http://dx.doi.org/10.14798/73.3.834 **CODEN RIBAEG ISSN 1330-061X (print), 1848-0586 (online)**

POPULATION DYNAMICS OF *Chrysichthys nigrodigitatus* (Lacépède, 1803) IN THE LOWER CROSS RIVER, NIGERIA

James Philip Udoh*, John Etitigwun Ukpatu, Okon Michael Udoidiong

Department of Fisheries and Aquatic Environmental Management, University of Uyo, P.M.B. 1017, Uyo - 520001, Nigeria

*Corresponding Author, E-mail: jamesudoh@uniuyo.edu.ng, jjamesphilip@gmail.com

ARTICLE INFO

Received: 23 April 2015
Received in revised form: 26 May 2015
Accepted: 15 July 2015
Available online: 16 July 2015

ABSTRACT

Silver catfish *Chrysichthys nigrodigitatus* (Lacépčde, 1803) constitutes the main fishery offering diversified livelihood to the artisanal communities in southeast Nigeria and has been heavily fished over time without attempts at conservation. This study was conducted to estimate the current population parameters needed for its rational exploitation. Estimates of growth and mortality of catfish in the Lower Cross River, Nigeria, were obtained from length-frequency data of 6637 individuals collected on monthly basis from November 2011 to October 2012. The estimated von Bertalanffy growth function (VBGF) parameters were: asymptotic length L_∞ = 120.23 cm total length, growth coefficient K = 1.50 year^{-1} and age at zero length, t_0 = 0.0 years. The amplitude of growth oscillations C = 0.75, winter point WP = 0.50 or 1 July and growth performance index, φ = 4.336. The rates for natural, fishing and total mortalities were: M =1.58, F = 2.55 and Z = 4.31 per year, respectively. This study reveals growth overfishing and threat of extinction of *C. nigrodigitatus* in the Lower Cross River system characterized by heavy fishing pressure on the length group 34.5 - 94.5 cm TL, reduced life span from 5 to 2 years, change from a slow growth pattern typical of siluroids to a fast one with current exploitation rate, E_{cur} (F /Z) = 0.62, about 15.8% higher than the allowable maximum exploitation rate, E_{max} = 0.522. In order to restore ecosystem health, a community-based multisectoral stakeholder consortium invested with limited equity and access for exploiting the fishery in tandem with its bio-ecological dynamics should be encouraged. Other policy instruments such as periodic prohibition of fishing, controlled pricing and public education are recommended for the sustainability and conservation of the fisheries.

Keywords:
Age
Growth
Mortality
Species Extinction
Stock Assessment
Yield Isopleths

How to Cite

Udoh, J. P., Ukpatu, J. E., Udoidiong, O. M. (2015): Population dynamics of *Chrysichthys nigrodigitatus* (Lacépčde, 1803) in the Lower Cross River, Nigeria. Croatian Journal of Fisheries, 73, 103-114. DOI: 10.14798/73.3.834

INTRODUCTION

Silver catfish *Chrysichthys nigrodigitatus* (locally known as *inaha*) occurs in the inland fresh and brackish waters and often in the shallow inshore low salinity coastal stretch in the Cross River of southeast Nigeria; operated by thousands of artisanal fishers. It is found in most of the major rivers in Africa including Nigeria, Senegal, Gambia, Ivory Coast, Liberia, Zaire, and Gabon (Ezenwa, 1981). The inshore waters receive freshwater from river runoff and consequently have relatively low and fluctuating salinity. The species undertakes upstream spawning migration between April and June (Moses, 1997) during the rainy season when there is plenty of food to feed on and bottom water temperature is between 23°C and 30°C (Falaye, 1981). It is a highly cherished and economically valuable freshwater species of Nigeria with dominant commercial catches in major rivers of Africa where they are exploited (Barau, 2000).

Studies on the distribution, reproduction and feeding habits have been conducted (Offem et al., 2008; Lawal et al., 2010; Atobatele and Ugwumba, 2011). The biology and dynamics has also been reported by many authors (Ezenwa, 1981; Ezenwa et al., 1987; Ekanem, 1992; 2000; Moses, 2001; Ofori-Danson et al., 2002; Abowei and Hart, 2007; Offem et al., 2008; Francis and Samuel, 2010; Lawal et al., 2010; Atobatele and Ugwumba, 2011; Francis and Elewuo, 2012; Asuquo et al. 2012). Population dynamics of fishes are studied with the major objective of rational management and conservation of the resource. Effective management and conservation of any fishery resource requires considerable knowledge regarding population parameters such as growth, age, recruitment pattern and mortality and exploitation level of the exploited stock. However, estimates of growth, mortality, exploitation, recruitment and yield, which are the fundamental steps for dynamic pool model and the major tools for assessment and management of resource, are lacking for *C. nigrodigitatus* in the Lower Cross River, Nigeria. Thus, the objective of this paper is to estimate population parameters of silver catfish *C. nigrodigitatus* using the FiSAT routine based on a 12-month length-frequency data. This is to provide the requisite parameters for informed scientific requirement for management and sustainable utilization and exploitation of the stock in the Lower Cross River, Nigeria.

MATERIALS AND METHODS

The Study Area

The study was conducted at Itu along the Lower Cross River (LCR), southeast Nigeria (4°25′ – 7°01′ N; 7°15′ – 9°3′ E, Fig. 1), in the rainforest zone. The area is characterized by mean annual temperature of 27°C and rainfall of 2500 mm (Ekanem, 2010). The main channel of the Cross River has a total surface area of 70,000 km^2 of which 50,000 km^2 is at the lower reaches. The river floods between July and October and at bankfull the LCR is approximately 7 m deep and inundates an area (floodplain) of approximately 8000 km^2 (Moses, 1987). The floodplain contains numerous swamps, pools and lagoons that are often isolated from the main river, particularly in the dry season (Moses, 1987). The river channels, floodplain pools, lakes and marginal swamps provide a range of habitats for different fish species (Ekpo and Udoh, 2013). The dominant factor influencing the climate of the area is the movement of the Inter-Tropical Front which gives rise to two seasons: wet (February to October) and dry (mid-November and ending in March) (Ekanem, 2010).

