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BREEDING SEASONALITY AND POPULATION DYNAMICS OF THE CATFISH *Schilbe mystus* (SCHILBEIDAE) IN THE CROSS RIVER, NIGERIA

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Abstract

Twelve consecutive months length frequency data (N = 6999) and FiSAT software were used in the study of the dynamics of exploited population the catfish *Schilbe mystus* in the Cross River Nigeria. Variation in monthly mean gonadosmtic index showed two peaks, March and September and this indicates that the species spawned twice in a year. Fitting the seasonalized von Bertalantffy growth function to our length frequency data gave the following growth parameters: $L\infty = 38$ cm, $k = 0.33$ y^{-1}, $C = 0.42$ and $WP = 0.96$. The seasonalized length converted catch curve procedure gave the instantaneous total mortality coefficient $Z = 2.97$ y^{-1}, the instantaneous natural mortality coefficient $M = 0.81$ Y^{-1}, the instantaneous fishing mortality coefficient $F = 2.16$ y^{-1} and the current exploitation rate $E = 0.73$. This high value of E points to the high fishing pressure on the stock. The analysis of probability of capture of each length class showed that the length at first capture Lc 28.67cm. The predicted maximum exploitation rate of $E_{max} = 0.59$. This stock was deemed overexploited because $E > E_{max}$. Relative yield isopleths were used to demonstrate the response of relative yield per recruit of the fish to variation Lc and E. Suitable management procedure must be instituted to avoid the collapse of the fishery.

Keywords: Breeding, population dynamics, *Schilbe mystus* Cross River estuary.

Introduction

Catfish or Siluriformes are valued food fish and constitute important commercial species in both the artisanal and industrial fisheries of West African countries. They are heavily exploited and widely cultured. The present world aquaculture production of about 300.000 tonnes per year makes catfish the fourth most widely cultivated freshwater fish after carp, salmonids and tilapia.

The *Silurformes, Schilbe mystus* is an important ichthyofaunal components of many tropical freshwater ecosystem. The biology and ecology have been reported. Idoho-Umeh and Victor (1993) reported that *Eutropius niloticus* and *S. mystus* constitute 85% by number and 94.7% by weight of all the four species of schilbeid fish exploited in the River Ase, Nigeria. Also, the seasonal patterns of abundance indicate that the species in non-migratory *S. mystus* is a piscivore with insects as a supplementary item in the diet (Adebisi, 1981 and Merron

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and Mann, 1995). There are more females than males in the population (Olatunde, 1978; Merron and Mann, 1995).

The report of Ayoade (2007) in Asejire and Oyan Lakes in South western Nigeria indicates that *S. mystus* can live for about 6 years, and obtain more than 50% of the asymptotic length at the first age.

There is dearth of information on *S. mystus* in the Cross River system. The aim of this work is to fill this gap in knowledge on the biology, fisheries and population dynamics of the species in the Cross River system. This is necessary for establishing a scientifically based management guideline for the stock.

Materials and methods

Monthly samples of *S. mystus* caught by means of nylon gillnets were obtained from the artisanal fishers in the Cross River (Fig. 1) from January to December, 1995. Total length of each specimen was measured to the nearest 0.01 cm. Total weight (g), and length of each specimen in a sub-sample (≈ 30) were also measured before dissecting it to weigh the gonad. Monthly mean gonadosomatic index GSI (gonad weight expressed as a percentage of body weight) and monthly mean condition index CI (weight of fish expressed as a percentage of length cube) were determined and plotted against month of sample collection.

FiSAT software (Gayanilo *et al*., 1996) was used for all the analyses. To determined asymptotic length, the Powell-Wetherall method (Powell 1979, Wetheral 1986) as modified by Pauly (1986) was used. In this procedure, the Beverton and Holt (1956) length-based Z-equation is rearranged into a linear regression equation of the form.

$$\overline{L}a + bL' \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where $\overline{L}$ = cut off length i.e. the smallest length of fully recruited fish, and $\overline{L}\,(L\infty + L')/[1 + (Z/K)]$ = the mean length of all fish $\geq L'$. From Eq. (1),

$L\infty$ (asymptotic length) = $-a/b$ and $Z/K = -(1+b)/b$

The seasonalized von Bertanlanffy growth function (VBGF) put forward by Pauly and Gaschutz (1979) and later modified by Somers (1981) takes the form:

$$L_1 = L\infty\,(1 - \exp\text{-}K\,(t-t_0) - (CK/2\pi)\sin 2\pi\,(t - t_s) + (CK/2\pi)\sin 2(t_o - t_s) \ldots\ldots\ldots\ldots(2)$$

where $L\infty$ is the asymptotic length, K the von Bertalanfffy growth coefficient, L_1, the, length at time, t, C the amplitude of growth oscillations, t_o the age of fish at zero length, t_s the time from birth to the start of growth oscillations, t_s is replaced with WP (winter point) which is equal to $t_o + 0.5$. If the effect of seasonal oscillation is not considered ie if C = O, Eq reverts to the original VBGF.

