condition factor of a given individual or a population. Individual condition is an important component in determining performance, survivorship and reproductive success in a fish [14]. In energetic terms, condition factor is the amount of energy available to an individual which may be allocated to various life functions such as reproduction, foraging and over-winter survival [15]. However, there is dearth of information on the characteristic relationship between length-weight and condition factor and the how parasitic infections influence the relationships in cultured fishes in Cameroon. Given the lack of information on morphometric characteristic of fish in the country, the present research was carried out to analyse the effect of ectoparasites on

length-weight relationship and condition factor of cultured fishes in West Cameroon to provide key elements for better fisheries management.

2. MATERIALS AND METHODS

2.1 Description of study area

The study was carried out in three administrative divisions (Menoua, Noun and Hauts-plateaux) of the West region of Cameroon (9°50' – 10°20' E and 5°10' – 5°40' N) (figure 1). The West Region has a typical sudano-guinean climate characterised by a short dry season (mid-November – mid-March) with a temperature range of 20 – 27ºC, long rainy season (mid-March – Mid-November) and temperature range of 16 – 23ºC, average annual rainfall of 1600 mm and relative humidity ranging from 49 – 97.9% [16].

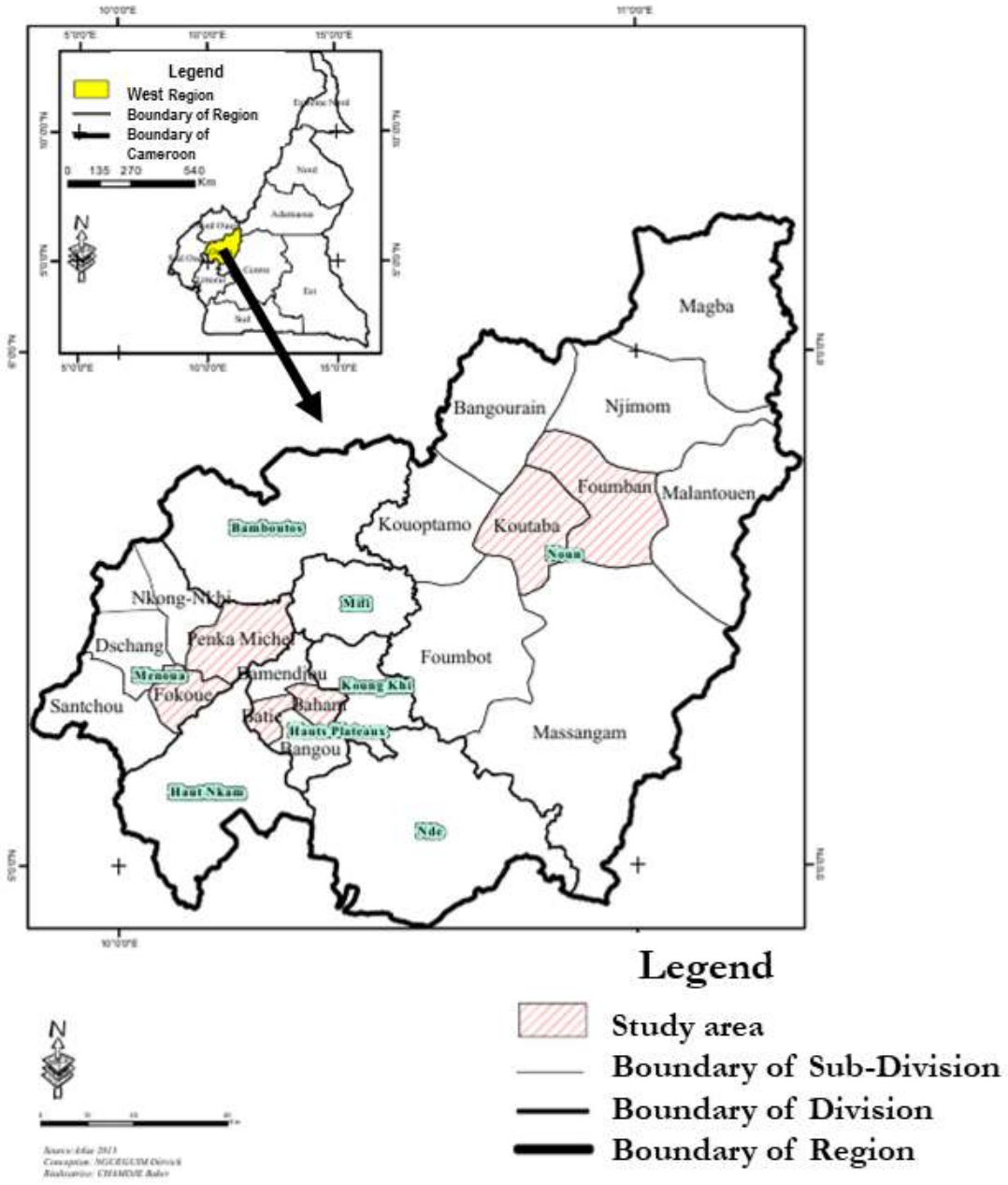


Figure 1: Map of Cameroon showing the West region, the administrative divisions in the region and administrative sub-divisions with study sites within Menoua, Noun and Hauts-plateaux administrative divisions. (Source: The Dschang Urban council in collaboration with the Cartography Unit of the University of Dschang, Cameroon produced the maps including study areas shaded pink in Menoua, Noun and Hauts-plateaux administrative divisions)**.**

2.2 Selection of fish farms and samples 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 fish farms and individual fish per farm in three administrative divisions (Menoua, Noun and Hauts-plateaux) of the West region of Cameroon. For lack of previously reported data, a default prevalence rate of 50% was used to estimate the number of fish required for detecting ≥ 1 infested fish with a desired 95% confidence and precision of ≥ 5% [17]. The selection of fish farms was done by random-number generation method of fish farmers and locations of fish farms from records at the Divisional Delegations of Livestock, Fishery and Animal Industries (DDEPIA). The selection procedure took into consideration costs, road accessibility (including distance and time to trek to farms), period at which farmers will harvest fish and farmer's willingness to participate in the study. Eligible farms for each study division was numbered and the study farms chosen randomly without replacing the number.