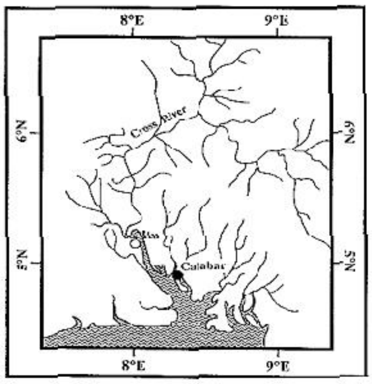

Fig 1. Map of the Cross River, southeast Nigeria showing Itu (sampling area)

Sampling

From November 2011 to October 2012, a total of 6637 individuals of *C. nigrodigitatus* caught by artisanal fishermen operating wooden canoes using hook and line, long line cast net and bottom-set gillnet (22-76 mm stretched mesh) and bottom-set traps (Offem et al., 2008) were randomly sampled. Fish samples were identified using keys and identification sheets by Fischer and Bianchi (1984) and Olaosebikan and Raji (1988). Total length (TL) of each individual was measured to the nearest 0.01 cm. The pooled length-frequency (L-F) data representing the annual cycle contained more than 10 length-classes of 10 cm size-class intervals (Gayanilo et al., 2002).

Modal Progression Analysis (MPA)

The modes in the polymodal length-frequency distribution and length-at-age for each cohort were identified using the Bhattacharya's method (Bhattacharya, 1967) incorporated in the FiSAT II package. Normal curves fitted on the polymodal length-frequency distributions used the NORMSEP procedure. The inverse von Bertalanffy growth function identified the lengths of the species at various ages.

Estimation of the Seasonalized von Bertalanffy Growth Parameters

FAO – ICLARM Stock Assessment Tools (FiSAT version 1.2.2) estimated the population parameters in this study. The FiSAT has been widely used for estimating population parameters of fish (Pauly, 1987; Abowei and Hart, 2007; Francis and Samuel, 2010) because primarily it requires only length-frequency data. ELEFAN-1 routine incorporated in the FiSAT II software estimated the parameters of the von Bertalanffy growth function (VBGF): asymptotic length (L_∞), growth coefficient (K) and age of the fish at zero length (t_o) (Pauly and David, 1981). The seasonalized VBGF developed

by Pauly and Gaschutz (1979) and later modified by Somers (1988) estimated the length-growth parameters.
The function takes the form:

$$L_t = L_\infty(1-\exp(-k(t-t_0)-(\tfrac{Ck}{2\pi})\mathrm{Sin}2\pi\,(t-t_0)+(Ck/2\pi)\ \mathrm{Sin}\ 2\pi\ t_0-t_s \quad (1)$$

where L_∞ is the asymptotic length, curvature parameter K = the von Bertalanffy growth coefficient, L_t = the length at age t; C = the factor that expresses the amplitude of growth oscillations, t_o = the hypothetical (negative) age at which the fish has a length of zero or the age of the fish at zero length, assuming the species had always grown according to the VBGF, and t_s = the 'summer point' is the time between birth and onset of the first growth oscillations (or the starting point of sinusoidal growth oscillation with respect to t = 0). In actual computation, t_s is replaced by WP (the winter point) so that WP = t_s + 0.5, which is the period of the year (expressed as a fraction of the year) when growth is slowest (von Bertallanffy, 1938).
Equation 1 fitted the length-frequency data and quantified the growth in length of individuals of the species; the starting point positions the growth curve on the data and defines the coordinates - sample number and variable starting point (Gayanilo and Pauly, 1997). Taylor's (1958) formula estimates the seeded value of the initial asymptotic length (L_∞):

$$L_\infty = \frac{L_{\max}}{0,95} \quad (2)$$

where L_{max} is the largest individual of the species observed in the samples.
ELEFAN 1 identifies the peaks in the L-F samples by restructuring the original data using a moving average over five length classes, then it searches for the best combinations of growth parameters (L_∞, K, C, WP) by plotting several growth curves through the L-F samples sequentially arranged in time, using a wide range of parameter combinations. The ELEFAN program uses a goodness of fit index (*Rn*) to judge the quality of a growth curve and the best growth curve attracts the highest (*Rn*) value which requires inputs of seeded growth parameter values. The index of goodness-of-fit (*Rn*) was calculated as:

$$R_n = 10\ (ESP/ASP)\ /\ 10 \quad (3)$$

Here ASP (available sum of peaks) is the sum of all values of available peaks, while ESP (expected sums of peaks) is the sum of all peaks and troughs which the growth curves pass through. *Rn* is an index of goodness-of-fit analogous but not equivalent to '*r*' in linear regression.
The ELEFAN I procedure was used to fit the seasonalized VBGF to the length frequency data. Preliminary estimates of the VBGF parameters, L_∞ and Z/K were obtained through the Powell-Wetherall plot (Powell, 1979; Wetherall, 1986). Final growth estimates were obtained through the ELEFAN I routine (Pauly and David, 1981) using the initial estimate of L_∞ as the seeded value. The K scan routine estimated a reliable K-value.

Growth Performance Index (Φ)

The overall growth performance index φ of *C. nigrodigitatus* was quantified using the estimated L_∞ and K (Pauly and Munro, 1984):

$$\Phi' = Log\ K + 2\ Log\ L_\infty \quad (4)$$

where L_∞ is the asymptotic length expressed in (cm) and K is the growth coefficient expressed in 'yr^{-1}'. The growth performance index assesses the reliability and accuracy of the growth parameters, L_∞ and K and it is also used to compare the growth performances of the species studied with other previous estimates available in the literature. The growth performance index also allows comparison of different species growth in terms of length, assuming that the species grow according to the VBGF (Pauly and Morgan, 1987).

Potential Longevity (T_{max})

The potential longevity was calculated using the formula of Pauly and Munro (1984):

$$T_{\max} = 3/K \quad (5)$$

The initial extreme length value of the species was used in ELEFAN I routine in FiSAT II package to produce the optimum growth curves with a wide range of seeded $L(_\infty)$ and K values. ELEFAN 1 estimated the observed and the predicted extreme lengths (L_{max}) and the range at 95% confidence interval for extreme length.