Using ELEFAN algorithm in FiSAT, the length frequency data were sequentially arranged and restructured. Then using $L\infty$ obtained from Eq. (1) as seeded value, Eq. (2) was fitted to our sequentially arranged and restructured length frequency data set to obtain optimized VBG coefficients.

Mortality in this fish population was described by the single negative exponential mortality model.

$$N_t = N_{oe}^{-zt} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where N_o is the initial number, N_t the number at time t, and Z the instantaneous total morality coefficient. Z in Eq. (3) was computed using the seasonlized length-converted catch curve (Pauly 1990, Pauly *et al* 1995) according to the regression equation.

$$\text{In } (N) = a + b_t' \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

where N is the number of fish in cohorts sliced by successive growth curves and t is the relative age of the fish in that cohort. b with sign changed gave the value of Z with seasonlity. Z without was estimated from the relationship.

$$\text{In } (N_i/\Delta_{ti}) = a + bt_1 \ldots\ldots\ldots\ldots (5)$$

where N_1 is the number of fish in length class i, $\Delta_{ti} = (I/K)$ in $[(L-L_1)/[L\infty - L_2)]$ = time used by the fish to grow through length class i, (L_1 and L_2 are the lower and upper limits of length class i). $t_i = (I/K)$ In $[1 - (L_1/L\infty)]$ = relative age corresponding to the midpoint of length class i, and b with sign changed give Z without seasonality.

The instantaneous natural morality coefficient M was estimated empirically using the model of Pauly (1980).

$$\text{Log } M = -0.006 - 0.279 \log L\infty + 0.6543 \log K + 0.4634 \log T \ldots\ldots\ldots\ldots\ldots (6)$$

where T is the mean annual surface water temperature in degrees centigrade (here 28.5°C).

The overall growth performance index Φ' was computed thus (Pauly and Munro, 1984).

$$\Phi' = 2 \log L\infty + \log K \ldots\ldots\ldots (7)$$

The probability of capture (P) of each length class (i) was analysed using the ascending left arm of the length converted catch curve (Pauly, 1987). This involved dividing the numbers actually sampled by the expected numbers (obtained by backward extrapolation of the straight portion of the catch curve) in each length class of the ascending part of the catch curve. By plotting the cumulative probability of capture against midpoint of class interval, a resultant curve was obtained from which the length at first capture Lc was taken as corresponding to the cumulative probability at 0.5. The seasonal recruitment pattern of the fish was re-constructed using the entire length frequency data. This entails back-projecting, along a trajectory defined by the computed VBGF, all the length frequency data onto a one year time scale (Pauly, 1987). Then using NORMSEP (normal separation) process of Haselblad (1966), the projected data were separated into their Gaussian components.

The method of Beverton and Holt (1966) as modified by Pauly and Soriano (1986) was used to predict the relative yield per recruit (Y'/R) thus $Y'/R = EU^{MK} [1-[3U/(I+m)]+[3U^2/(1+2m)]-[U^3/(1+3m)] \ldots\ldots (8)$

where $E = F/Z$ = current exploitation rate i.e. the proportion of death caused by fishing activity, F = the instantaneous fishing mortality coefficient, $U = 1 - Lc/L\infty)$ = the proportion of growth to be completed by the fish after entry into the exploitation, phase, $m = (1 - E)/M/K) = K/Z$. The relative biomass per recruit (B'/R) was estimated as,

$$B/R = (Y'/R)/F \ldots\ldots\ldots\ldots (9)$$

Then E_{max} (exploitation rate i.e. the proportion of death caused by fishing activity, F = the marginal increase of Y'/R is 0.1 at E = 0) and $E_{0.5}$ (the exploitation rate under which the stock is reduced to 50% of its virgin biomass) were estimated through the first derivative of the Beverton and Holt (1966) function. Yield isopleths were constructed to investigate the impact on yield of the variation in LcL∞ (a proxy for mesh size) and E (a proxy for effort).

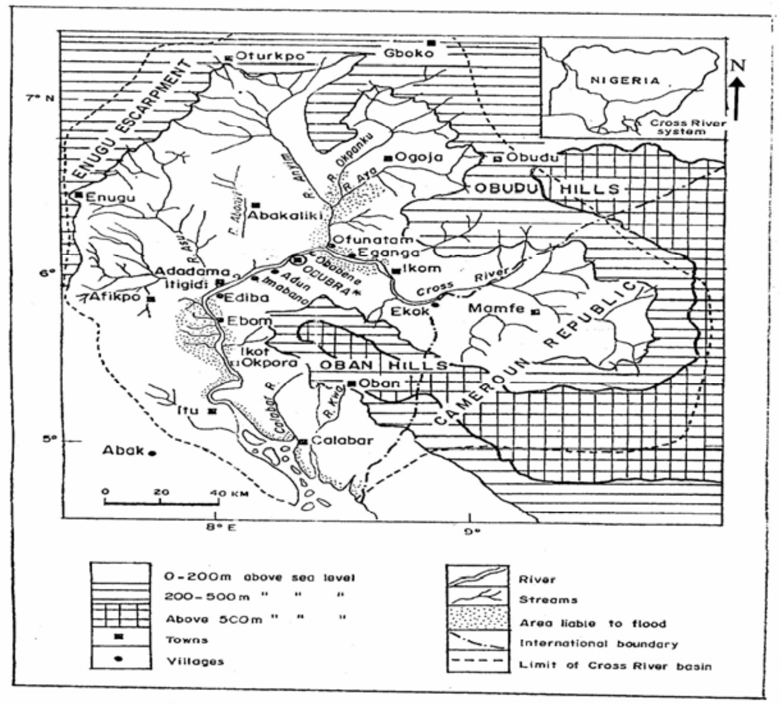

Fig. 1: Map of Cross River System showing the sampling stations at Obubra, Nigeria

