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TROPHIC ECOLOGY, GROWTH AND POPULATION DYNAMICS OF *Synodontis clarias* (PISCES: SILURIFORMES: MOCHOKIDAE) (LIN: 1758) IN THE CROSS RIVER, NIGERIA

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Abstract- To improve on management strategy of mochokid catfish, (*Synodontis clarias*) in the Cross River, biological and biometric data including; stomach content, standard length and total weight of 500 fish were collected monthly, from January, 2009 to December, 2011 and used to investigate the trophic ecology and population parameters. Stomach content showed the fish to be euryphagus and benthic feeder, with inter-seasonal difference in food item. Length-weight relationship was described as W = -3.97 + 0.98 L (male), W = -19.7 + 1.00L (female) and W = -6.73 + 0.99L (combined sex). Condition factor ranged from 0.32±0.7 minimum for males (midriver) to 2.25±0.6 maximum also for males (downriver) with monthly variation for both sexes peaked between June and July, and November and January, with better conditions for males than females. Growth parameters were $L\infty$ = 72.12, 79.23 and 76.34; k = 0.22 year^{-1} 0.34 and 0.31 for males, females and combined sex, respectively. Index of growth performance (Φ') = 3.11 (males), 2.65 (females) and 3.78 (combined sex). Longevity potential (t_{max}) was 30.34, 33.56 and 32.33 years, for male female combined sex, respectively. Z and M were 0.45 year^{-1}, 0.67 year^{-1}, 0.55 and 0.24, 0.38 and 0.29 year $^{-1}$ while F, E and E_{max} values were 0.18, 0.34 and 0.28 years^{-1} , 0.66, 0.86, and 0.78) and 0.78, 0.87 and 0.98 for males, females and combined sex, respectively, indicate that overfishing of *S. clarias* is not occurring in the Cross River (i.e., E < E_{max}). However, E exceeded $E_{0.5}$ (0.29, 0.34 and 0.39) and was not close to $E_{0.1}$ (0.54, 67 and 0.66) for males, females and combined sexes, indicating that the present exploitation rate must be maintained for males, females and combined sexes to achieve the optimum yield per recruit.

Keywords- Cross River, Length-weight relationship, Condition factor, Growth performance index, Diet habit, Mortality rates

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Introduction

Among the Cross River fishes, the family Mochokidae, known as squeaker or upside-down catfish [1] is very common. Local riverine people regard it as palatable with high protein content and in great demand. Among the three species in Cross River, *Synodontis clarias* is dominant species [2]. It is of great economic importance as food fish with good aquaculture attributes and well prized ornamental qualities. Their aquaculture attributes includes; ability to withstand handling stress, disease resistance, palatability and high potential yield. Thus culture fishery resource distributed in the Nigerian inland water mass, offer a promising potential in the Nigerian fishery scenario which can be further improved by a thorough knowledge of the exploitable biomass of the river system.

The species are common and widely distributed in tropical and subtropical water systems, experience frequent growth fluctuations due to changes in food composition and environmental variables among others. *S. clarias* is fatty with considerable amount of fat in the abdominal cavity [3] and adipose dorsal fin is present [1]. They have formidable defences against predation with strong and serrated spines at the front of dorsal and pectoral fins [3]. It is sluggish, slow during the day but active at night [4].

The essential component in understanding the dynamic changes in the fishery of any water-body lie in the determination of age and growth of the fish species. Age and growth determination are essential for the estimates of production, stock size, recruitment and mortality [5] and helps to estimate the potential yield per recruit in the study of fish population dynamics [6]. Understanding the relationship between body structures and fish diet could be important for predicting the diet habit. Studies on stomach composition could provide useful information in positioning of the fishes in a food web in their environment and in formulating management strategy options in multi species fishery [7], is useful in defining predator-prey relationships, estimation of trophic level [8], in the creation of trophic models as a tool to understanding complex ecosystems [9] and the use to reduce intra and inter specific competition for ecological niche [10]. Research on the growth parameters; age trophic ecology of different species in various water bodies have been quite intense [12-15]. No research was available on these parameters in *Synodontis clarias* in Cross River.

Therefore objective of this paper was to characterize the population dynamics of S. *clarias* in the Cross River, using parameters of age, size, growth of the population and feeding. We also analyzed parameters related to mortality (total, natural, and fishing) and the current status of the stock of this species using Beverton and Holt's model of analysis of yield per recruit.

Materials and Methods

Study Site

The study site is the Cross River, a floodplain river located at the south eastern part of Nigeria on Latitude 4°, 25´- 7°.00´ N, Longitude 7°.15´-9°.30´ E [Fig-1]. It is bounded in the south by the Atlantic Ocean, east by the Republic of Cameroun, the Nigerian states of Benue in the North, Ebonyi and Abia in the west and Akwa Ibom in the south-west. Climate of the study area is characterized by a dry season from November-March and wet season from April-October. Highest precipitation (3050 ± 230mm) occurs in August, and lowest (300 ± 23mm) in March. The mean annual temperature ranges from 15.5 ± 7.6°C in wet period to 32.6 ± 5.4°C in dry period. Three sampling sites were selected randomly, one each upriver, middle river and downriver. Upriver site is located 3km from the river source with rocky, gravel and sandy substratum. The shoreline is covered with savanna grassland, and wood and paper industries are located close to the source. The middle river site is at 100km distance from river source; it has a rocky substratum and shoreline and is sparsely shaded by forest and savanna grassland. Downriver has a muddy substratum and opens into the Cross River estuary, with shoreline thickly shaded with rainforest.