Estimation of Mortalities

The seasonalized length-converted catch curve analysis of FiSAT II with the option accounting for oscillation in growth estimated the instantaneous rate of total mortality (Z) (Pauly, 1990; Gayanilo and Pauly, 1997; Gayanilo *et al.,* 2002). The right descending arm of the length converted catch curve, which pertains to length groups fully recruited to the fishery, was then fitted with regression line in the form:

$$L_n(N) = a + b_t \quad (6)$$

where (N) is the number of fish of relative age or (pseudo) cohorts 'sliced' by means of successive growth curves; t is the time needed for the fish to grow through a length class in that pseudo-cohort. The slope (b) of the curve with its sign changed gives an estimate of *Z*. The natural mortality (*M*) was estimated using Pauly's (1980) empirical formula:

$$Log\ M = -\ 0.0066 - 0.279\ Log\ L_{\infty} + 0.6543\ LogK + 0{,}463\ LogT \quad (7)$$

where *T* was 28.0°C (the mean annual surface water temperature in the study area).
Fishing mortality (*F*) was calculated from the differences of:

$$Z - M = F \quad (8)$$

where *Z* is the total mortality, *F*, fishing mortality and *M*, the natural morality.
The fraction of mortality of the fish caused by the fishermen, i.e. exploitation rate:

$$E = F/Z \quad (9)$$

was obtained by dividing *F* by *Z* (Beverton and Holt, 1966; Gulland, 1971; Pauly, 1984; Pauly and Soriano, 1986; Abowei and Hart, 2007). Equation 10 estimates the optimum length L_{opt} as:

$$L_{opt} = L_{\infty}\ [3/(3 + M/K)] \quad (10)$$

where L_{∞} and *K* are parameters of the von Bertalanffy growth function, and *M* is the instantaneous rate of natural mortality (Froese, 2006).

Relative Yield- Per-Recruit (Y'/R) and Relative Biomass-Per-Recruit (B'/R) Analyses

To show different levels of the exploitation yield-per-recruit analyses were carried out alongside the probabilities of capture (Pauly and Soriano, 1986; Gayanilo et al., 2002 and Nwosu et al., 2007). The relative yield-per-recruit (*Y'/R*) and relative biomass-per-recruit (*B'/R*) were determined by the knife-edge recruitment and selection ogive approaches (Beverton and Holt, 1966) modified by Pauly and Soriano (1986) using yield–per-recruit routine in FiSAT II to estimate the levels of exploitation that would give optimum yields. The modified form allows for the input of probabilities of capture for the smallest sized fish, thus reducing the bias in yield estimates due to the effect of gear selection and/or incomplete recruitment. Other input requirements in this procedure are critical size ratio ($L_c/L_{¥}$) and mortality-growth ratio (*M/K*). The *Y'/R* model provides information needed for conservation and management of stocks (Sparre and Venema, 1992).
Reference points assessing the status of *C. nigrodigitatus* stock in the LCR, Nigeria, includes: $E_{0.1}$ (the exploitation level at which the marginal increase in yield-per-recruit reaches 1/10 (10%) at *E* = 0); $E_{0.5}$ (the exploitation level which will result in a reduction of the unexploited biomass by 50% through the first derivation of the Beverton and Holt (1966) function and E_{max} (the exploitation level that produces the maximum yield-per-recruit). The yield-per-recruit analysis places a spotlight on the rate of exploitation and predicts the effect on the equilibrium catch of a change in selectivity (e.g. change in mesh size of net) as well as a change in the fishing efforts or fishing mortality (Moses, 1997; Gayanilo et al., 2002).
Relative biomass-per-recruit (*B'/R*) was estimated from the relationship:

$$B'/R = \frac{Y'/R}{F} \quad (11)$$

Yield Isopleth

The relationship between the three variables (*Y'/R*= yield-per-recruit, *F* = fishing mortality and L_c= length-at-first-capture) was represented by a contour map known as Isopleth diagram (Beverton and Holt, 1966). The impacts on yields of changes of exploitation rate (*E*) and length-at-first-capture - asymptotic length ratio, $L_c/L_{¥}$ in relation to a change of mesh size was assessed using the yield isopleth diagrams, produced by plotting fishing mortality (*F*) on the x-axis and length-at-first-capture (L_c) on the y-axis and drawing lines of equal values of yield-per-recruit. The line of equal yields are called yield isopleths and show the *Y'/R* for various combinations of fishing mortality coefficients (hence fishing intensity) and the length-at-first-capture (hence gear selectivity). The yield isopleths demonstrate the response of the yield-per-recruit of *C. nigrodigitatus* to both variation in L_c and the fishing pressure as indicated by the exploitation rate *E* over a wide range of both parameters (Gayanilo et al., 2002).

$$\text{Yield isopleths} = \frac{L_c / L_{\infty}}{F / Z}$$

Length Structured Virtual Population Analysis (VPA) and Cohort Analysis

The estimated length-structured virtual population analysis (*VPA*) and cohort analyses were carried out using the FiSAT routine. The cohort was reconstructed backward in time, starting with the last caught animals of a cohort (the terminal catch). Population cohorts were estimated by a backward projection method that requires specification of a guess of the number of survivors and the fishing mortality rate in the oldest age group in all remaining months or years (Pope, 1972; Gulland 1971). This is possible with the monthly length – frequency data (Nwosu and Wolfi, 2006; Nural Amin *et al*., 2008).
The values of $L_{¥}$, *K, M, F*, ***a*** (constant) and ***b*** (exponent) were inputs for the *VPA* analysis. The (t_o) value was taken as zero.

Practical reviews of *VPA* methods were, among others, given by Pauly (1984) and Jones (1984). The length structured *VPA* permits an estimation of the fish population for the most recent year, that is, the standing stock and fishing mortalities (Gayanilo et al., 2002).

RESULTS

Table 1 shows the monthly L-F data of 6,846 *C. nigrodigitatus* used in the present analysis. There were variations in the size of *C. nigrodigitatus* landed at the sampling station with maximum total length (L_{max}) of 104 cm, while the smallest was 15.0 cm TL. The 44.5-55.5 cm TL (40-59 cm TL) mid-length size groups were numerically dominant, comprising over 43% of the population, while the least value of 0.12% was observed at the length class 100-109 cm TL (Fig. 2a,b). Multiple modes in the monthly length frequency data, for at least three consecutive months, traced the growth of a cohort (Fig. 3).

Analysis of the length-growth parameters using the ELEFAN-1 routine estimated the best values of the seasonalized VBGF as: asymptotic length, $L_{¥}$ = 120.23 cm *TL*, VBGF growth constant, K = 1.5 year^{-1}. The amplitude of growth oscillations (C = 0.75) reveals significant oscillations in the growth due to temperature and energy abundance, while the winter point, WP = 0.5, indicates time when growth is slowest; the response surface (Rn) was calculated as 0.254. The Z/K = 2.87 (Table 2). The growth performance index, φ, was estimated at 4.336, while L_o was 88.99 cm *TL*. Using the estimated value of the average growth coefficient (K = 1.5 year^{-1}), the longevity, t_{max}, was estimated at about 2.0 years. The value of the age of the fish at zero length (t_o) was unknown (not determined using the ELEFAN-1 routine) and assumed to be zero, t_o = 0. From these parameters, von Bertalanffy growth model for *C. nigrodigitatus* was established as:

$$L_t = 120.23\ [1 - exp^{(-1.5(t-(0))}] \qquad (13)$$

(a)