Results

A total of 6922 specimens of *S. mystus* were collected over a period of 12 consecutive months (Table 1). Monthly trends in the mean GSI of both sexes of *S. mystus* (Fig. 2) reveal breeding peaks in March and September. Variation in mean CI are not closely related to those of the GSIs.

The preliminary estimate of $L\infty$ and Z/K from the Powell-Wetherall plot (Fig. 3) were 32.93cm and 3.93cm respectively. The preliminary values was seeded into ELEFAN and the seasonlized growth curve parameters obtained were $L\infty = 38.0$ cm, $K = 0.33\ y^{-1}$. $C = 0.42$ $WP = 0.96$. The curves were superimposed over the length frequency histograms in Fig. 4. The seasonalised length converted catch cure (Fig. 5a) gave a $Z = 2.97\ y^{-1}$. The non-seasonalized length converted catch curve gave Z 3.44 Y-1 (Fig. 5b). The instantaneous natural mortality coefficient. M was $8.01y^{-1}$. F (the instantaneous fishing mortality coefficient as $2.16y^{-1}$ from the relationship Z = F + M. The exploitation rate E (=F/Z) was 0.73. From the analysis of the probability of capture of each length class, the length at first capture Lc was 28.67cm (Fig. 6) With the knife edge selection procedure the relative yield per recruit analysis gave the following summary statistics: $E_{max} = 1.0$. $E_{0.1} = 1.0$ $E_{0.5} = 0.44$ (Figs. 6 a & b). With the selection ogive approach, the relative yield per recruit analysis gave the following results: $E_{max} = 0.59$, $E_{0.1} = 0.57$, $E_{0.5} =- 0.31$ (Figs. 7c & d). The response of relative yield per recruit of the fish to variations in Lc and E over a wide range of values using the yield contours is shown in Fig. 8. The analysis of recruitment pattern indicates that there are two pulsed recruitment peaks in a year (Fig. 9).

Table 1. Length (cm) frequency data of Schilbe mystus taken from the Cross River at Obubra (Nigeria) from January to December 1995. ML = mid point of length class interval, N = 6922

ML/Date	01/95	02/95	03/95	04/95	05/95	06/95	07/95	08/95	9/95	10/95	11/95	12/95
5.45										4		3
6.45	10									63	2	14
7.45	8		1							134	10	198
8.45	6	1	0		1	2				183	87	96
9.45	3	0	2		2	4				167	132	36
10.45	0	0	0		5	21		4	1	139	93	14
11.45	1	1	0		0	63	14	16	10	73	46	2
12.45	2	0	0		5	86	27	56	32	10	27	0
13.45	10	2	0		2	23	98	66	45	0	5	1
14.45	27	8	0		1	11	17	12	29	28	2	
15.45	48	16	0		0	3	8	6	6	165	1	
16.45	67	36	1	1	0	2	2	3	0	142		
17.45	143	23	0	2	1	1	0	0	0	134		
18.45	98	97	140	3	0	0	0	0	1	120		
19.45	93	158	139	8	2	0	0	0	0	89		
20.45	26	170	98	25	5	0	0	6	0	73		
21.45	7	131	73	23	8	2	2	0	0	130		
22.45	0	163	41	92	17	6	6	8	0	87		
23.45	0	139	52	129	46	8	13	9	0	71		
24.45	0	98	18	126	93	23	12	7	9	63		
25.45	1	49	7	83	36	10	0	6	0	77		
26.45	0	20	3	40	14	2	0	2	0	127		
27.45	0	5	2	21	7	1	2	1	2	151		
28.45	0	0	0	0	2		1		1	98		
29.45	0	0	0	1	1					36		
30.45	1	1	0							10		
31.45			0							1		
32.45			0									
33.45			1									
SUM	551	1118	554	248	202	200	136	2375	405	364	405	364