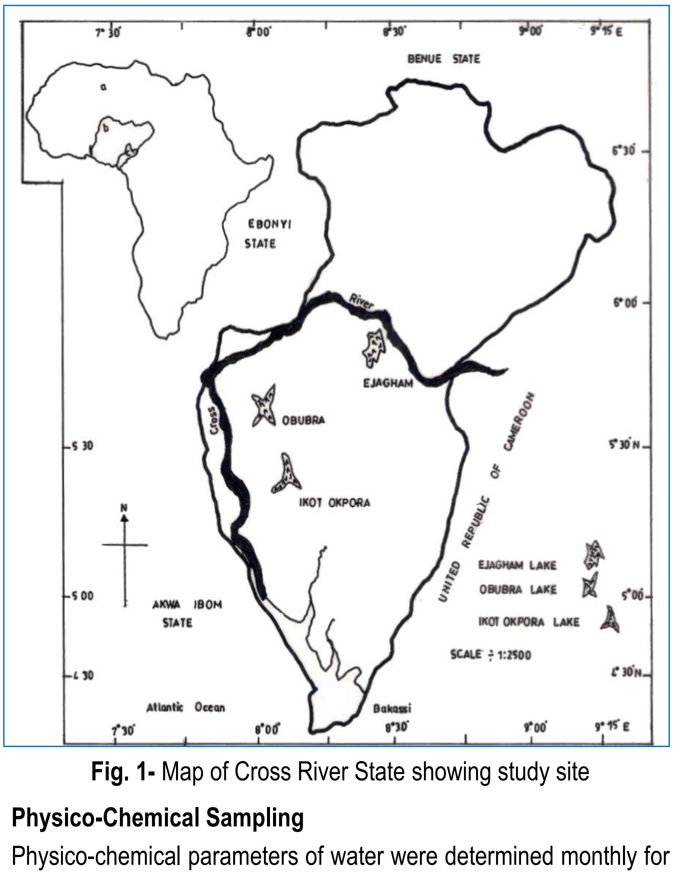

Fig. 1- Map of Cross River State showing study site

Physico-Chemical Sampling

Physico-chemical parameters of water were determined monthly for two years (January 2006 -December 2007). Standard methods for the examination of water and waste water [16] were used for all measurements. Monthly rainfall data for the study area were obtained from meteorological stations, located in each of the three reaches. Habitat variables, water level and river width were measured in three places in each reach and averaged.

Fish Sampling

Fish samples for all assessments in each site were randomly collected twice every month, in the day (2400- 0600 hours and night (0830-1200 hours) and during wet and dry seasons, from randomly selected artisanal fishermen whose fishing gears were mainly seine net (10-34mm stretched mesh size) and gill net (22-76mm stretched mesh size). Fish samples, 300 males and 200 females were preserved in 10% formalin prior to laboratory examination. In the laboratory, data obtained from each fish included; date of capture, length, weight, sex and food records. Standard length (SL) and total length (TL) were measured to the nearest 0.1cm and weighed (wt) to the nearest 0.1g. Samples were identified using FAO Species Identification Sheet [17] and sexed by visual observation.

Diet Studies

Specimens for diet studies were dissected and their guts removed immediately after capture and stored in formaldehyde solution (4%) until the contents were analyzed. Gut analysis was later carried out, food items identified to the lowest possible taxon and analyzed quantitatively for percentage composition by number (N) and frequency of occurrence (FO). Diet breath estimates the diet spectrum and was calculated using the diversity index of Shannon- Wiener (H); $H = -\sum pi \ln pi$ where, pi is the proportion by the number of food type i, Food richness; expressed using Margalef's index: d= (S-1)/ logN) where d= Margalef's index, S is the number of species and N is the number of individuals and Gut Repletion Index (GRI) which is the percentage of non-empty stomach was estimated for samples from each reach.

Growth

Length-Weight Relationship (LWR)

Length-weight relationship of fish was estimated from the equation

$$W = aL^b \ [18].$$

W = weight of fish in grams, L = total length of fish in centimeters, "a" is proportionality constant and "b" is the allometric coefficient both estimated by method of least squares [19] using logarithmically transformed expression;

$$\log W = \text{lag } a + b \log L.$$

To investigate whether the species followed cube law the values of the exponent "b" was tested against '3' applying Student's t test. An ANOVA was used to determine if there were significant differences in the LWR between the sexes. Fulton's condition factor (CF) was determined using the expression by [20] as

$$K = \frac{W100}{L^3}$$

K= condition factor, W = total weight (g) and L = total length (cm).