(b)

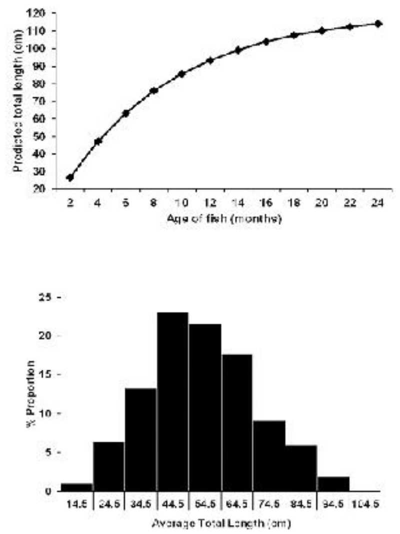

Fig 2. Predicted mean-length-at-age curve (a) and length composition (b) of C. *nigrodigitatus* in the Lower Cross River, Nigeria ($L_{¥}$ = 120.23 *cmTL*, K = 1.50 yr^{-1}, t_0=-0.0, φ' = 4.31)

Figure 4 presents the optimized growth curves superimposed on the restructured length-frequency histograms, while Figure 2a shows the predicted length at age based on the exponential model.

From the length-converted catch curve (Fig. 5), computed total (Z) and natural mortality coefficient (M) for *C. nigrodigitatus* were Z = 4.13 year^{-1}; M = 1.58 year^{-1} and derived fishing mortality coefficient, F = 2.55 year^{-1}. The current exploitation ratio, E_{cur} was computed as (F/Z) = 0.62, indicating that about 62.0% of the total mortality of the available stock was caused by exploitation, while the allowable limit of exploitation rate, E_{max} = 0.524 yr^{-1}, indicated that a maximum of about 52% of the available stock was fishable annually (lower than the exploitation ratio, E_{cur} = 0.62). The optimum yield of a fishery is taken when the

Table 1. Length – frequency data of C. nigrodigitatus from the Lower Cross River, Nigeria, between November 2011-October 2012 (n = 6637; Size class interval = 10cm)

Mid length, cm	14/1/11	15/12/11	13/01/12	16/02/12	12/03/12	14/04/12	17/05/12	13/06/12	15/07/12	16/08/12	14/09/12	16/10/12	Total	% Total
14.5						2	20	14	24	13			73	1.10
24.5	26	2	4	3	27	12	76	148	88	31		4	421	6.34
34.5	116	14	24	8	116	14	148	222	122	20	51	24	879	13.24
44.5	201	181	144	17	211	18	135	248	148	128	73	30	1534	23.11
54.5	108	188	181	133	148	188	44	117	118	45	46	114	1430	21.55
64.5	140	178	18	118	122	149	35	187	113	56	35	19	1170	17.63
74.5	110	111	3	122	59	49	10	30	20	54	23	10	601	9.06
84.5	95	71	2	92	30	38	9	17	4	23	9	8	398	6.00
94.5	38	3	1	41	4	2	7	14	4	9			123	1.85
104.5	2	1		4				0	1				8	0.12
SUM	836	749	377	538	717	472	484	997	642	379	237	209	6637	100.00

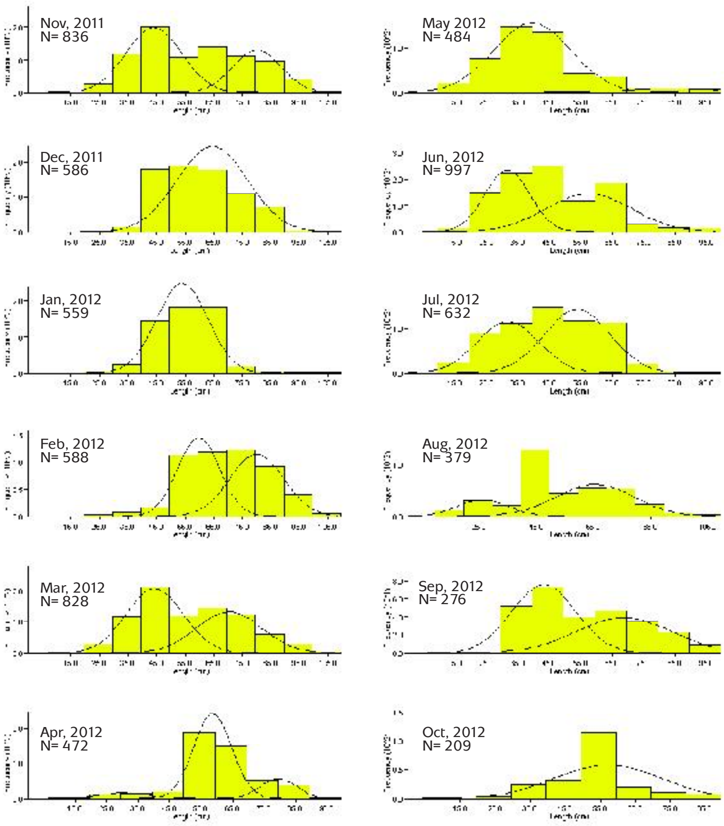

Fig 3. Monthly length frequency distributions of *C. nigrodigitatus* from the Lower Cross River, Nigeria (November 2011 – October 2012, n = 6637)

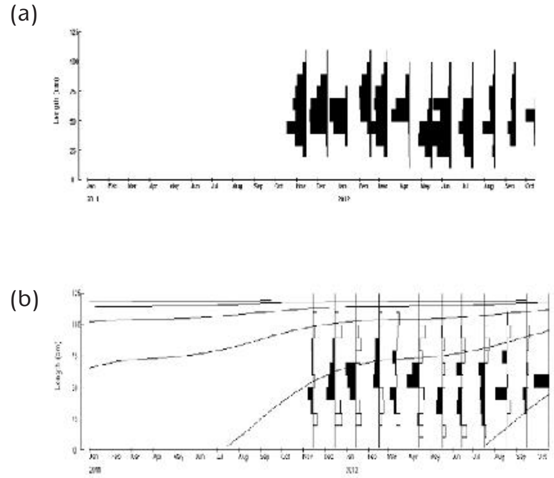

Fig 4. Seasonalized von Bertalanffy growth curves of *C. nigrodigitatus* as superimposed over (b) normal length frequency histograms and (b) the restructured length-frequency histograms. The black and white bars are positive (peaks) and negative (troughs) deviations from the weighted moving averages of three length classes and they represent pseudo-cohorts [$L_{¥}$ =120.23cm, K = 1.5yr^{-1}, C= 0.75, winter point = 0.50; the estimated, Rn = 0.254]