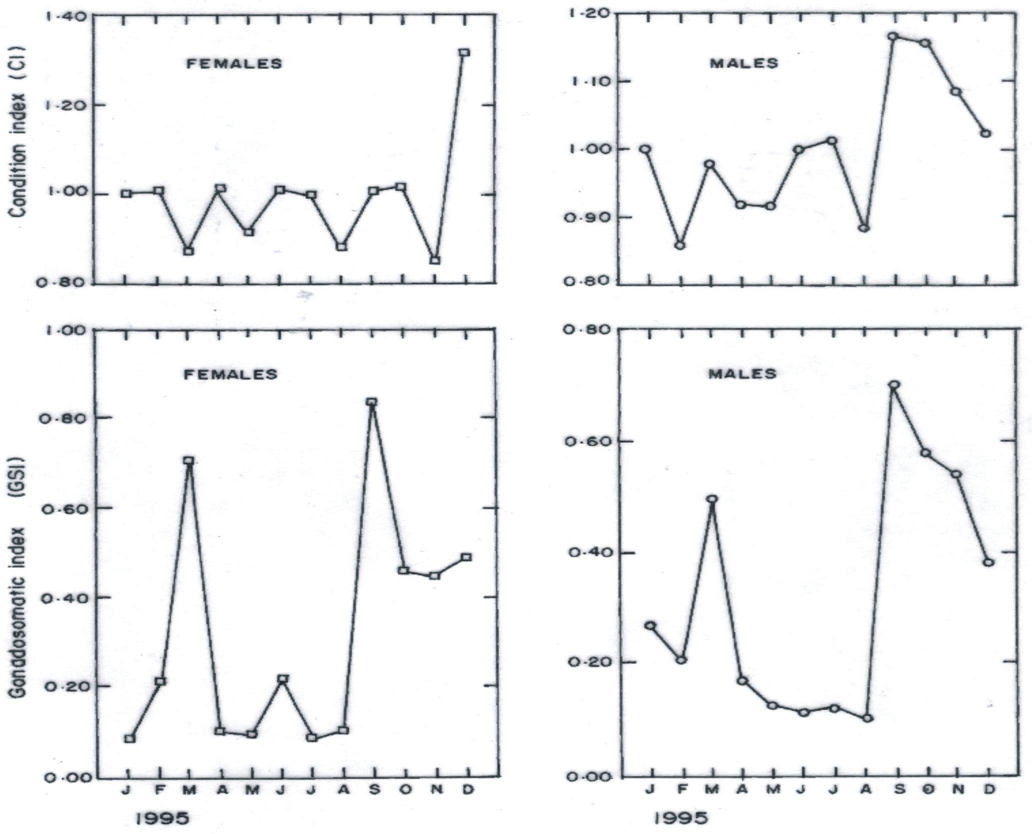

Fig. 2: Monthly variation in mean condition index of *Schilbe mystus* in Cross River, Nigeria