Parameters of Growth

Age determination and growth were analyzed for the species from length frequency modes. This based on the integrated approach of [18] illustrated in [22] where the length frequency distribution in the respective years of sample were placed sequentially. A smooth curve interconnecting the peaks, assumed to be new year-class entering recruitment, intercepts the succeeding horizontal lines, read as length- at- age of the species. Based on the monthly distributions of standard length frequency, the following growth parameters were obtained: $L\infty$ = asymptotic standard length (cm) and k = growth coefficient (years). These parameters were evaluated using the ELEFAN I routine within the computer program FiSAT II [23], which is based on the Von Bertalanffy equation:

$$L_t = L\infty [1\text{-}exp(^{-k (t-t0)})],$$

where L_t = length in age t, $L\infty$ = asymptotic standard length; k = growth coefficient, and t_0 = parameter referring to length of fish at birth. Index of growth performance was quantified using the model proposed by [24]. Longevity potential was estimated according to the equation

$$T_{max} = 3/K \text{ [18]}.$$

The length-age structure was evaluated using the Von Bertalanffy equation. We use the parameters $L\infty$ and K calculated in this paper and replaced *t* with ages ranged from 0 to 4.5 years. The parameter t_0 was considered to be o because biologically speaking it is not significant [25].

Population Dynamics

The natural mortality rate was evaluated using [18] empirical model:

$\ln M = -0.0152 - 0.279 \ln L_\infty + 0.6543 \ln K + 0.4634 \ln T$

$L\infty$ and k are the growth parameters obtained from the Von Bertalanffy equation and T = mean water temperature (°C), which was 27.1°C. Total mortality rate (Z) was estimated using Beverton and Holt's model

$$Z = k^*(L\infty\text{-}L_m)/(L_m\text{-}Lc)$$

Lc = mean length of first capture (i.e., the time at which the fish are recruited for the fishery) and L_m = mean length starting from Lc. For the purpose of this study Lc was considered to be 26.67, 30.45, 28.55 for male, female and combined sex. The mortality rate due to fishing (F) was calculated as the difference between the total mortality rate (Z) and the natural mortality rate (M) (i.e., F = Z-M).

Growth Performance Index

To compare the overall performance of the fish species, growth performance (φ) [26] has been used as follows

$\varphi = \text{Log}_{10} K + 2 \text{ Log}_{10} L_\infty$ for length

$\varphi = \text{Log}_{10} K + 2/3 \text{ Log}_{10} W_\infty$ for weight.

Yield Models

Yield per recruit model (Y'/R) was calculated using Beverton and Holt's method and the Knife Edges option in the program FiSAT II [22] according to the following model:

$Y'/R = EU^{M/K} [1\text{-}(3U/1 + m) + (3U^2/1 + 2m)\text{-}U^3/1 + 3m)]$

where m = (1-E)/(M/k) = k/Z; U = 1-(Lc/L_∞) and E = F/Z (exploitation rate). We also calculated E_{max} (exploitation rate of maximum sustainable yield), $E_{0.1}$ (exploitation rate at which the marginal increment of Y'/R is 10% of its virgin stock), and $E_{0.5}$ (exploitation rate that will result in a 50% reduction of the non-exploited biomass). The relative biomass per recruit (B'/R) was estimated as

$$B'/R = (Y'/R)/F.$$

For these estimates we used the routine ELEFAN I in the program FiSAT II [22].

Statistical Analysis

The χ^2 test was used to test the null hypothesis that the male to female ratio of the population was 1:1. Before applying parametric tests, the data were transformed (log + 1) and their normality and homogeneity were tested using Kolmogorov-Smirnov's and Bartlett's tests, respectively. A one-way ANOVA was applied to test the null hypothesis of equal RGS values for different periods of the year and Tukey test was accomplished to detect statistical differences. The t test was applied to test whether the value of *b* of the length-weight relationship was equal to zero and whether *b* = three (the condition of isometric growth). Because the data for the abiotic factors did not meet the assumption of variance normality and homogeneity, Spearman's nonparametric correlation test was applied to examine the possible relationships between abiotic factors and reproductive period through values of RGS. For all statistical analyses $p < 0.05$.

Results

Water depth, water discharge, water velocity and dissolved oxygen vary significantly between reaches ($p>0.05$) [Table-1].

Table 1- Mean variation and F-values of the analysis of variance (ANOVA) of physico-chemical parameters of water measured at three sampling sites. I: Upriver, II: Mid-river, III: Downriver

Properties	Upriver	Midriver	Downriver	F-value	ANOVA
Physical					
Conductivity (uScm^{-1})	26.6 ±11.0	28.1±11.5	25.3±8.2	0.64	p>0.05
Water temperature (ºC)	29.0 ± 2.2	24.6±1.2	27.2±0.4	2.44	P>0.05
Water depth (m)	2.4±0.3	3.1±0.6	5.2±0.5	3.12	P<0.05
Water discharge(m^{3}s^{-1})	236.71±12	1496.46±82	176.8±13	4.6	p<0.05
Water velocity (m/s)	2.03±0.33	1.23±0.3	0.6±0.23	3.55	p<0.05
Transparency (cm)	27.6±3.4	28.5±14	25.5±4.4	1.34	p>0.05
Chemical					
Dissolved oxygen (mg/l)	7.6±0.3	8.61±0.2	5.31±0.5	4.45	P<0.05
pH	6.9±0.2	7.0±0.7	7.9±0.1	3.27	p>0.05