Overall, nine fish farms (03 per administrative division) located in different sub-administrative areas of the administrative divisions were selected for the study.Selection of individual fish from each chosen farm was based on a calculated sampling fraction of five (every fifth fish was sampled) for use at each visit during harvesting. 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 transportation to market. Thereafter, every fifth fish (adding 5 to previous picked number) was chosen as sample. A total of 2254 cultured fish species from fish farms in Menoua (522), Hauts-plateaux (775) and Noun (957) divisions were selected for the study. Specialised and unspecialized (draining of water, net fishing and or landing nets) as earlier described by Ngueguim et *al.,* [18] were used capture live fish samples and placed in aerated plastic tanks (containing water from the fish farm before handling to avoid any contamination) for proper labelling, recording of identification characteristics and preliminary external examination for ectoparasites and pathologies [19]. To preserve the maximum freshness, the fish the samples were rapidly transported to the Ichthyology and Applied Hydrobiology Laboratory of the University of Dschang for dissection and further analyses. Manipulation and examination of all fish specimens was done within 12 hours after capture. The fish species determined with

the aid of previously described keys [20-22] were composed of *Clarias gariepinus* (692), *Cyprinus carpio* (593) and *Oreochromis niloticus* (969).

2.3 Morphometric measurements

The size (standard and total lengths (cm)) of the fishes were measured using a measuring tape and thread while the weight of each fish was measured using an electronic balance (0.1g error margin). The sizes (x) were classified according to Shehata et *al.* [23] as follows: small sizes of (25cm ≥ x < 40 cm) for *C. gariepinus*, (12 cm ≥ x < 22 cm) for *C. Carpio* and (14 cm ≥ x ≤ 21 cm) for *O. niloticus*, and large sized group; being 40 cm ≥ x ≤ 55 cm for *C. gariepinus*, 22 cm ≥ x ≤33 cm for *C. Carpio* and from 22 cm ≥ x ≤30 cm for *O. niloticus*. The weights (X) were classified based on Biu et *al.,* (2014) as follows X<50gm, 50gm<X≤100gm, 100gm<X≤150gm, 150gm<X≤200gm and X>250gm.

2.4 Determination of the sex

The sexes of the fish were determined the fish were dissected and the gonads inspected using previously described procedures [24, 25]. Briefly, pressing the abdomen of some adult fish specimens caused the release of whitish milk 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 milky semen (male) for immature fishes.

2.5 Detection of ectoparasites on fish

Standard procedural restraining manipulations were used for safety purposes of the researchers and to avoid suffering of the fishes. The fish samples were examine for ectoparasites using hand lens [26-28]. Briefly, systematic head to tail skin scrapings and scraping from fins and gills of the sampled fish done with the use of swab stick, mixed with 3ml of 0.9% saline, smeared on clean grease-free glass slides were examined under the light microscope for external parasites in the Ichthyology and Applied Hydrobiology Laboratory. Each sample was examined independently as described by Ekanem et *al.* [28]. The identification of parasites was based on

distinctive and morphological features with the aid of reference keys for taxa of fish parasites [29-32].

2.6 The length-weight relationship

The parameters of length-weight relationships were calculated by using the following equation:

$W = aL^b$ [24, 33-35],

Where, b is an exponent usually between 2 and 4;

W: weight of the fish in grams (gm),

L: Length of the fish (cm);

a: Constant (intercept)

b: the length exponent (slope).

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.

2.7 The Fulton's Condition factor (K)

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. In all individuals' total length, standard length and body mass were measured. The allometric equation where the b exponent is a constant was used to compare the health index of the different category of fishes.

Thus, Fulton's condition factor (K) was calculated using the formula: $K = W*100/ L^b$,

Where W = weight of fish (g), L = standard length of the fish (cm), b= coefficient of allometry considered equal to 3) [24, 36].

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 1 indicated fat fish and less than 1 indicated skinny fish. This morphometric index assumes that the heavier fish for a given length the better condition.

2.8 Data analysis

Microsoft office Excel 2007 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 [17]. The ectoparasite prevalence of the fish species was calculated as the number of fish infected divided by the total number of fish examined and expressed as a percentage [17, 37]. A fish sample was classified as infected if it was positive for any ectoparasite group. A positive test was coded as 1 and the negative test as 0. The chi-square test was used to determine the degrees of associations and relationship between the risk factors and ectoparasite infection [38]. Linear regression table was used to ascertain the significance of the relationship derived from the length weight analysis of infected and uninfected fish species.The relationships between factors such as host sex, weight, total length, locality, and parasitic infection were obtained from pooled data using analysis of variance (ANOVA) and significant level was set at $p < 0.05$.

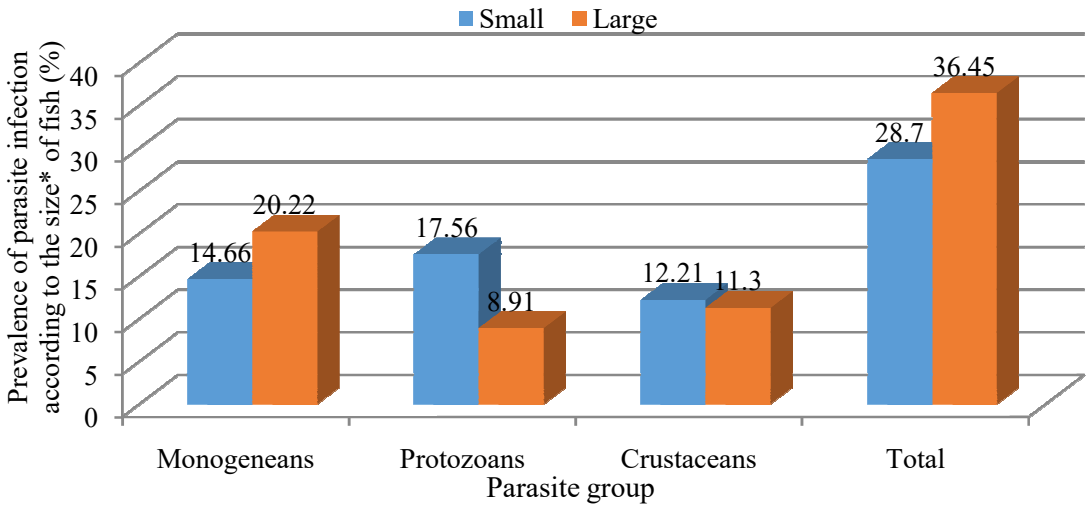
3. RESULTS

3.1 Prevalence of ectoparasites of fish species according to morphometric measurements

Overall, 786 (34.87%) of 2254 examined cultured fish species in the West region of Cameroon were infected with ectoparasites as follows *O. niloticus* (34.37%), *C. carpio* (37.10%) and *C. gariepinus* (33.67%). The fishes sampled were infected with Monogeneans (15.79%), Protozoans (15.79%) and Crustaceans (12.02%) at individual level. Though the prevalence and associated risk factors of ectoparasite infections of cultured fish species in the West region of Cameroon have been previously described [18], the distribution of the prevalence of these ectoparasites according to various length and weight of the cultured fish species are shown in figure 2. The

size (P=0.001, X^2=10.59) and weight of the fish species(P<0.0001, X^2=32.24) significantly influenced the ectoparasites prevalence of the cultured fishes.