fishing mortality (F) is about equal to the natural mortality (M), i.e. $F = M$ or $E = F/Z = 0.5$; hence, $E > 0.5$ indicates that *C. nigrodigitatus* of the Cross River system is over-exploited (Table 2). The species has a short lifespan of 2 years and attains over 64% of the asymptotic length ($L_{¥}$) at six months of age, as estimated from its von Bertalanffy growth model. The relative yield-per-recruit and relative biomass-per-recruit for *C. nigrodigitatus* using the knife-edge selection procedure (E_{max} = 0.524, $E_{0.1}$= 0.453, $E_{0.5}$ = 0.320) assume that only fishes greater than or equal L_c (37.15 cm) are retained by the gear. The values from the selection ogive procedure are: E_{max} = 0.522, $E_{0.1}$ = 0.455, $E_{0.5}$ = 0.321 (Fig. 6a,b). The values indicate the stock was overexploited since (0.62) $E_{cur} > E_{max}$ (0.52), i.e. current level of exploitation ratio has exceeded the exploitation corresponding to the maximum yield per recruit by over 10% (Fig. 7). The yield isopleths of *C. nigrodigitatus* are presented in Fig. 6a,b for knife-edge and ogive selections, respectively. The critical size ratio $L_c/L_{¥}$ is 0.309, and mortality-growth ratio, M/K, is 1.05. The length structured virtual population analysis (VPA) of *C. nigrodigitatus* (Fig. 8) indicates that survivorship of cohorts was high until later in life. The *VPA* shows that natural mortality was higher in the smaller length groups, while it decreased gradually as the fish grew up to 54.5 cm; beyond this length, mortality was mainly due to fishing pressure, with the length group 34.5 - 94.5 cm being the most exploited (subjected to heavy fishing pressure).

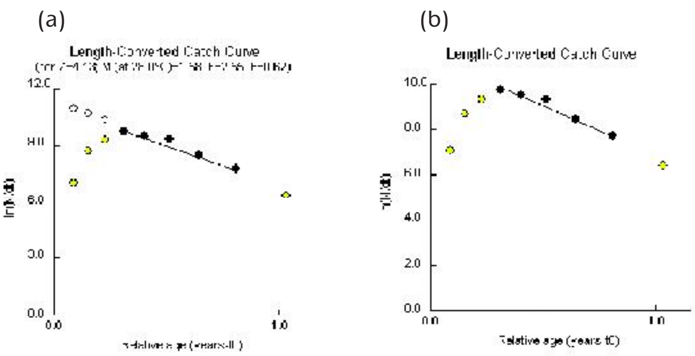

Fig 5. Length converted catch curves of *C. nigrodigitatus*: the darkened full dots represent the points included in the least square linear regression, the open dots represent the point either not fully recruited or nearing $L_{¥}$. Regression equation: Y = 11.17 - 4.130 X, N = 12, r = 0.9617

DISCUSSION

The criteria for using length-frequency data is an important consideration; the L-F data should exhibit peaks with apparent shift in modal length over time (Wolff, 1989) and compose of not less than 1500 in total sample size collected over a period of six months. The L-F data (Table 1) meets these criteria.

The most widely used model in describing fish growth is the VBGF but its defect is that it does not take into consideration the effect of seasonal changes on growth (Abowei and Hart, 2007). However, Gayanilo and Pauly (1997) and Gayanilo et al. (2002) developed and incorporated the seasonalized VBGF in the FiSAT II software with the inclusion of the amplitude of growth oscillations, C, and winter point, WP, both of which seek to identify the effects of seasonal changes on growth of species. The winter point, *WP* = 0.5, or 1 July, indicates that growth is slowest between April and August (Fig. 4). This coincides with the major spawning period (April to August) when most of the stored energy is mobilized for gonadal development and spawning processes, during which the growth rate of *C. nigrodigitatus* was found to be notably suppressed (as observed from the slight suppression in the growth curve, Fig. 4). The suppression of growth between April and August reveals definite impact of seasons on the growth of the species. The amplitude of growth oscillation, *C* = 0.75 corresponds to the temperature oscillation of the Lower Cross River as reported by Etim and Enyenihi (1991), Etim and Brey (1994), Etim et al. (1994). The tendency of the amplitude of seasonal growth oscillations to reach high value of 0.75 indicates that *C. nigrodigitatus* in the Lower Cross River experiences quite strong seasonality in growth. Pauly (1987) had suggested that growth oscillation is mainly due to temperature changes in the investigated area. Thus, the habitat temperature deviation between the wet and dry seasons around the sampling area, as reported by Etim and Enyenihi (1991), Etim and Brey (1994), was recorded at about 8°C, t_2-t_1 (t_1 = 22°C, wet season and t_2 = 30°C, dry season).

In this study, the value of t_o (= the theoretical age of the fish at zero length, L_t = 0) was not determined because the ELEFAN I procedure is not capable of extracting t_o from L-F data. The parameter t_o is a location parameter and its absence does not underscore the accuracy of other parameters computed from the seasonalized VBGF (Gayanilo et al., 2002). The starting sample (SS) replaces t_o in the FiSAT II procedure. However, Pauly (1980) derived an empirical relationship for t_o based on VBGF parameters: L_∞ and *K*. Using this relationship, Ekpo and Udoh (2013) derived t_0 = - 0.20 for *Chrysichthys auratus,* while Udoh (1994) obtained t_0 = - 0.85 for the same species in the LCR, the latter being a more reliable reference point. By applying Pauly's (1980) empirical relationship for *C. nigrodigitatus* in the Lower Cross River system, in this study t_0 was - 0.07.

Table 2. Seasonalized VBGF parameters of *C. nigrodigitatus* from the Lower Cross River, southeast Nigeria

Population parameters	Estimates
Sample number, *N*	6637
Total mortality, *Z* (yr^{-1})	4.31
Natural Mortality, *M* (yr^{-1})	1.58
Exploitation rate, *E*	0.67
Fishing mortality, *F* (yr^{-1})	2.55
Asymptotic length, L_∞ (cm)	120.23
Growth coefficient, *K* (yr^{-1})	1.5
Amplitude of growth oscillation (*C*)	0.75
Winter Point (*WP*)	0.5
Growth performance index, *φ*	4.336
Total mortality- Growth coefficient ratio, *Z/K*	2.87
Potential longevity, t_{max} (years)	2
Observed extreme length (cm)	104.5
Predicted extreme length, M_{max} (cm)	111.84
Range at 95% confidence Interval (cm)	105.95-117.72
Allowable limit of exploitation, E_{max}	0.524
Response surface (*Rn*)	0.254