Dietary Habit

There was no spatial variation in the dietary items found in stomach of *S. clarias* but there was diel difference with Gut Repletion Index of 100% [Table-2]. During the dry season, predominant food items in the stomach of *S. clarias* were planktons; cyanophytes (87%), dinoflagellates (64.2%), copepods (54.2%), cladocerans (64.4%) and fish species (62.2%) while insects (55.5%), gastropods (75.5%), trichocerca (66.4%) and trichotria (70.4%) and mollusk were more frequent in the wet [Fig-2]. Also occurred in the diet but in lesser quantity were ostracods, diatoms and detritus constituting only 24.4% of the diet. The prominence of detritus in the diet indicated that the fish is a bottom or benthic feeder and feed more actively at night. The wide variability in food supply enables *S. clarias* to maintain its overwhelming prominence in Cross River, and its euryphagus habit makes it suited for pond culture.

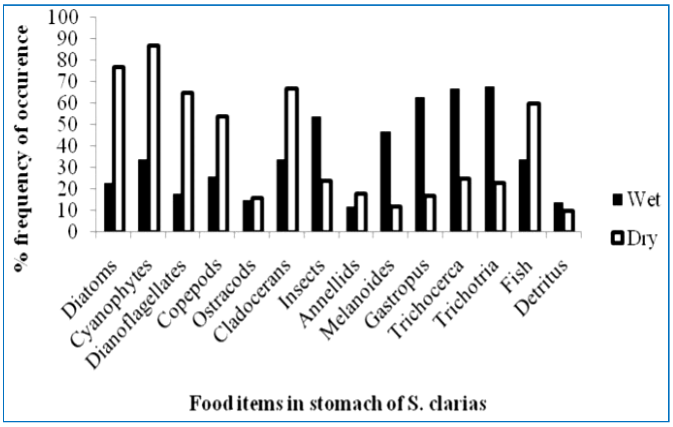

Fig. 2- Food item frequency distribution of *S. clarias* in Cross River sampled per season from artisanal fishery

Table 2- Diel variations in the food habits of S .clarias in the Cross River inland wetlands

Food Items	Frequency of occurrence				Method Numerical				
	Day	Night	X2	P	Day	Night	X2	P	
Annelid worms	14	64	15.4	>0.001	28	45	23.6	>0.001	
Cladocerans	201	387	113	>0.001	16	67	34.1	>0.001	
Insects:									
Adult	123	233	143.2	>0.001	178	234	178	>0.001	-
Trichotrim	98	211	205.2	<0.001	234	356	51.2	<0.001	
Crustacean:									
Ostracods	23	98	107	>0.001	156	235	166.2	<0.001	
Gastropods	116	433	178.6	<0.001	167	345	183.6	<0.001	
Decapods	176	222	161	<0.001	87	198	101	<0.001	
Planktons									
Cyanophytes	234	567	165	>0.001	112	267	267	<0.001	-
Diatoms	189	399	221	>0.001	200	322	176	<0.001	
Dinoflagellates	180	444	301	>0.001	200	322	321	>0.001	
Detritus	13	56	12.1	>0.001	5	12	5.4	>0.001	-
Trichocerca	109	298	111.3	<0.001	569	189	227.4	<0.001	
Food richness	11	11			11	11			
Diet breath (H)	0.88	2.11			0.98	3.21			
Gut repletion index	100%	100%			100%	100%			-

Length-weight Relationship

The standard length varied from 10.2-50.4, 9.8-48.6 and 9.7-49.2cm with mean of 25.6 ± 4.9, 28.65 ± 5.3 and 26.4 ± 3.2cm, whereas the total weight varied from 30.5-1223.5, 29.4-1406.2 and 28.7-1387.4g with mean of 426.4 ± 13.2, 506.4 ± 23.2 and 489.6 ± 18.9 for males, females and sex combined of *S. clarias*, respectively.