(a)



*: The sizes (x) were classified according to Shehata et *al.* (2018) as follows: small sizes of (25cm ≥ x < 40 cm) for *C. gariepinus*, (12 cm ≥ x < 22 cm) for *C. Carpio* and (14 cm ≥ x ≤ 21 cm) for *O. niloticus*, and large sized group; being 40 cm ≥ x ≤ 55 cm for *C. gariepinus*, 22 cm ≥ x ≤33 cm for *C. Carpio* and from 22 cm ≥ x ≤30 cm for *O. niloticus.*

(b)

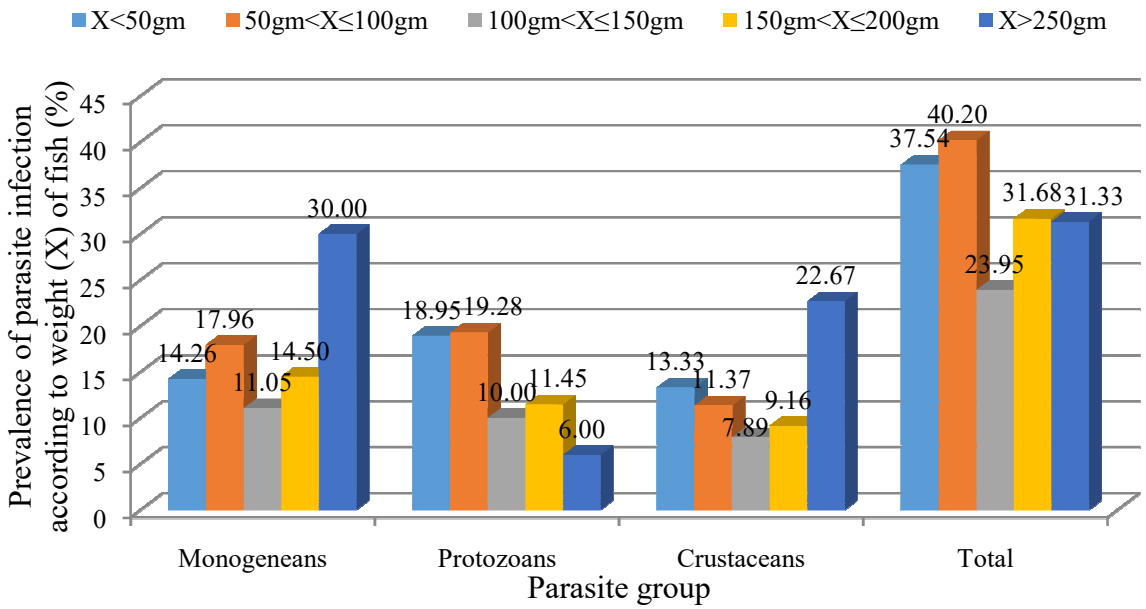


Figure 2: Prevalence of ectoparasites of cultured fish species at individual level according (a) lengths and (b) weights in West Region of Cameroon

3.2 Effect of ectoparasite infection on Length – Weight relationships and Fulton's condition (K) factor of fish species

Overall, there was a moderate to strong positive correlation (R^2 range from 0.4153 to 0.8051) existed in the length – weight relationship and negative allometric growth type of the fishes was observed in this study (Table 1 and 2). The high R^2 indicated that the variability of the fish species were associated length. Also, the Fulton's condition factor (K) of the sampled cultured fishes was significantly influenced by sex and season ($p<0.001$) but not by species ($p>0.05$). However, ectoparasite infection influenced the Fulton's condition index (K) of the fishes sampled in the present study with the K value being significantly ($p<0.05$) higher in uninfected fishes than infected fishes (Table 2). Species significantly ($p<0.05$) influenced the K value among the infected fishes and not ($p>0.05$) among the uninfected fishes. Uninfected female and male fishes showed significantly ($p<0.05$) higher K values than in the infected female and male fishes. The difference in K value between infected and uninfected fishes was not affected by dry and season. The "a" and " b" values, equations of length-weight relationships and K values for all uninfected and infected sampled fishes as well as according to sex and season are shown in Tables 1 and 2.

Table 1: Length – Weight relationships and Fulton's condition factor (K) (g/cm^3) of all cultured fish species (uninfected and infected fish species) according to species, sex and season in West Region of Cameroon