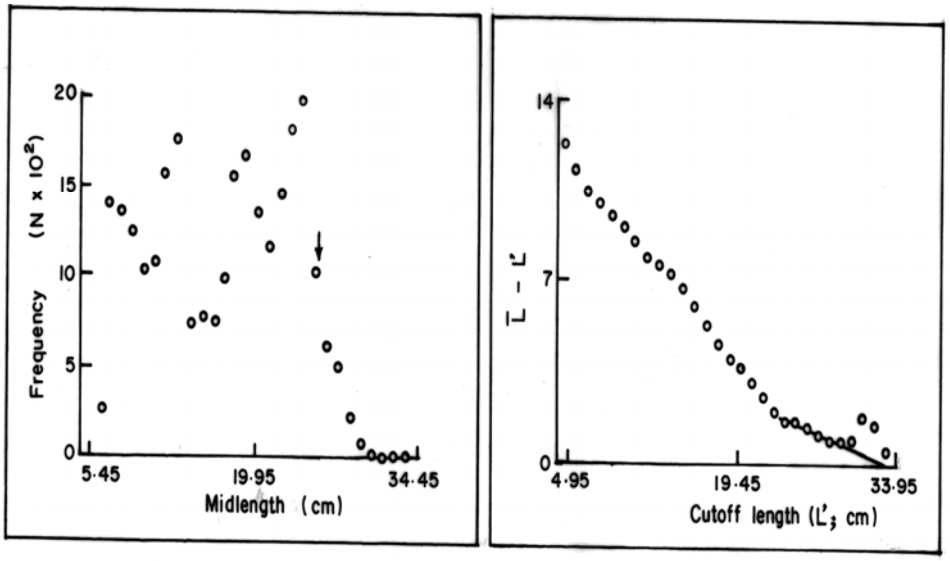

Fig. 3: Powell – Wetheral plot for *Schilbe mystus* in Cross River, Nigeria

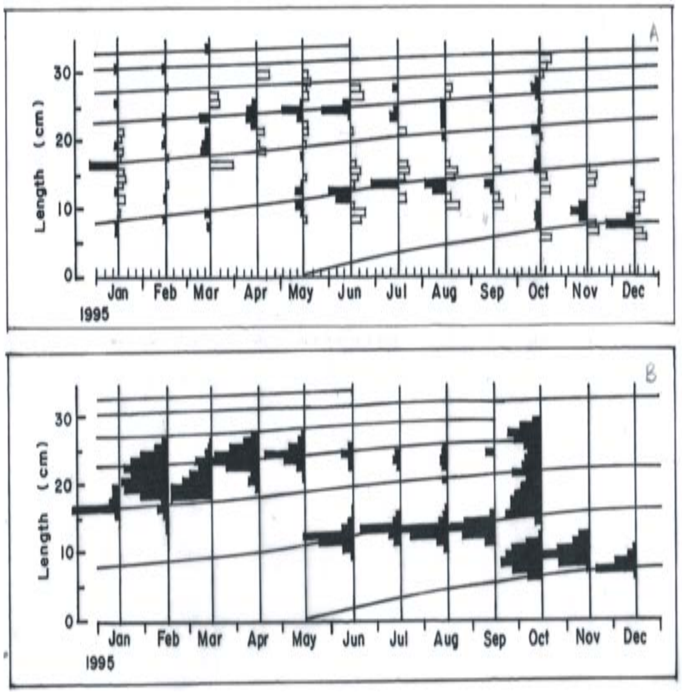

Fig. 4: Length frequency histogram of *Schilbe mystus* in Cross River, Nigeria superimposed von Bertalanffy (a) normal (b) restructured

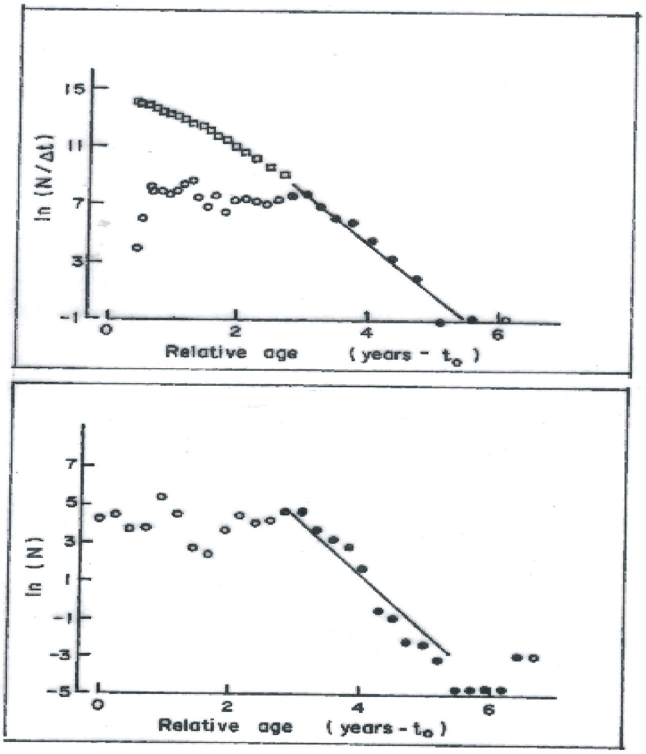

Fig. 5: Length converted catch curves of *Schilbe mystus* in Cross River, Nigeria (a) seasonalized (b) non seasonalized

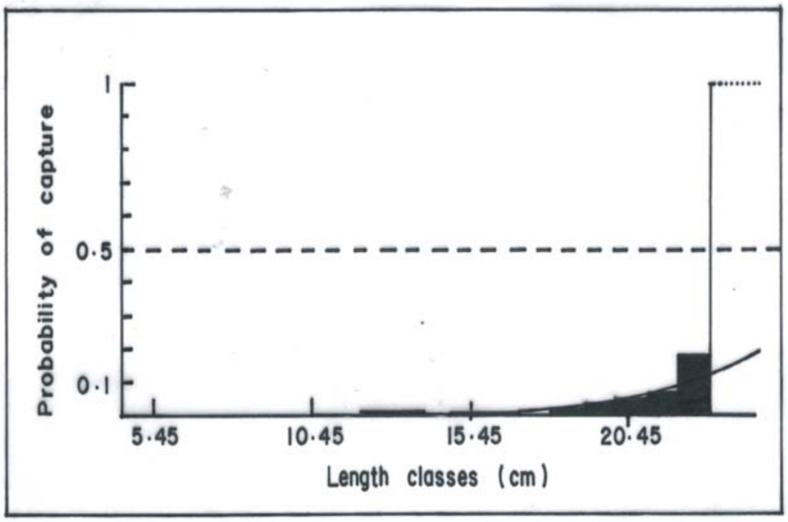

Fig. 6: Probability of capture of each size of *Schilbe mystus* in Cross River, Nigeria