Table 3- Population parameters of S. clarias from Cross River, Nigeria

Symbol	Population parameters	Male	Female	Combined
A	Weight-standard length relationship intercept (constant)	0.39	0.41	0.36
B	Weight-standard length relationship slope (exponent)	3.68	3. 98	3.76
L_∞	Asymptotic length cm	72.12	79.23	76.34
K	Growth coefficient $year^{-1}$	0.22	0.34	0.31
t_0	Age at which length is nil year	-2.34	-2.78	-2.11
W_∞	Asymptotic weight g	3456.23	3893.34	3145.22
S	Survival rate	0.65	0.54	0.61
A	Annual mortality rate	0.52	0.65	0.63
Z	Total mortality coefficient $year^{-1}$	0.42	0.72	0.65
M	Natural mortality coefficient $year^{-1}$	0.24	0.38	0.39
F	Fishing mortality coefficient $year^{-1}$	0.18	0.34	0.28
E	Exploitation rate $year^{-1}$	0.43	0.76	0.57
L_c	Length at first capture cm	26.67	30.45	28.55
t_c	Age at first capture year	3.57	4.34	4.78
Wt_c	Weight at first capture g	288.34	411.34	401.34
L_r	Length at first recruitment cm^{-1}	13.5	21.87	17.94
t_r	Age at recruitment, year	0.56	1.89	0.79
Wt_r	Weight at recruitment year, g	54.67	201.45	189.56
Φ_L	Growth performance in length	3.11	2.65	3.78
Φ_W	Growth performance in weight	1.22	2.87	3.02
t_{max}	Maximum age, year	30.34	33.56	32.23
Y/R	Yield per recruit, g	54.44	176.34	108.12
Y/R'	Relative yield per recruit, g	0.11	0.14	0.13
B/R	Biomass per recruit, g	304.55	278.23	288.45
F_{msy}	Optimum fishing mortality coefficient, $year^{-1}$	0.88	1.56	1.25
E	Exploitation rate $year^{-1}$	0.66	0.86	0.78
E_{max}	Maximum exploitation rate $year^{-1}$	0.78	0.87	0.98
$E_{0.1}$	Exploitation rate gives 1/10 of marginal increase in Y/R	0.54	0.67	0.66
$E_{0.5}$	Exploitation rate which reduces the unexploited biomass to 50%	0.29	0.34	0.39

Length-weight relationship and condition factor analysis of *S. clarias* comprising 300 individuals showed significant regression (P<0.005) of weight on length with r values of 0.990, 0.997 and 0.997 for Lower river, mid-river and upriver samples respectively [Table-3].

The length-weight relationship can be described as

W_t = -3.97 + 0.98 Lt (Upriver)

W_t = -19.7 + 1.00Lt (Midriver) and

W_t = -6.73 + 0.99Lt (downriver).

The value of the mean annual allometric coefficient 'b' was 0.99 ± 0.134 and the overall LWR significantly deviated from the cube value (b=3) (P>0.05). The populations of *S. clarias* in the study sites can therefore be considered as having heterogenous groups with body weight varying differently from the cube of total length. The high values of the correlation coefficient (r) perform a good measure for the strength of these equations and closeness of the observed and calculated of the fish weight.

Condition Factor (K)

Mean condition factor ranged from 0.32±0.7 minimum for males (midriver) to 2.25±0.6 maximmum also for males (downriver) with significant (P < 0.05) difference between reaches. Also, there was significant monthly variation in the condition factor with both sexes recording highest between June and July, and between November and January. Least values were obtained from March to April and September to October [Fig-3]. The values of the condition factors revealed better conditions for males than females.

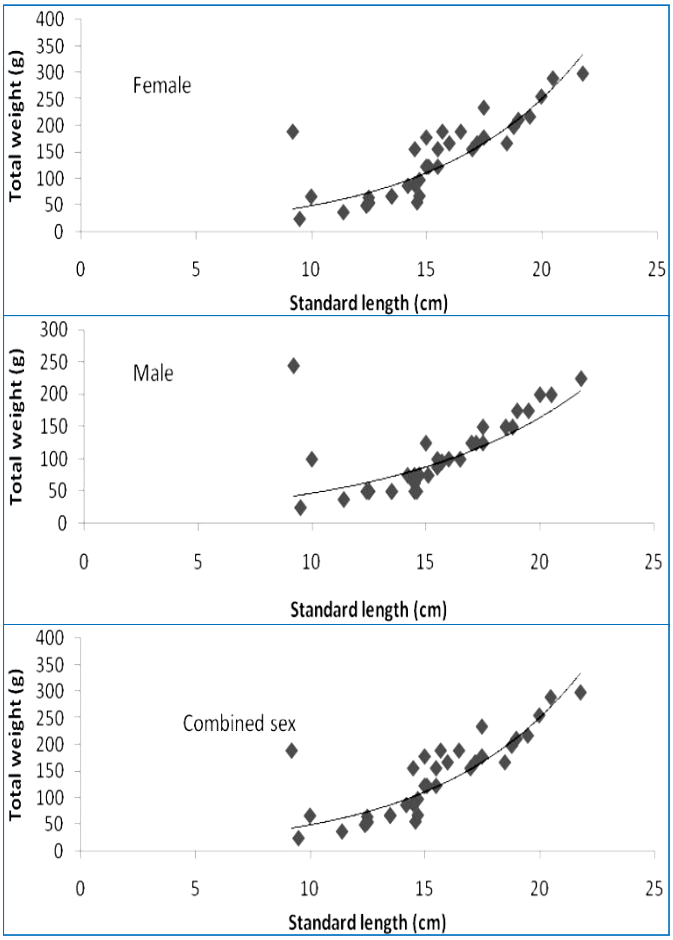

Fig. 3- Length-Weight Relationship of the sexes of *S. clarias* from Cross River

Parameters of Growth

The growth parameters were estimated to be L_∞ = 72.12, 79.23 and 76.34cm and k = 0.22 year^{-1}, 0.34 and 0.31 for males, females combined sex respectively [Table-4]. Accordingly, the growth of *S clarias* was described by the von Bertalanfy's growth equation:

$L_t = 72.12[1\text{-exp}\ (^{-0.22\ (t\text{-}t_0)})]$ for males

$L_t = 79.23(\ 1\text{-exp}\ (^{-0.34\ (t\ -\ t_0\ )})$ for females

$L_t = 76.34(\ 1\text{-exp}\ (^{-0.31\ (t\ -\ t_0\ )})$ for combined sex

The equations of the theoretical growth in weight were obtained by applying the length-weight relationship to the growth in length equations as follows

$W_t = 3456.23\ [1\text{-exp}\ (^{-0.12\ (t\text{-}t_0)})]^{2.27}$

$W_t = 3893.34\ [1\text{-exp}\ (^{-0.11\ (t\text{-}t_0)})]^{2.29}$

$W_t = 3145.22\ [1\text{-exp}\ (^{-0.22\ (t\text{-}t_0)})]^{2.28}$ for male, female and combined sex respectively.

Table 4- Comparison of population parameters of S. clarias (irrespective of sex) from Cross River Upriver, Mid-river and Downriver

Parameters	Upriver	Mid-river	Downriver
A	0.41	0.39	0.48
B	3.23	3.11	3
L_∞	87.32	82.11	91.77
K	0.43	0.35	0.65
t_0	-1.87	-2.33	-2.54
W_∞	2123.43	4321.12	6043.54
S	0.45	0.54	0.71
A	0.32	0.43	0.59
Z	0.65	0.54	0.68
M	0.14	0.38	0.56
F	0.32	0.54	0.68
E	0.33	0.46	0.67
L_c	26.67	36.33	38.21
t_c	2.44	3.56	4.78
Wt_c	304.34	411.34	501.34
L_r	12.43	15.23	27.12
t_r	0.65	1.09	1.79
Wt_r	154.67	168.23	244.32
Φ_L	3.43	3.65	4.87
Φ_W	1.65	2.66	4.11
t_{max}	28.43	33.56	44.23
Y/R	65.77	154.56	213.78
Y/R'	0.21	0.27	0.45
B/R	145.12	278.23	388.45
F_{msy}	1.11	1.56	2.25
E	0.66	0.76	0.88
E_{max}	0.78	0.87	0.98
$E_{0.1}$	0.44	0.67	0.86
$E_{0.5}$	0.21	0.44	0.69

Fish Population Dynamics

Age Composition

The data revealed that age group (IV) is the least and contributed about 1.01 and 2.28% for males and combined sexes, respectively, while for the females it was found that age group zero and contributed about 2.49%. the frequency of fishes of age group I and II were dominant in the catch and constitute about 41.23 and 28.98, 38.26, and 27.23, 39.34 and 29 12% for *S. clarias* males, females and combined sexes, respectively [Fig-4].

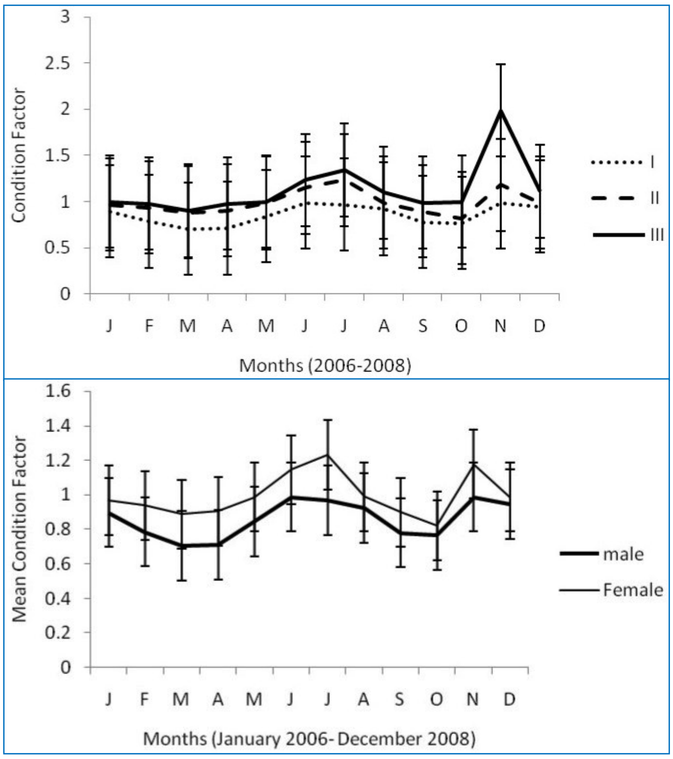

Fig. 4- Monthly mean variation of condition factor of male and female *S. clarias* combined from Cross River by reach and sex

Longevity Potential and Length and Age Structure

The longevity potential was estimated to be t_{max} = 30.34, 33.56 and 32.33 years for males, females and combined sexes. The length-age structure analysis showed that most of the *S. clarias* caught in the fishery were 10.5-15.5 years old (94.9%), of which 60.2% were 10.5 years old [Table-5].