Factors	Variable	a mean value (95% CI)	b mean value (95% CI)	R^2	Standard Length (cm) mean±S.D (min- max)	Weight (g) mean±S.D (Min – Max)	W-L equation	Growth Type	K factor (g/cm^3) mean±S.D (Min – Max)	F-value (p-value)
Total	*N* = 2254	0.5414 (0.4124-0.6704)	1.3794 (1.3321-1.4267)	0.5926	16.16±6.45 (6.00 – 43.10)	92.06±68.00 (9.03 – 517.93)	$W= 0.2351L^{1.3794}$	Negative allometry	2.84±2.64 (0.06 – 19.76)	
Species	*O. niloticus* (*N*=969)	0.0937 (0.0254-0.1620)	1.4698 (1.4096-1.5300)	0.7036	14.27 ±5.68 (6.00 – 30.00)	69.07±47.50 (9.03 – 166.24)	$W= 0.09371L^{1.4698}$	Negative allometry	2.89 ±1.91 (0.16 – 14.88)	0.561 (0.571)
	C. carpio (*N*=593)	-0.3669 (-0.4972-(-0.2365)	1.9561 (1.8456-2.0665)	0.6718	15.74±5.70 (7.50 – 43.10)	114.93±90.18 (11.50 – 517.93)	$W= -0.36691L^{1.9561}$	Negative allometry	3.01±2.05 (0.06 – 19.76)	
	C. gariepinus (*N*=692)	0.7868 (0.6862-0.8874)	0.9303 (0.8504-1.0103	0.4306	19.09±6.98 (7.00 – 36.50)	104.66±59.98 (13.5 – 420.15)	$W= 0.7868L^{0.9303}$	Negative allometry	1.11 ±0.83 (0.29 – 16.04)	
Sex	Male (N=998)	0.0942 (0.0085-0.1799)	1.4925 (1.4202-1.5647)	0.6228	6.00 – 36.50 (16.09 ±6.12)	91.21 ±68.57 (9.03 – 420.15)	$W= 0.0942L^{1.4925}$	Negative allometry	2.81 ±2.66 (0.30 – 19.76)	23.655 (<0.001*)
	Female (N=1256)	0.3299 (0.2561-0.4037)	1.3040 (1.2418-1.3663)	0.5739	7.00 – 43.10 (16.17 ±6.70)	92.74 ±67.55 (15.05 – 517.93)	$W= 0.3295L^{1.3040}$	Negative allometry	2.63 ±2.06 (0.06 – 14.58)	
Season	Dry season (N=1278)	0.2557 (0.1874-0.3240)	1.3722 (1.3148-1.4296)	0.6329	16.28 ±6.42 (7.00 – 43.10)	94.05±65.58 (13.58 – 300.00)	$W= 0.2557L^{1.3722}$	Negative allometry	3.01 ±2.96 (0.06 – 16.44)	26.904 (<0.001*)
	Rainy season (N=976)	0.2147 (0.1218-0.3077)	1.3833 (1.3045-1.4620)	0.5493	6.00 – 36.50 (15.95 ±6.48)	89.45 ±70.98 (9.03 – 517.93)	$W= 0.2147L^{1.3833}$	Negative allometry	2.52 ±1.92 (0.16 – 19.76)	

*where a and b means regression coefficients and r means correlation coefficient and K factor means condition factor

Table 2: Comparison of Length – Weight relationships and Fulton's condition factor (K) (g/cm^3) of ectoparasite infected and uninfected cultured fishes according to species, sex and season in West Region of Cameroon

Factors	Variable	a mean value (95% CI)	b mean value (95% CI)	R^2	Standard Length (cm) mean±S.D (min- max)	Weight (g) mean±S.D (Min – Max)	W-L equation	Growth Type	K factor (g/cm^3) mean±S.D (Min – Max)	F-value (p-value)
Total	Uninfected (*N*=1468)	0.2819 (0.2115-0.3523)	1.3575 (1.2981-1.4169)	0.578	16.10±6.48 (6.00 – 36.50)	96.14±69.68 (9.03 – 517.93)	$W= 0.2819L^{1.3575}$	Negative allometry	2.65 ± 2.08 (0.16 – 19.76)	**27.870 (0.005*)**
	Infected (*N*=786)	0.1336 (0.0444-0.2227)	1.4322 (1.3572-1.5072)	0.6417	16.20±6.40 (7.00 – 43.1)	184.45±64.08 (10.78 – 335.11)	$W= 0.1336L^{1.4322}$	Negative allometry	2.43±1.75 (0.06 – 16.44)	
Uninfected fish species	*O. niloticus* (*N*=636)	0.0556 (-0.0314-0.1426)	1.515 (1.4399-1.5901)	0.7122	15.12±6.01 (6.00 – 30.00)	78.33±51.78 (9.03 – 166.24)	$W= 0.0556L^{1.515}$	Negative allometry	2.80±2.05 (0.16 – 14.88)	2.237 (0.107)
	C. carpio (*N*=373)	0.8401 (-0.9798-(-0.7004)	2.377 (2.2576-2.4963)	0.8051	15.26 ± 4.88 (7.5 – 27.00)	115.82±93.02 (11.50 – 517.93)	$W= 0.8401L^{2.377}$	Negative allometry	3.01 ±1.76 (0.70 – 19.76)	
	C. gariepinus (*N*=459)	0.9076 (0.7934-1.0218)	0.8512 (0.7583-0.9440)	0.4153	18.15±7.67 (7.0 – 36.5)	104.81±63.04 (13.5 – 420.15)	$W= 0.9076L^{0.8512}$	Negative allometry	1.16±1.07 (0.29 – 16.04)	
Infected fish species	*O. niloticus* (*N*=333)	0.3158 (0.2049-0.4268)	1.2395 (1.1375-1.3416)	0.6331	12.65 ±4.61 (7.00 – 27.50)	51.37 ±31.15 (10.78 – 164.53)	$W= 0.3158L^{1.2395}$	Negative allometry	3.06 ±1.62 (0.26 – 14.88)	66.536 (<0.001*)
	C. carpio (*N*=220)	0.1217 (-0.1051-0.3484)	1.5211 (1.3317-1.7105)	0.5348	16.54 ±6.80 (7.5 – 43.10)	113.43±85.32 (17.25 – 300.00)	$W= 0.1217L^{1.5211}$	Negative allometry	3.00±2.47 (0.06 – 16.44)	
	C. gariepinus (*N*=233)	-0.4148 (-0.6168-(-0.2129))	1.8121 (1.6582-1.1966)	0.6997	20.94±4.85 (7.5 – 34.00)	104.37± 53.57 (18.21 – 335.11)	$W= -0.4148L^{1.8121}$	Negative allometry	1.07±0.55 (0.37 – 14.22)	
Femalefish	Uninfectedfish (N=791)	0.4493 (0.3541-0.5446)	1.2246 (1.1439-1.3052)	0.5294	15.98 ±6.52 (7.00 – 36.00)	95.44 ±65.76 (15.05 – 517.93)	$W= 0.4493L^{1.2246}$	Negative allometry	2.79 ±2.29 (0.16 – 14.21)	20.030 (<0.001*)
	Infected fish (N=465)	0.1065 (-0.0035-0.2165)	1.4547 (1.3625-1.5469)	0.6749	16.49 ±6.98 (7.50 – 43.10)	88.14 ±70.34 (15.05 – 311.33)	$W= 0.1065L^{1.4547}$	Negative allometry	2.52 ±2.07 (0.06 – 16.44)	
Male fish	Uninfected fish (N=677)	0.0667 (-0.0357-0.1691)	1.528 (1.4420-1.6142)	0.6426	16.24 ±6.42 (6.00 – 36.50)	96.94 ±74.04 (9.03 – 420.15)	$W= 0.0667L^{1.538}$	Negative allometry	2.95 ±2.89 (0.30 – 19.76)	5.031 (0.025*)
	Infected (N=321)	0.1919 (0.0368-0.3470)	1.383 (1.2518-1.5143)	0.574	15.77 ±5.43 (7.00 – 34.00)	79.11 ±53.40 (10.78 – 335.11)	$W= 0.1919L^{1.383}$	Negative allometry	2.53 ±2.06 (0.37 – 14.22)	
Dry season	Uninfected fish (N=731)	0.3221 (0.2385-0.4057)	1.3514 (1.2812-1.4217)	0.6619	16.31 ±6.47 (7.00 – 27.50)	101.77 ±65.13 (13.58 – 300.00)	$W= 0.3221L^{1.3514}$	Negative allometry	2.62 ±1.84 (0.70 – 16.04)	0.001 (0.982)
	Infected fish (N=547)	0.1586 (0.0517-0.2655)	1.4071 (1.3173-1.4969)	0.6347	16.24 ±6.36 (7.50 – 43.10)	83.74 ±64.81 (17.25 – 300.00)	$W= 0.1586L^{1.4071}$	Negative allometry	2.46 ±1.91 (0.60 – 16.44)	
Rainy season	Uninfected fish (N=737)	0.2557 (0.1446-0.3667)	1.3519 (1.2576-1.4461)	0.519	15.90 ±6.47 (6.00 – 36.50)	90.55 ±73.53 (9.03 – 517.93)	$W= 0.2557L^{1.3519}$	Negative allometry	2.51 ±1.89 (0.16 – 11.72)	0.536 (0.464)
	Infected fish (N=239)	0.0786 (-0.0839-0.2412)	1.488 (1.351-1.6252)	0.6583	16.10 ±6.50 (7.00 – 34.00)	86.08 ±62.49 (10.78 – 335.11)	$W= 0.0786L^{1.488}$	Negative allometry	2.68 ±2.39 (0.26 – 14.88)	