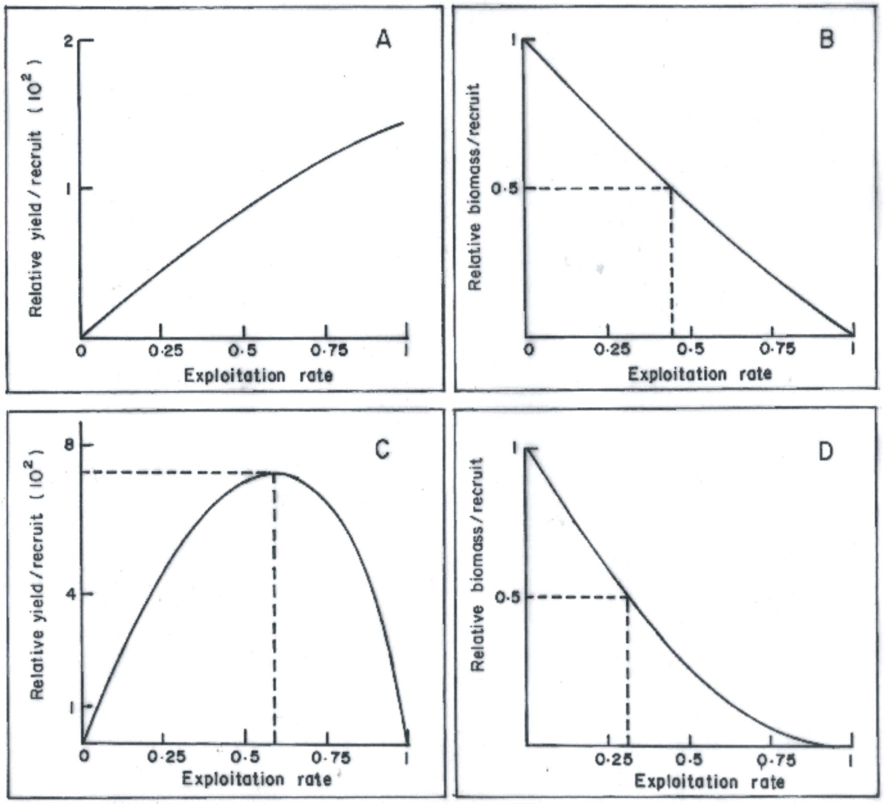

Fig. 7: Computed recruitment of *Schilbe mystus* in Cross River, Nigeria through knife- edge selection procedure (a) relative yield (b) relative biomass at E_{max} = 1.0 – 0.4
(a) relative yield (b) relative biomass at E_{max} = 0.59 – 0.31