The asymptotic length (L_∞) is the largest theoretical mean length that a fish could attain (if it grows throughout life) in its habitats given the ecological peculiarities of its environment. L_∞ = 90 cm TL, 98.25cm TL and 120.23 cm TL for *C. nigrodigitatus* in the Nun River (Abowei and Hart, 2007), Lower Cross River Estuary (Ajang et al., 2013) and in the Lower Cross River system (this study), respectively (Table 2, 3). For a given species in a particular habitat, there should be one L_∞ but in reality the actual value depends on several factors, e.g. the biological nature of data (length frequency, growth increment or age-length or age-at-length data) and the mathematical and computing procedure used. The L_∞ for *C. nigrodigitatus* in this study was 2-4 times higher than values obtained for other localities by different authors (Table 2). The speed at which a species grows to its final length (size), growth coefficient, *K*, is measured per year. *K* for *C. nigrodigitatus* was estimated at 1.5 yr^{-1} in this study (Table 3), differing (2-10 times higher) from the values obtained elsewhere (Table 3). It is typical for siluroid fishes to exhibit very slow growth rate (Table 3), unlike the fast growth rate exhibited by *C. nigrodigitatus* in this study area. However, the *K* value falls within the range (0.39 to 1.6 yr^{-1}) estimated for various tropical fish stocks (Pauly et al., 1984) and is therefore reliable. *C. nigrodigitatus* in this study area also exhibited the highest natural mortalities compared to others (Table 3), which is in conformity with the assertion of Beverton and Holt (1966) that the fast-growing species exhibit high *K*-values vis-ã-vis high natural mortalities. The differences in the size ranges examined and sampling scheme could account for the differences observed in the

Table 3. Growth and Other Fisheries Parameters for *C. nigrodigitatus* From Different Localities

Species	L_∞ cmTL	K (Yr^{-1})	C	WP	L_c	Z (Yr^{-1})	M (Yr^{-1})	F (Yr^{-1})	φ	E	Z/K	Locality	Source
C. nigrodigitatus						0.88	0.66	0.22		0.25		Andoni River, Nigeria	Francis and Samuel, 2010
C. nigrodigitatus	116.8											New Calabar River, Nigeria	Francis and Elewuo, 2012
C. nigrodigitatus	90.1	0.538				1.68	0.703	0.976	2.63	0.58	3.12	Nun River, Nigeria	Abowei and Hart, 2007
C. nigrodigitatus	44.5	0.65				3.77	1.24	2.53	3.12	0.65	5.80	Lake Volta, Ghana	Ofori-Danson et al., 2002
C. auratus	31.0 cm SL	0.66				2.63	1.30	1.33	2.76	0.51	3.98	Lake Volta, Ghana	Ofori-Danson et al., 2002
C. auratus	25.03	0.60			14.0 *cmTL*	1.94	0.63	1.31	2.57	0.68	3.23	Lower Cross River, Nigeria	Ekpo and Udoh, 2013
Chrysichthys spp.		0.15				0.47	0.19	0.28			3.13	Lower Cross River, Nigeria	Udoh, 1994
C. nigrodigitatus	68.38	0.96				6.27	1.22	5.05	3.29	0.81	6.53	Cross River Estuary, Nigeria	Ajang et al., 2013
C. nigrodigitatus	120.2	1.50	0.75	0.55	36.3	4.31	1.58	2.55	4.31	0.62	2.87	Lower Cross River, Nigeria	This study

L_∞ = Asymptotic Length, K = Growth Coefficient, C = Growth Oscillations, WP = Winter Point, L_c = Length-at-First-Capture, Z = Instantaneous Rate of Total Mortality, M = Instantaneous Rate of Natural Mortality, F = Instantaneous Rate of Fishing Mortality, φ = Growth Performance Index, E = Exploitation Rate

population parameters (Table 3). Life span and the maximum size a fish can attain during its lifetime influences its size at maturity, however, the relative larger size of *C. nigrodigitatus* at maturity and fast growth rate could be an intrinsic adaptation to attain a high asymptotic length in response to high fishing pressure, i.e. fishing mortality. The short life span observed in this study is an indication of overfishing, threat to extinction, and calls for urgent management intervention. Overall growth performances of 2.63 and 3.12, computed by Ofori-Danson et al. (2002) and Abowei and Hart (2007), respectively, are below our estimate of 4.336 (Table 3). These differences could be due to different ecological peculiarities and demographic structure of stocks, and spatio-temporal pattern in abiotic components of the habitat or environment (freshwater).

This study examined and explained the effects of fishing on *C. nigrodigitatus* stock in the Lower Cross River using mortality estimates (total, natural and fishing mortality rates). Wrong estimates of potential yield could result in over exploitation or under exploitation of the fish stock. The instantaneous total mortality coefficient, *Z*, indicates that both natural death (*M*) and fishing (*F*) contributed to fish mortality. The *Z* value estimated in this study (Z = 4.31yr^{-1}) falls within the range of values (2.46 - 7.07 yr^{-1}) estimated by Pauly et al. (1984) for several tropical fish stocks and is greater than the estimate (1.68 yr^{-1}) of Abowei and Hart (2007). Similarly, *F*, 2.73 yr^{-1} in this study is higher than F = 0.976yr^{-1}

(a)

(b)

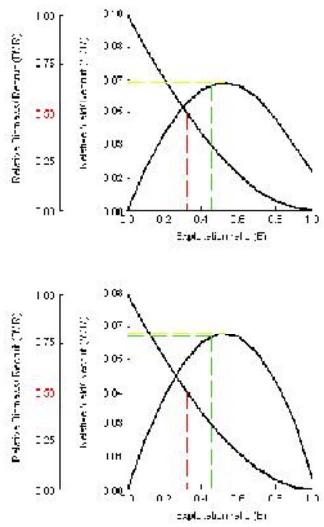

Fig 6. Relative yield-per-recruit and relative biomass-per-recruit for *C. nigrodigitatus* using (a) the knife-edge selection procedure (E_{max} = 0.524, $E_{0.1}$ = 0.453, $E_{0.5}$ = 0.320) based on the unrealistic assumption that only fishes greater or equal L_c are retained by the gear, and using (b) the Ogive selection procedure (E_{max} = 0.522, $E_{0.1}$ = 0.455, $E_{0.5}$ = 0.321)

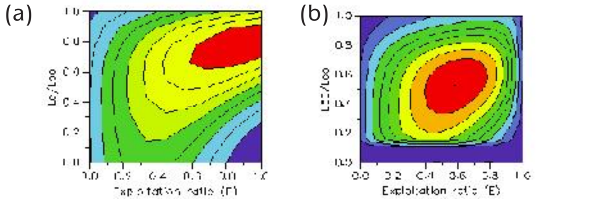

Fig 7. Yield isopleths for *C. nigrodigitatus:* (a) for knife–edge selection procedure [E = 0.62, Critical ratio, L_c/L_∞ = 0.309, M/K = 1.05], (b) for Ogive selection procedure [E = 0.62, critical ratio L_c/L_∞ = 0.305, M/K = 1.05].