*where a and b means regression coefficients and r means correlation coefficient and K factor means condition factor

4. DISCUSSION

The present study revealed mix fish species farming of *Oreochromis niloticus*, *Clarias gariepinus* and *Cyprinus carpio* with high prevalence of multiple ectoparasites (single and co-infections) in the West region of Cameroon. The identified ectoparasites include Monogeneans, Protozoans and Crustaceans. Overall, size (length) and weight were major factors of ectoparasites infection of the cultured fishes. The higher infection rates recorded among the large size and heavier (>100gm) fishes was associated to their bigger body surface and longer exposure to ectoparasites in the ponds compared to the smaller, lighter (<100gm) and younger fishes. These findings are in agreement with [39] who recorded higher infections rates in larger (65%) and >120g weight (100%) fishes than smaller (17%) and <120 g weight (41.6 – 76.92%) fishes. The large and heavier fishes were more adventurous and fed more on diverse food sources due to their size than small size fishes. Similarly, higher prevalence rates have been recorded among big and long fishes though juvenile fishes seem to be more susceptible to parasitic infection with prevalence rates reducing with age of the fishes [1, 18, 25, 40].

The length-weight relationship serves as an important tool that gives information on growth and its pattern in fish [41] as well as measures of other zootechnical parameters such as productivity. Its parameters (*a* and *b*) have wide applications in fish biology and fisheries management. The weight vary according to the length in fish while the fish length is a major indicator of production efficiency [40]. In the present study, the correlation coefficients of combined data revealed a high degree of relationship between body length and weight (above 76%) for fish irrespective of parasitic status. The coefficient of determination (r^2) was also moderate suggesting that the increase in weight gain of fish was attributed to the increase in body length [42, 43].

The exponential values of the length–weight relationship (b values) of cultured fishes were less than 3 ($b<3$) suggesting negative allometric growth patterns since fishes with *b* values less than 3 showed more axial growth (length) than weight [44]. However, the values obtained in this study were less than the lower value of the recommended range (2 - 4) for fresh water fishes [45-47]. Variations in b values have been attributed to sample size variation, stages in life, growth difference, change in physiological condition during spawning periods, gonad development, sex, physicochemical conditions of the environment and other environmental factors such as food and

space [48-50]. However, feeding before weighing would alter the weight of the stomach content as well as the total weight of the fish.

Condition factor (K) reflects the physiological state of a fish in relation to its welfare [47] and frequently used to compare the effects of biotic and abiotic factors on the health or general well-being of a fish population [42, 51, 52]. The K value also gives information when comparing two populations living under certain feeding, climate, density and other conditions [42, 46]. Condition factor (K) of 1.00 suggests that the fish is poor, long and thin, 1.20 indicates that the fish is of moderate condition and acceptable while 1.40 are for good and well-proportioned fishes [53].

The mean condition factor of sampled fishes in the present study were greater than one (>1), suggesting good fish health, good level of feeding and proper environmental conditions [54, 55]. Overall, the mean value of condition factor obtained for the uninfected fishes was significantly higher than that of infected fishes. This implies that the parasitism did not favour growth and survival of the fish. The influence of environmental conditions on growth and survival of have been previously described [42, 56, 57].

Results from this study also revealed that, the male fishes and fishes sampled during the dry season exhibited higher condition factors than female fishes and fishes sampled during the rainy season. The variations in condition factors could be attributed to factors such as changes in environmental factors with time (e.g. water quality), availability of natural food supply, physiological condition (e.g. accumulation of fat and gonads development) [42, 58] and stage of maturity [59, 60]. Improved and better environmental conditions (physicochemical and biological parameters) are associated to higher the condition factor of fishes and vice versa [42, 61, 62]. This agrees strongly with the results in the present study whereby the higher condition factor and growth performance of uninfected fishes as well as fishes sampled during the dry season when most of the water quality parameters were within the satisfactory ranges. Furthermore, variation in K values due to biological interactions involving intra-species and inter-species competition for food and space such as sex, stages of maturity, state of stomach contents and availability of food and the health status have been described [63, 64]. Though the condition factor of uninfected fishes was not influenced by species, difference in species was a major factor in the condition in infected fishes. Among the infected fished, the highest condition was recorded in *O. niloticus* followed by *C. carpio* and *C. gariepinus*. Reduced K values due to stress [65] in fishes

infected with parasites, bacteria, virus as well as fishes in poor water quality factors stop eating have been recorded [66]. Individual growth and condition are important components of performance for fish survival and reproductive success [14].