Table 5- Age- mean standard length structure of S. clarias, sampled from artisanal fishery at Cross River

Relative age (Years)	Mean length (cm)	N	%
0	5.67	13	5
5.5	14.11	21	12
10.5	18.12	124	87.1
15.5	23.92	97	48.2
20.5	28.45	48	23.2
25.5	34.32	16	12.5
30.5	34.33	12	3.2
35.5	36.55	8	2.8
40	40.23	4	0.5
45.5	41.64	2	0.2

Mortality Rates

Z and M were estimated to be 0.45 year^{-1}, 0.67 year^{-1}, 0.55 and 0.24, 0.38 and 0.29 year $^{-1}$ for males, females and combined sexes, respectively. Thus, F was estimated to be 0.18, 0.34 and 0.28 years $^{-1}$ for males and females and combined sexes, respectively. Mortality due to fishing was less important than the other causes of mortality (F < M).

Mean Selection Length (length at first capture)

The mean selection length (L_c) of *S. clarias* , the size at which 50% of the fish are retained in the gear was found to be 26.67, 30.45, 28.55cm for males, females and combined sexes, respectively. The corresponding mean selection age t_c was estimated to be 3.57, 4.34 and 4.78 years, where as the corresponding mean selection weight 288.34, 411.34 and 401.34g for *S. clarias* males, females and combined sexes, respectively.

Length (L_r) and Age (t_r) at Recruitment

The values of L_r of *S. clarias* were 13.50, 21.87, 17.94cm and those of t_c were 0.56, 1.89 and 0.79 years, whereas the corresponding W_r were 54.67, 201.45 and 189.56 years for *S. clarias* for males, females and combined sexes, respectively.

Growth Performance Index (Φ) and the Maximum Age (t_{max})

Growth performance index (**Φ**) and the maximum age (t_{max}) were found to be 3.11, 2.65 and 3.78 of growth performance in length (**Φ_L**) and 1.22, 2.87 and 3.02 of growth performance in weight (**Φ_w**), respectively, whereas the values of maximum age (t_{max}) were 30.34, 33.56 and 32.23 years for *S. clarias* males, females and combined sexes, respectively.

Yield per Recruit, Biomass Per Recruit (Y/R and B/Y)

Y/R and B/R were determined as functions of L_{50} / L∞ and M / K, respectively. It means that the calculated yield per recruit (Y/R) was 54.44, 176.34 and 1.8,12g, whereas, biomass per recruit B/R was 304.55, 278.23 and 288.45g for *S. clarias* male, female and combined sex, respectively. The results show that the yield per recruit (Y/R) and Biomass per recruit (B/R) of *S. clarias* irrespective of sex, as a function of fishing mortality, by F-values. The estimated yield per recruit increases continuously with the increase in the fishing mortality reaching its climate at Maximum Sustainable Yield (MSY) then it remained constant or decrease.

The relative yield per recruit (Y/R)' increase with the increase in exploitation rate. The values of E (0.66, 0.86, and 0.78) and E_{max} (0.78, 0.87 and 0.98) for males, females and combined sex, respectively, indicate that overfishing of *S. clarias* is not occurring in the Cross River (i.e., E < E_{max}). However, the value of E exceeded the value of $E_{0.5}$ (0.29, 0.34 and 0.39) and was not close to $E_{0.1}$ (0.54, 67 and 0.66) for males, females and combined sexes hence exploitation rate must be maintained for males, females and combined sexes to achieve the optimum yield per recruit.

Discussion

Diet Studies

There was no spatial variation in the dietary habit of *S. clarias* but there was seasonal difference. The feeding habit of *S. clarias* has been found to be overlapping [28]. They utilize various materials found in the environment, thus can live as herbivores, predators, detrivores, Omnivores, as well as plantivores [29]. A number of factors are attributable to changes in the feeding habits of fish species. The size of the fish, sex, season, water temperature, habitat and competition as some of these factors [31, 32]. Morphological changes in the feeding apparatus of the fish as a result of age may also lead to a change in the feeding habits. The feeding habits depend on the availability of feed in water [32].

Phytoplankton dominate food items in the stomach during the dry season while crustaceans and mollusk were more abundant during the wet. This findings agree with some other authors [32,33] who mentioned that synodontis lives at the bottom of the river feeding on mollusk, crustaceans, mud sand and algae. Further confirmation about *Synodontis* sp. being omnivorous had been made [33].

Seasonality in the diet of Siluriformes has been reported by Offem et al [34] and Wooton [35] and both agreed that is caused by variations in the availability of food in the environment, and these variations can occur for many reasons, including life cycle changes of prey, changes in the predators preying on the food item, and changes in the foraging habitat [36]. In fresh waters in Nigeriaa, the diet of silurids varied from phytoplankton to zooplankton to detritus depending on the availability of the items in the environment [36]. In addition to phytoplankton and zooplankton, insects, vegetation, and fish were part of the diet in Agbokim waterfalls [37].

Length-Weight Relationship

The length-weight relationship showed high correlation (r) and values of the exponent (b) showed that the ponderal growth was allometric in males, females and combined sexes. This is in agreement with other findings [38,39,33] for *Synodontis schall* in Lake Nasser, River Nile at El-kanater and River Nile at Assuit, respectively. The value of exponent was not affected by sex, position and season, which disagree with the findings by [40-42], that the geographic location and the associated environmental condition like season, disease and parasites may affect the value of "b".