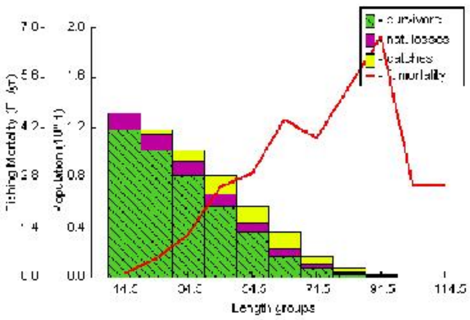

Fig 8. Length-structured virtual population analysis (VPA) for *C. nigrodigitatus* in the Lower Cross River, Nigeria [K=1.5yr^{-1}, L_∞ =120.23cm, M = 1.58yr^{-1}, F = 2.55yr^{-1}, a = 0.0001, b = 3.00]

obtained by Abowei and Hart (2007) for *C. nigrodigitatus* in southeast Nigeria. The estimate of *M* affects the value of yield. The *M* in this study (1.58 yr^{-1}) suggests that the species does not contribute much (as prey organism) to the trophic interrelationships of the ecosystem, probably because it is a predator. The *M/K* ratio ascertained the reliability and accuracy of growth parameters like the estimated *M*. The ratio generally falls within the range of 1.0 – 2.5 for most fishes (Beverton and Holt, 1966; Mohamed, 1996) for any result to be valid for scientific interpretations and deductions and is supposed to be constant for a group of species or closely related families or taxa. In this study, the *M/K* value (1.05) falls within the accepted range thereby rendering these mortality values valid for scientific inferences and subsequent management purposes. The *M* value is a necessary input in the computation of many models in the studies of fish population dynamics.

The mortality values, Z = 4.31 yr^{-1}, F = 2.73 yr^{-1} and M = 1.58 yr^{-1}, indicate that fishing pressure causes more deaths than the combined effects of disease, predation and senescence. The high fishing mortality implies high fishing effort, including mass capture of the fish during their upstream migrations into river floodplains for spawning in the wet season. Varying the fishing effort influences variations in fishing mortality (Moses, 2001).

When *Z/K* from the Powell-Wetherall plot is less than 1 (Z/K < 1), growth dominates the stock as in the case of *C. nigrodigitatus* in the Nun River (Abowei and Hart, 2007). When Z/K > 1, mortality dominates the stock; if it is equal to 1 then the population is in an equilibrium state, when mortality balances growth. In a mortality-dominated population, if *Z/K* ratio = 2, then it is a lightly exploited population. *Z/K* in this study was 2.87 (Table 1) which is consistent with high levels of mortality reported for *Chrysichthys* stock in southeast Nigeria (Table 3).

The relative yield per recruit (Y'/R) is a function of different values of exploitation rate (*E*) and length-at-first-capture, *Lc*. The plot of relative yield per recruit (Y'/R) and biomass per recruit (B'/R) against exploitation rate (E) for *C. nigrodigitatus* (Fig. 6) showed that the maximum Y'/R was obtained at nearly the same value of E_{max} = 0.524 for ogive selection and 0.522 for knife-edge selection. The ogive and knife-edge selections recorded $E_{0.1}$ and $E_{0.5}$ values of 0.453 and 0.324, and 0.455 and 0.321, respectively. The present finding indicates the fishery is over-exploited: E_{cur} > E_{max}, requiring a 10-40% reduction in *F*. The VPA signifies that the most exploited fish were of 34.5 - 94.5 cm TL, while L_c/L_∞ = 0.309 (considering that 21 - 71% of growth was yet to be completed by the fish as at the time of capture). According to Fishbase, the species reaches maturity between 14 and 27.5 cm TL (Froese and Pauly, 2015), while Offem et al. (2008) reported that it attained maturity at 11.5 cm TL (male) and 16.7 cm TL (female) in the Cross River; suggesting that the most exploited sizes in our study are matured . However, to achieve sustainable catches with the least impact on the stocks, the fish are best taken at L_{opt} = 89.0 cm TL, where the product of survivors times mean individual weight reaches a maximum and offers more weight per individual (biomass) than at L_c (Froese and Binohlan, 2000; Froese, 2004).

A critical size ratio (L_c/L_∞) of 0.309 and E_{cur} = 0.62 indicates that *C. nigrodigitatus* in this study are caught at high effort levels (Pauly and Soriano (1986), with evidence of periodic oscillations of yield owing to exploitation strategies of fishermen. This calls for reduction in fishing effort by the use of 50 mm mesh size and above (Ajang et al., 2013) in order to attain maximum sustainable level.

The virtual population analysis (*VPA)* is a necessary precursor for standing stock and fishing mortalities assessments. The *VPA* revealed the *C. nigrodigitatus* fishery of the Lower Cross River does not suffer recruitment overfishing but growth overfishing, with fishing mortality dominating (*F>M*) and determining the population structure. Survivorship of cohorts was high until later in life. However, overfishing in the schooling areas reduces the stock abundance of *C. nigrodigitatus* of the Lower Cross River.

The strategies to be adopted for managing this fishery to avoid overfishing and sustainable development include i) the voluntary obligations of fishermen to acknowledge the breeding seasons (particularly in July/August) as closed seasons and prohibit fishing in that period; ii) state-controlled pricing and imposition of higher prices and taxes on the captured species displayed for sale during the breeding/closed seasons to discourage capture by fishermen and purchase by consumers; iii) encouragement of agricultural fairs and shows to educate the fishing and riverine communities (particularly pupils, students, clerics and women) on the bio-ecological dynamics of their priceless gift (*C. nigrodigitatus*); iv) the issuance of fishing concessions (*custodias*), fishing leases or territorial use rights for fishing (TURFs) to groups (communities), local civil society organizations, fishing cooperatives and associations, community-based fisheries management committees (CBFMC) but not to single individuals or entrepreneurs (Beitl, 2012). Further protection could be provided by establishing *inaha* parks to protect the spawning stock biomass in its breeding grounds in the LCR floodplains and to prohibit their capture during upstream migrations (Moses, 1987). Additionally, the State Departments of Fisheries should establish and empower *Inaha* community-based fisheries management committees (CBFMC) to coordinate and support *Inaha* fishermen and fishermen groups to: i) provide management plans fashioned to suit the bio-ecological dynamics of fishery resources; ii) provide maps delineating their fishing areas, list of members (fishers and processors); iii) provide memorandum of association and names of officers, and iv) establish external linkage for technical assistance (Yamamoto, 1995; Pomeroy et al., 1996).