In the present study, the condition index was significantly different between the parasitized and non-parasitized fishes. These results are consistent with previous studies [67] which have reported that the pathogenicity of parasites was linked to several factors including host (size, age and health), parasite (stage of development and size) and environment (stress, isolation, pollution).

5. CONCLUSION

The study showed that ectoparasite infection significantly influence the length-weight relationship and condition factor of cultured fishes in the west region of Cameroon. Irrespective of the parasitic status, the fishes showed negative allometric growth pattern and there was relationship between body weight and length of fish. However, male fishes, fishes sampled during the dry season and uninfected fishes had better condition and were relatively healthier compared to female fishes, fishes harvested during the rainy season and infected fishes.

5.1 COMPLIANCE WITH ETHICAL STANDARDS

The study is not reporting results from an experiment on animals or humans. The researchers performed risk assessment to avoid hazards to persons involved in the project. Permission for the study and Ethical approval were obtained from the required authorities in the West of Cameroon [Regional delegation of Livestock, Fisheries and Animal Industries (RDEPIA) and Faculty of Agronomy and Agricultural Sciences of the University of Dschang, Cameroon] before carrying out the study. The purpose of the study was explained (with the assistance of local veterinary and Fisheries practitioners, community leaders and trusted intermediaries) to fish farmers in the selected administrative divisions.

CONSENT

Fish farmers and their farms were included in the study when verbal informed consent was obtained. Completing questionnaires further implied consent to participate in the study.

ETHICAL CONSIDERATION

The researchers performed risk assessment to avoid hazards to persons involved in the project. Permission for the study and Ethical approval were obtained from the required authorities in the West of Cameroon [Regional delegation of Livestock, Fisheries and Animal Industries (RDEPIA) and Faculty of Agronomy and Agricultural Sciences of the University of Dschang, Cameroon] before carrying out the study. The purpose of the study was explained (with the assistance of local veterinary and Fisheries practitioners, community leaders and trusted intermediaries) to fish farmers in the selected administrative divisions. Fish farmers and their farms were included in the study when verbal informed consent was obtained. Completing questionnaires further implied consent to participate in the study.

DATA AVAILABILITY

The raw data used to support the findings of this study are available from the corresponding author upon reasonable request.

REFERENCES

1) Osuigwe DI, Obiekezie AI: Assessment of the growth performance and feed utilization of fingering Heterobranchus longifilis fed raw and boiled jack bean (*Canavalia ensiformis*) seed meal as fish meal substitute. *Journal of Fisheries International* 2007, 2:37-41.

2) FAO: La situation mondiale des pêches et de l'aquaculture 2016. Contribuer à la sécurité alimentaire et à la nutrition de tous. In. Rome, Italie: FAO; 2016: 224.

3) Adeosun KP, Ume CO, Ezugwu RU: Analysis of socio-economic factors of fish pond production in Enugu State, Nigeria. *Journal of Tropical Agriculture* 2019, 57(1):27 - 34.

4) Efole T, Mikolasek O, Aubin J, Eyango M, Pouomogne V, Ombredane D: Sustainability of fishpond culture in rural farming systems of Central and Western Cameroon. . *International Journal of Agricultural Sustainability* 2016, 15.

5) Obosi K, Agbeja YE: Assessing the Level of Aquaculture Biosecurity Regulations Compliance in Ibadan, Nigeria. *Donnish Journal of Agricultural Research* 2015, 2(3):012-019.

6) Olaoye OJ, Ashley-Dejo SS, Fakoya EO, Ikeweinwe NB, Alegbeleye WO, Ashaolu FO, Adelaja OA: Assessment of Socio-Economic Analysis of Fish Farming in Oyo State, Nigeria.

Global Journal of Science Frontier Research Agriculture and Veterinary 2013, 13(9):Version 1.0 2013.

7) Ntsama ISB, kTambe BA, Takadong JJT, Nama GM, Kanscica G: Characteristics of fish farming practices and agrochemicals usage therein in four regions of Cameroon. *Egyptian Journal of Aquatic Research* 2018, 44(145 - 153).

8) Thilakaratne IDSIP, Rajapaksha G, Hewakopara A, Rajapakse RPVJ, Faizal ACM: Parasitic infections in freshwater ornamental fish in Sri Lanka. *Diseases of Aquatic Organisms* 2003, 54:157–162.

9) Bamidele A, Hassan A, Adeogun AO: Gastrointestinal helminth parasites of the fish *Synodontis clarias* (Siluriformes: Mochokidae) from Lekki lagoon, Lagos, Nigeria. *Rev Biol Trop* 2008, 56:2021-2026.

10) Bamidele A, Otubanjo OA, Hassan AA: Helminth parasites of Malapterurus electricus Malapteruridae from Lekki Lagoon, Lagos, Nigeria. *J Am Sci* 2007, 3(3):1-5.

11) Bamidele A, Pentho KM, Kayode SJ, Lambe O, David UU: Condition factor and gastrointestinal parasitic fauna of three fish species as stress indicators in lekki lagoon, Lagos, Nigeria. *Egyptian Academic Journal of Biological Sciences* 2015, 7(1): 1 – 13.

12) Shalaby SI, Ibrahim MM: The relationship between the monogenetic trematode, Cichlidogyrus tubicirrus magnus (first record in Egypt) and morphological lesions of gills among Tilapia nilotica. *Egyptian Journal of Comparative Pathology and Clinical Pathology* 1988, 1(1):116-126.

13) Ndome CB, Eteng AO, Ekanem AP: Length-weight relationship and condition factor of the smoothmouth marine catfish (*Carlarius heudelotii*) in the gulf of Guinea, Niger delta, Nigeria. *AACL Bioflux* 2012, 5(3):163-167.