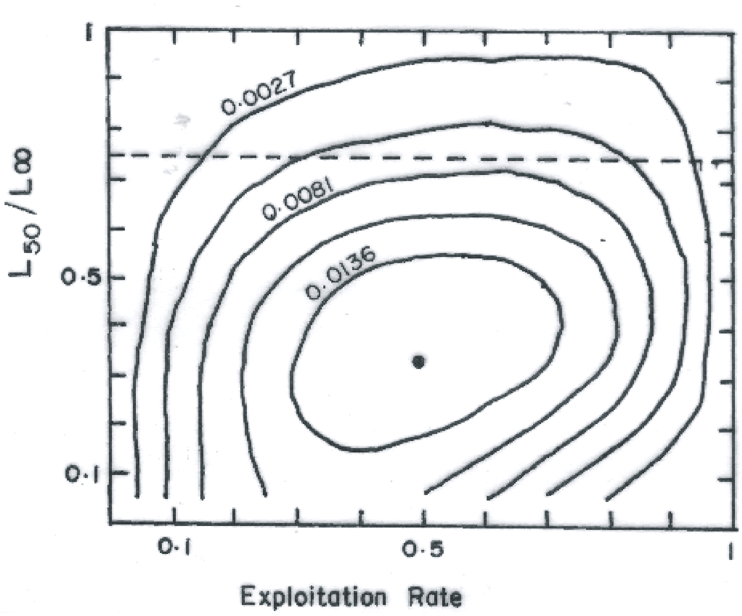

Fig. 8: Relative yield diagram of *Schilbe mystus* in Cross River, Nigeria

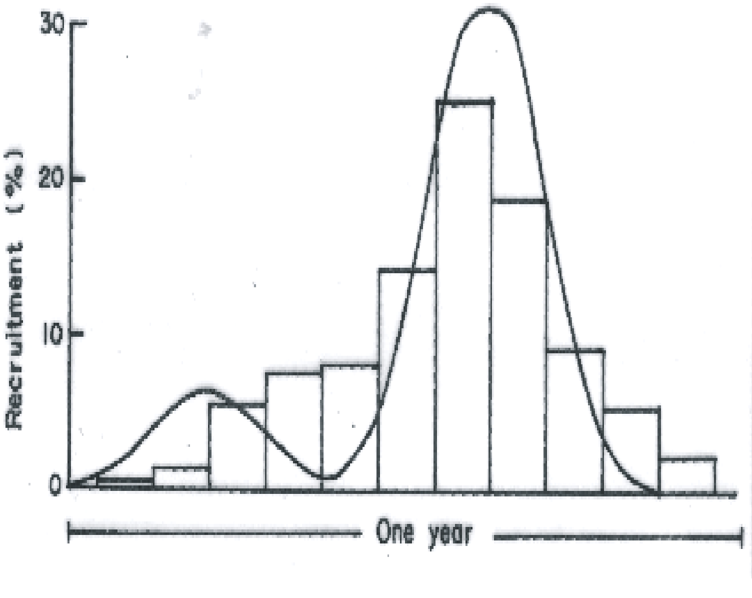

Fig. 9: Recruitment pattern of *Schilbe mystus* in Cross River, Nigeria

Discussion

Peaks in the cycles of GSI are indicators of spawning period. Thus the species spawned twice a year in March and September when rain is scanty. Patterns in the cycle of CI were irregular. *S. mystus* in Lake Kainji, Northern Nigeria breeds during the period of scanty rain (Olatunde, 1978). In the northern riverine flood plain of Okovango Delta, Botswana it spawns in midsummer during flood period, but in the Southern drainage rivers it spawns in spring about two to three months after the winter flood (Merro and Mann, 1995). In Sondu-Miru River (Kenya) it spawns during the rainy season from March to June, and October to November (Ochumba and Manyale, 1992). GSI is useful not only in elucidating fish breeding period, but also as an indicator of the amount of material invested in the gonad. It is a measure of the primary reproductive effort (involving prezygotic maturation biosynthesis and accumulation within the gametes of the fish (Miller, 1984) At the highest breeding peak, the gonad constituted about 0.8% of the body weight of females and 0.7% of the body weight of males. This is low compared with the average value of 20-30% in many fishes, an exception being the cichlid *Oreochromis leucostictus* whose ripe ovary is only 3% of the body weight (Wootton, 1990).

Three different types of data are needed in elucidating the growth of fishes: (1) Growth increment data e.g. from marked-recapture experiment, (2) length at age data, e.g. from annuli on hard parts such as scales, otoliths, etc. or (3) length frequency data. The use of marked-recapture procedure is easy for sedentary organisms like bivalves, but not for highly mobile organisms like fishes. Sclerochronologial analysis is premised on the knowledge that annuli formation on skeletal structures occurs during unfavourable periods of the year (e.g. cold winter condition) when growth may slow down or stop completely. In the tropics, temperature is relatively stable and elevated throughout the year, (for example, in the sampling area the mean minimum water temperature observed was 24°C while the mean maximum is 30°C). Thus the extent of growth retardation was not sufficient for the formation of clear annuli on hard parts. However, some scientists have used annuli in tropical fish growth study and linked such annuli formation to various factors like reproductive stress, food scarcity or cessation of feeding (Thakur, 1981; Reis, 1986), increased siltation induced by strong river inflow during the monsoon with subsequent adverse impact on feeding and metabolism (Conrad et al 1995), fall in water level and increasing water turbidity (Olatunde, 1979). Despite these reports and for other reasons, the analysis of growth annuli is still not widely used in the tropics. In the low latitude areas; many species do not exhibit growth annuli on their bony parts and where they exist, they may not be distinct. Often, the laboratory procedure involved in ageing and validation are costly and time consuming. As evident by the frequent discrepancy between different readers or by the fact that different structures (e.g. otolith, spine, scales, vertebrae) from the same fish often give different results, the method is not as objective as it might seem. Other sources of bias are that the annuli on older fishes are generally difficult to read e.g. in arid fishes after age five split annuli become frequent and interpretation difficult. Additionally the diameter of the modular cavity in spines increases with age thus preventing accurate location of first annuli (Conrad *et al*., 1995). A certain proportion of the bony parts sectioned for use might not be suitable in quality. In some cases the proportion of such ineligible samples could be as high as 50% (Conrad et al 1995): thus the validity of the results in terms of its accurate representation of the whole population could be compromised.

Length frequency data was used in this study because the annuli on hard parts (scales, otoliths and spines) of *S. mystus* were not distinct. Length frequency data are easy to collect and the range of information that could be extracted from such data far exceeds those from any other single source. Properly collected time series length frequency data offers an important record from where one could extract invaluable information concerning recent life history (e.g. growth, mortality rates, recruitment and even migration period) of the fish in question. There are many computer-supported methods (e.g. Mix by Macdonald and Pitcher, 1979; ELEFAN by Pauly and David, 1981; Projmat by Rosenberg *et al.,* 1986; LFSA by Saprre 1987; FiSAT by Gayanilo *et al.,* 1996) for the analysis of length frequency data of fish. Isaac (1990), Tomalin (1995), among others, have compared the efficacy of some of these methods. ELEFAN has some obvious advantages over other procedures. It is the most widely used method due, probably, to the fact that the software is neither copy-protected nor copy-righted and its distribution is often supported by free training course in different world regions. The underlying theory is easy to understand even by those who are not "statistically sophisticated" (Tomalin, 1995). Assumption of normality in the distribution of data set is not required. To obtain reliable estimates of growth and other fishery parameters, one must ascertain the suitability of the length frequency data. In quantity, a total sample size of 1500 or more accumulated over a period of at least six months is adequate (Pauly, 1987). In quality, there should be distinct peaks with apparent shift in modal length over time. The quantity and quality of the length frequency data in this study met these criteria.