Condition Factor

The condition coefficient of the fish which measures the physiological wellbeing of the fish [43,44] is considered as a measure of "fitness" of the fish in a population. It may also be considered as a rough measure of the state of the fish, weather heakthy or unhealthy, starved or well-fed, spawning or spent [34]. The condition coefficient in this study showed that the value of "K" increased with decreased length of fish, which agrees with findings by Hassan [33] who observed decrease in K with increased length. The interspatial difference of the condition factor with lower reaches having higher K value may be due to different ecological and feeding conditions of the habitats [44]. The seasonal difference can be as a result of seasonal changes in food availability and spawning activity]45].

Growth Parameters and Mortality Estimates

The growth parameters for *S. clarias* estimated were biologically good because the growth performance rate of Φ_L = 3.11 for males, 2.65 for females and 3.78 for combined sex was within the range estimated for other *Synodontis* populations [41,47,33]. The growth parameters estimated for the species male, female and combined sex (L∞ = 72.12, 79.23, 76.34; k = 0.22, 0.34 and 0.31 and longevity 30.34, 33.36, and 32.23 years) respectively, indicated rapid growth and relatively higher longevity as against 6, 5 and 7.6 years recorded by Tharwat [48], Hassan [33] and Authman et al [42] in River Nile respectively. According to some authors [49, 50], species at a low trophic level, such as S. *clarias*, tend to have rapid growth, short longevity, and early sexual maturation, which did not fit our results. When we compared the growth parameters (L∞ and k) and the mortality rates (Z, M, and F) estimated for *Synodontis* species in our study with those estimated in other studies, several differences were apparent. Various endogenous and exogenous factors influence fish growth [51], and these might be responsible for the observed differences. For instance, growth and mortality rates can be affected by the level of fishing effort [25], and exploitation rate of different fishery resources as well as overfishing throughout the past and present years [6]. It is likely that fishing effort will affect the growth and mortality rates of *S. clarias* in the Cross River.

The results also indicated that the growth in weight of fish downriver is higher than those of other sites. The variation of weights at different lengths among different regions of the river are mainly attributed to water temperature which can affect fish growth directly by affecting the physiology of the fish [52,53] and food availability in these areas [54,55]. Also this may be due to interplay between a complex of genotype, body size, physiological conditions of the fish and environmental condition [55].

The main causes of mortality in fish can be either fishing or natural mortality [26] Natural mortality coefficient of *S. clarias* from Cross River is the higher than the average given by [18] for 175 fish stocks (0.2 and 0.3). The high survival rate indicate lower fishing ie this further shown by the exploitation ratio (E) and fishing mortality (F) in this study as 0.78 and 0.28, respectively. The high survival rate in this study is indicating that the gears used is not effective in catching *S. clarias* due to the fish behavior peculiarities which enables them to escape fishing recruitment. There was selective mortality among different age groups for the combined sex and the selection is in favor of smaller fish sizes due to their vulnerability to the fishing gears as they outnumbered matured fish. Also the presence of age zero-group for *S. clarias* from Cross River indicate that the fish are subject to accidental fishing early in life. This may be attributed to the fact fishing in African rivers and the tributaries is mainly concentrated on tilapias which are relatively smaller in size [46].

The population parameters of *S. clarias* from the different regions of the Cross River. The patterns of growth (φ), L_{∞} and K values of von Bertalanffy model, fishing, natural and total mortality of the different population in the various regions were different. The findings refer to the variability of fishery characteristics of *S. clarias* populations of different localities [46]. Also, the variation in population parameters of *S. clarias* in different areas can be due to different prevailing conditions of food and temperature in these areas [55].

Exploitation of the Stock

The value of Y/R in this study indicates that the current exploitation level (E) of the *S. clarias* in the Cross River is significantly higher than that associated with $E_{0.5}$, $E_{0.1}$ and Y/R', for male, female and combined sex and very close to E_{max}. The stock can therefore be considered as over- fished. Also, F > M, which suggest that the current fishing effort is higher than the maximum sustainable level. *S. clarias* is therefore not well established in the Cross River and the fish stock currently is being over fished because the level of exploitation by the artisanal fisheries is higher than maximum sustainable level, and this implies that measures to prevent an increase in fishing effort in the region are necessary.

Conclusion

The assessment of the present state of the *S. clarias* resource indicates that the current exploitation rate is higher than the estimated maximum exploitation level. It is also higher than the exploitation rate which will maintain 50% of the unexploited stock biomass, and this implies that measures to prevent an increase in fishing effort in the region are necessary. Besides there is selective mortality towards smaller fish sizes. This implies that juvenile individual are the target of the fishery and the stock dynamics of the species in this area of study will be seriously affected. The high vulnerability of juvenile fish to capture by gears will result to the reduction of future yield of this species. Thus, the protection of immature fish is probably the key factor to preserve the spawning stock, as a priority in the sustainability of the resource and management of *S. clarias* fishery and thus will protect both biodiversity in the area of study and the fish as a food source.

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