14) Forseth T, Naesje TF, Jonsson B, Harsaker K: Juvenile migration in brown trout: A consequence of energetic state. *Journal of Animal Ecology* 1999, 68:783–793.

15) Al-Azizz SA, Al-Niaeem KS, Al-Hasson HAH: Seasonality Of The Monogenean From Some Perciform Fishes İn Iraqi Marine Waters. *IOSR Journal of Agriculture and Veterinary Science* 2017, 10(5):103-105.

16) IRAD: Rapport annuel des activités. In. Yaounde, Cameroon: Institut de Recherche Agricole pour le Développement; 2013: 112.

17) Thrusfield M: Veterinary epidemiology. (3rd ed.). Oxford, UK: Blackwell Science Ltd, a Blackwell publishing company.; 2007.

18) Ngueguim DF, Kouam MK, Tiogue CT, Miegoue E, Feumba AK, Zebaze LBF, Awah-Ndukum J: Prevalence and associated risk factors of ectoparasite infections of cultured fish species in the West region of Cameroon. *International Journal of Fisheries and Aquatic Studies* 2020, 8(3):310-320

19) Langdon J, Jones B: Design and implementation of health testing protocols for fish with special reference to sample size, test sensitivity and specifity, predictive value and risk. In. Australian Standard Diagnostic Techniques for Fish Diseases; 2002.

20) Idodo-Umeh G: Freshwater fishes of Nigeria. (Taxonomy, Ecological notes, Diet and utilization.). In. Idodo-Umeh publishers. Benin City, Nigeria; 2003: 232.

21) Olaosebikan BD, Raji A: Field Guide to Nigerian freshwater Fishes, 2nd edn. Federal College of Fresh Water Fisheries Technology. New Bussa Nigeria; 2004.

22) Holden M, Reed W: West African Freshwater Fish. Longman group Ltd.; 1972.

23) Shehata SM, Mohammed RA, Ghanem MH, Abdelhadi YM, Radwan MK: Impact of the Stresses Environmental Condition on the Prevalence of Parasite in Fresh Water Aquaculture *Journal of Fisheries Sciencescom* 2018, 12(2):009-019.

24) Akombo PM, Atile JI, Adikwu IA, Araoye PA: Morphometric measurements and growth patterns of four species of the genus Synodontis (cuvier,1816) from Lower Benue River, Makurdi, Nigeria. *International Journal of Biological Research* 2013, 1(4):059-065.

25) Mbakane EM, Luus-Powel WJ, Matla MM, Theron J: Three Dactylogyrids (Dactylogyridae Bychowsky 1933: Monogenea) from selected cyprinid species of the Nwanedi-Luphephe Dams in the Limpopo Province, South Africa. *Journal of the South African Veterinary Association* 2010, 81:186-187.

26) Bichi AH, Ibrahim AA: A survey of ecto and intestinal parasites of *Tilapia zilli* (gervias) in tiga lake, kano, Northern Nigeria. *Bayero J Pure and App Sci* 2009, 2(1):79 – 82.

27) Omeji S, Solomon SG, Obande RA: A comparative study of the common protozoan parasites of Heterobranchus longifilis from the wild and pond environments in Benue State. *Pakis J Nutri* 2010, 9(9):865-872.

28) Ekanem AP, Eyo VO, Sampson AF: Parasite of landed fish from Great Kwa River, Calabar. Cross River, Nigeria. *International Journal of Fisheries and Aquaculture* 2011, 3(12):225-230.

29) Kabata Z: Parasitic Copepoda of the British Fish. In., vol. 152. The Ray Society, London, UK; 1979: 468.

30) Frimeth JP: NWFHS Laboratory Procedure Manual.1:3 p. In.; 1994.

31) Robert RJ: Fish Pathology. In. Bailliere TindalBooks. London, UK; 1978.

32) Poulder BD, Curtis EW, Yanong PER: Common Freshwater Fish Parasites Pictorial Guide. In. Edis IFAS Extension, University of Florida. http://edis.ifas.ufl.edu/; 2005.

33) Le Cren ED: The length-weight relationships and seasonal cycle in gonad weight and condition in the perch (Perca fluviatilis). . *Journal of Animal Ecology* 1951, 20:201-219.

34) Pauly D: Some simple methods for the assessment of tropical fish stocks. FAO. Fisheries Technical Pap. . In.: FAO, Rome., 234; 1983.

35) Froese R, Cube l: Condition factor and weight–length relationships: history, meta-analysis and recommendations. . *Journal of Applied Ichthyology* 2006, 22:241-253.

36) Dekić R, Savić N, Manojlović M, Golub D, Pavličević J: Condition factor and organosomatic indices of rainbow trout (Onchorhynchus mykiss, wal.) from different brood stock. *Biotechnology in Animal Husbandry* 2016, 32(2):229-237.

37) Bush O, Lafferty AD, Lotz JM, Shostak AW: Parasitology meets ecology on its own terms: Margolis et al. revisited. . *J Parasitol* 1997, 83:575-583.

38) Kouam MK, Manjeli J, Inouss NN, Teguia A: Assessment of biosecurity level in small-scale broiler farms in the Western highlands of Cameroon (Central Africa). *Tropical Animal Health and Production* 2018, 50(1529–1538):10.

39) Ogonna CA, Nnamonu EI, Aka MD: Survey of Ectoparasites of Cultured Fish from Selected Farms in Ebonyi State: Potential for Food and Nutrient Security. *International Journal of Research in Pharmacy and Biosciences* 2017, 4(7).

40) Ghorbani A, Salamatdoustnobar R, Maghami SSG, Motallebi V: The effect of different levels of prebiotic on the length of fingerling rainbow trout. *African Journal of Biotechnology* 2012, 11(36):8928-8931.

41) Ighwela A, Ahmed B, Abol-Munafi B: Condition factor as an indicator of growth and feeding intensity of Nile tilapia fingerlings (*Oreochromis niloticus*) fed on different levels of maltose. *American-Eurasian Journal of Agriculture and Environmental Sciences* 2011, 11(559563).

42) Komba EA, Munubi RN, Chenyambuga SW: Comparison of body length-weight relationship and condition factor for Nile tilapia (*Oreochromis niloticus*) cultured in two different climatic conditions in Tanzania. *International Journal of Fisheries and Aquatic Studies* 2020, 8(3):44-48.