Asymptotic size is the largest length the species could attain (granted it grows throughout life) in its habitat given the ecological peculiarities of that environment. It is an extrapolated and theoretical measure or it is better viewed as nothing more than a summary statistics. For a given species in a particular habitat, there should be one asymptotic size, but in reality the actual value depends on several factors e.g. the biological nature of the data (length frequency growth increment or length at age data), the mathematical model and the computing procedure used. In sexually dimorphic organisms, asymptotic size is also a function of gender. Our computed $L\infty$ value for *S. mystus* in the Cross River is 38.0cm. The curvature parameter K is an indicator of the speed the fish grows towards its asymptotic size hence it is used as a measure of growth rate. Siluroid fishes are not fast growing species, as indicated by their often low K values. Some workers have used Hotelling T_2 test (Bernard, 1981), likelihood ration test (Kimura, 1980) to carry out direct inter-or intra-specific comparisons of two or all three VBGFs coefficients others like Galluci and Quin (1979), Misra (1980) have carried out univariate comparisons based on either t-or chi-squared tests. Biologically, direct comparison of growth parameters is not plausible because fish growth is not linear. One stock can grow old faster than another when young and slower than the other when older. Hence, as Moreau (1987) pointed out, comparison of growth parameters is a multivariate problem that must take both $L\infty$ and K into consideration. We used the overall growth performance index Φ' because it meets these criteria, is easy to estimate and exhibit the least variance when compared with other alternative indices (e.g. Φ = K. L∞). Frank (1974) and Olatunde (1979) did not estimate the VBGFs in their work, so the Ford-Walford procedure was used to compute L∞ and K from the length at age data presented in their work. In lake Kariba, the VBG coefficients for *S. mystus* are L∞ = 52 cm, k = 0.054 y^{-1} with Φ' = 2.164, in Lake Kainji L∞ = 33.13, K= 0.196 y^{-1} with Φ' = 2.678. Olatunde (1979) had compared the corresponding length at every age and concluded that the Kainji populations of *S. mystus* grew faster than the Kariba lake population. Considering our computed Φ' values, the Cross River population has the best growth performance, followed by Kainji and the Kariba lakes populations in that order.

The preponderance of juvenile (specimens < 7.45cm in total length) in our samples showed that juveniles were recruited to the population during the dry season months of October to January. Our analysis of recruitment showed that for exploitable phase, there are two peaks of recruitment in a year.

Two different length-based methods were used to estimate the instantaneous total mortality coefficient. Z. Length based method for Z-estimation assume that the population has an equilibrium (steady-state) age composition, the recruitment is constant in relation to age, the mortality rate in relation to age and time is also constant. In real life, no population ever meets these conditions: thus. Z from length-based methods are often biased. Such errors are usually very high in animals with strong seasonal growth oscillations where the values of C in equation (2) are close to one. The steady state requirements were simulated by pooling together along time-series of length frequency data. Pauly (1990) and Pauly *et al.* (1995) has shown that despite such simulations non-seasonalized length converted catch curves could still yield biased results when compared with age-structured catch curves. On the other hand, Z from seasonalized length converted catch curves are similar to those from age-structured catch curves. Age structured catch curves are unbiased because growth in age has no seasonality. We thus accept the Z-value of $2.97y^{-1}$ from our seasonalized length converted catch curve as accurate. Z/K ratio is important in quantifying the interplay between mortality and growth in a population. If Z/K ratio is < 1, the population is growth dominated, if Z/K = 1, then mortality balances growth in such population (Barry and Tegner, 1989). In a mortality dominated population, a Z/K value of two indicates a light level of exploitation. In this work Z/K was 3.93. Thus the level of exploitation was more than "light".

In deriving their model Beverton and Holt (1966) had assumed that the probability of capturing is zero for any fish whose length is < Lc, and that it is one for a fish whose length is > Lc. This is the so-called "knife edge" selection concept which was justified on the grounds that in real-life some compensation occurs as some fishes < Lc will sometimes be caught and some fishes > Lc will sometimes escape from the gear. In large, long-lived fishes (e.g. cod) the selection process occurs over a small range of length such that this knife-edge selection assumption may be valid (Pauly and Soriano, 1986). In fishes with small L∞, the selection range may cover the entire length classes such that the relative yield per recruit computation with knife-edge selection assumption would generate a large bias. To eliminate such bias, we used the selection ogive procedure which incorporates probability of capture of each size class in computing the relative yield per recruit. Using the knife edge selection procedure an E_{max} value of one was obtained but the more realistic selection ogive procedure (Fig. 7C & D) gave an E_{max} of 0.59. Thus, from comparison, selection ogive procedure constitutes a departure from the knife edge approach with a great impact on relative yield per recruit estimation especially at high levels of E. The current value of 0.73 is in excess of the predicted E_{max} of 0.59. This implies that the species is overexploited. This result is also in line with the deduction from the Z/K ratio.

Based on the critical size $Lc/L\infty$ (which is a proxy for mesh size) and the current exploitation rate E (which is a proxy for fishing effort), relative yield contours obtained could be categorized into four components or quadrants each with its characteristics (Pauly and Soriano, 1986). With $Lc/L\infty = 0.74$ and $E = 0.73$, the relative yield isopleth falls into quadrant D. Thus, in terms of fishing regime, small *S. mystus* were caught at high effort levels, consequently the stock is over fished. Considered that open-access fishery are proned to be over-capitalized or over-exploited if not properly managed, then possible management intervention schemes should be considered. Increasing the minimum mesh size, limiting the number of entry into the fishery, reducing effort or setting quota are some of the management options that could be considered. Whatever, prevention of stock depletion is not to be pursued in abstraction. Social goals such a maximizing employment in the fishery, enhancing the economic status of the fishing community, and optimizing the net benefit of the fishery to the society are some policy options that must be taken into consideration in adopting any management strategy.

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