43) Muchlisin ZA, Fransiska V, Muhammadar AA, Fauzi M, Batubara AS: Length-weight relationships and condition factors of the three dominant species of marine fishes caught by traditional beach trawl in Ulelhee Bay, Banda Aceh City, Indonesia. *Croatian Journal of Fisheries* 2017, 75:104-112.

44) Vicentin W, Costa FEDS, Suarez YR: Length-weight relationships and length at first maturity for fish species in the upper Miranda River, southern Pantanal wetland, Brazil. *Journal of Applied Ichthyology* 2012, 28(1):143-145.

45) Bagenal TB, Tesch FW: . Methods of Assessment of Fish Production in Fresh Waters. IBP Handbook No.3. Edn 3: Oxford Blackwell Scientific Publication, London; 1978.

46) Golam MM, Al-Misned FA: Length-Weight Relationships, Condition Factor and Sex-Ratio of Nile Tilapia, (*Oreochromis niloticus*) in WadiHanifah, Riyadh, Saudi Arabia. *World Journal of Zoology* 2013, 8(1):106-109.

47) Anani FA, Nunoo FKE: Length-weight relationship and condition factor of Nile tilapia, *Oreochromis niloticus* fed farm-made and commercial tilapia diet. *International Journal of Fisheries and Aquatic Studies* 2016, 4(5):647-650.

48) Hossain MY, Hossen MA, Pramanik MNU, Sharmin S, Nawer F, Naser SMA, Bahkali AH, Elgorban AM: Length–weight and length–length relationships of five Mystus species from the Ganges and Rupsha rivers. *Bangladesh Journal of Applied Ichthyology* 2016, 32:994-997.

49) Jobling M: Environmental factors and rates of development and growth. In: *Fish Biology: Hand book of fish biology and fisheries.* Edited by Hart PJ RJ, vol. 1: Oxford: Blackwell Publishing Ltd; 2008: 97-122.

50) Prasad G, Ali PHA: Length-Weight relationship of a cyprinid fish *Puntius filamentosus* from Chalakkudy River, Kerala. *Zoos' Print Journal* 2007, 22(3):2637-2638.

51) Otieno ON, Kitaka N, Njiru JM: Length-weight relationship, condition factor, length at first maturity and sex ratio of Nile tilapia, (*Oreochromis niloticus*) in Lake Naivasha, Kenya. *International Journal of Fisheries and Aquatic Studies* 2014, 2(2):67-72.

52) Dambatta MA, Bilyaminu H, Zakari H, Umar AF, Abdulrashed I, Sogbesan OA: Length - Weight Relationship and Condition Factor of *Oreochromis niloticus* in Wudil River Kano State, Nigeria. In: *In the 7th International Conference on Biological, Chemical and Environmental Sciences; Budapest, Hungary.* 2017: 3237.

53) Barnham C, Baxter A: Condition Factor, K, for Salmonid Fish. In.: Fisheries Notes.1–3.; 1998.

54) Ujjania NC, Kohli MPS, Sharma LL: Length-weight relationship and condition factors of Indian major carps (*C. catla, L. rohita and C. mrigala*) in Mahi Bajaj Sagar, India. *Research Journal of Biology* 2012, 2(1):30 - 36.

55) Ayode AA: Length-Weight Relationship and Diet of African Carp Labeoogunensis (Boulenger, 1910) in Asejire Lake South-western Nigeria. *Journal of Fisheries and Aquatic Science* 2011:1816-4927.

56) Olopade OA, Taiwo IO, Ogunbanwo AE: Length-weight relationship and condition factor of Leuciscusniloticus (De Joahhis, 1853) from Epe Lagoon, Lagos State, Nigeria. *Ege Journal of Fisheries and Aquatic Science* 2015, 32(2):165-168.

57) Nehemia A, Maganira JD, Rumisha C: Length-Weight relationship and condition factor of tilapia species grown in marine and fresh water ponds. *Agriculture and Biology Journal of North America* 2012, 3(3):117-124.

58) Ndiaye W, Diouf K, Samba O, Ndiaye P, Panfili J: The Length-Weight Relationship and Condition Factor of white grouper (Epinephelusaeneus, Geoffroy Saint Hilaire, 1817) at the south-west coast of Senegal, West Africa. *International Journal of Advanced Research* 2015, 3(3):145-153.

59) Olurin KB, Aderibigbe OA: Length-Weight Relationship and Condition Factor of Pond Reared Juvenile *Oreochromis niloticus*. *World Journal of Zoology* 2006, 1(2):82-85.

60) Khallaf E, Galal M, Athuman M: The biology of Oreochromisniloticus in a polluted canal. *Journal of Ecotoxicology* 2003, 12:405-416.

61) Keyombe JL, Malala JO, Waithaka E, Lewo RM, Obwanga BO: Seasonal changes in length-weight relationship and condition factor of Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758) (Cichlidae) in Lake Naivasha, Kenya. *International Journal of Aquatic Biology* 2017, 5(1):1-11.

62) Migiro KE, Ochieng E, Munguti JM: The Length-Weight Relationship and Condition Factor of Nile Tilapia (*Oreochromis niloticus*) Broodstock at Kegati Aquaculture Research Station, Kisii, Kenya. *International Journal of Advanced Research* 2014, 2(5):777-782.

63) Nugroho RA, Santoso YGG, Nur FM, Hariani N, Solikin S: A preliminary study on the biodiversity of fish in the Suhui River, Muara Ancalong, East Kutai, Indonesia. *AACL Bioflux* 2016, 9(2):345-351.

64) Gupta S: A review on *Mystus cavasius*, a popular food fish of Indian subcontinent. *International Journal of Fauna and Biological Studies* 2014, 1(6):27-31.

65) Lemly AD: Role of season in aquatic hazard assessment. *Environmental Monitoring and Assessment* 1997, 45:89–98.

66) Shinkafi BA, Ipinjolu JK: Morphometric Relationships and Relative Condition Factor of *Auchenoglanis occidentalis* (Cuvier and Valenciennes) from River Rima, North-Western Nigeria. *Journal of Fisheries International* 2010, 5(4):61-66.

67) Zouhir R, Amara R, Trilles J-P: Impact des parasites sur les performances biologiques de *Mullus barbatus barbatus* L. INOC-Tischreen University. In: *International conference on Biodiversity of the Aquatic Environment.* 2010.