CONCLUSION

This study serves as an important reference point to the overfishing and threat of extinction of *C. nigrodigitatus* in the Lower Cross River system, particularly with heavy fishing pressure on the length group 34.5 - 94.5 cm TL. The state of the stock requires reduction of fishing effort and devolution of powers from state-controlled fisheries to community control over shared natural resources through the adoption of a community-based fisheries management (CBFM) approach. A multisectoral stakeholder consortium should therefore be constituted to define the bio-ecological dynamics of the *C. nigrodigitatus* fishery in the Lower Cross River system and work out achievable objectives with priority for the fishery and then the fishermen.

Sažetak

DINAMIKA POPULACIJE *Chrysichthys nigrodigitatus* (Lacépède, 1803) IZ DONJEG SLIVA RIJEKE CROSS, NIGERIJA

Srebrni som, *Chrysichthys nigrodigitatus* (Lacépčde, 1803), predstavlja glavnu ponudu ribarstva raznolikim životnim zajednicama u jugoistočnoj Nigeriji. Intenzivno je izlovljavan tijekom vremena bez pokušaja njegove zaštite. Ovo istraživanje je provedeno kako bi se procijenio trenutan populacijski parametar potreban za racionalno iskorištavanje. Podaci za procjena rasta i smrtnosti soma u donjem slivu rijeke Cross u Nigeriji dobiveni su od duljine frekvencije 6.637 individua prikupljanih mjesečno od studenog 2011. do listopada 2012. Procijenjeni von Bertalanffy-evi parametri rasta (VBGF) su: asimptotska duljina L_∞ = 120,23 cm totalne dužine, koeficijent rasta K = 1,50 godina^{-1} i dob nulte dužine, t_0 = 0,0 godina, amplituda oscilacije rasta C = 0,75, točka zimovanja WP = 0,50 ili 1. srpnja te indeks performanse rasta, φ = 4,336. Stopa smrtnosti za prirodne i ribolovne populacije te ukupne smrtnosti iznosile su: *M* = 1,58, *F* = 2,55 i *Z* = 4,31 godišnje.

Ova studija prikazuje porast izlovljavanja i opasnost od izumiranja *C. nigrodigitatus* u donjem slivu rijeke Cross što se očituje teškim ribolovnim pritiskom na dužinski razred 34,5 - 94,5 cm TL, smanjenim životnim vijekom od 5 do 2 godine, promjenom sporog rasta tipičnim za somove na ubrzan rast s trenutnom stopom eksploatacije, *Ecur* (F / Z) = 0,62 koja je oko 15,8% viša od dopuštene maksimalne brzine eksploatacije, *Emax* = 0,522. Kako bi se revitalizirao ekosustav, višesektorski konzorcij zajednice dionika zalaže se za ograničenu jednakost i tandemski pristup iskorištavanju ribarstva uz poticanje bio-ekološke dinamike. Ostali politički instrumenti, kao što su periodične zabrane ribolova, kontrolirane cijene i edukacija, preporučuju se za održivost i očuvanje ribarstva.

Ključne riječi: dob, rast, smrtnost, izumiranje vrste, procjena stoka, iskorištavanje

REFERENCES

Abowei, J. F. N., Hart, A. I. (2007): Size Composition, Age, Growth, Mortality and Exploitation Rate of *Chrysichthys nigrodigitatus* from Nun River, Niger Delta, Nigeria. African Journal of Applied Zoology and Environmental Biology, 9, 44-50.

Ajang, R. O., Ndome, C. B., Ekwu, A., Uttah, E. C., Iboh, C. I. (2013): Population dynamics and gillnets selectivity of *Chrysichthys nigrodigitatus* (Lacépčde 1803) in lower reaches of the Cross River Estuary, Nigeria. Ethiopian Journal of Environmental Studies and Management, 6,11, 31 - 40.

Asuquo, P. E. Enin, U. I., Job, B. E. (2012): Ontogenetic Variation in the Diet of *Chrysichthys nigrodigitatus* (Lacépčde 1803) in a Tropical Estuarine Ecosystem in Nigeria. Journal of Fisheries and Aquatic Sciences, 10, 1- 6.

Atobatele, O. E., Ugwumba, A. O. (2011): Condition factor and diet of *Chrysichthys nigrodigitatus* and *Chrysichthys auratus* (Silurifomes: Bagridea) from Aiba reservoir, Iwo, Nigeria. Revista de Biologia Tropical, 59, 3, 212-220.

Barau, R. (2000): Biodiversity of Estuarine Fish Fauna in West Africa. Naga, The ICLARM Quarterly, 23, 4, 77.

Beitl, C. M. (2012): Shifting policies, access, and the tragedy of enclosures in Ecuadorian mangrove fisheries: towards a political ecology of the commons. Journal of Political Ecology, 19, 94-113.

Beverton, R. J. H., Holt, S. J. (1966): Manual of Methods for Fish Stock Assessment: Part II Tables of Field Function, FAO Fisheries Biology Technical Paper, 38, 4, 67-69.

Bhattacharya, C. G. (1967): A Simple Method of Resolution of a Distribution into Gaussian Components. Biometrics, 23, 115-135.

Ekanem, E. M. (2010): Climate characteristics. In: Usoro, E. J., Akpan, P. A. (eds.), Akwa Ibom State: A geographical perspective. A special publication of the Department of Geography and Regional Planning, University of Uyo, Nigeria, pp. 91-101.

Ekanem, S. B. (1992): Studies on the Freshwater Pond Culture of *Chrysichthys nigrodigitatus* (Lacépčde 1803), Ph.D. Thesis University of Calabar, Nigeria.

Ekanem, S. B. (2000): Some reproductive aspects of *Chrysichthys nigrodigitatus* (Lacépčde 1803) from Cross River Nigeria. Naga, ICLARM Quarterly, 2, 2, 12-19.

Ekpo, I. E., Udoh, J. P. (2013): Age and Growth of *Chrysichthys auratus* in the Lower Cross River, Southeast Nigeria. International Journal of Ecosystem, 3, 4 , 64-71.

Etim, L., Brey, T. (1994): Growth, Productivity and Significance for Fishing of the bivalve *Egeria radiata* (Donacidae) of the Cross River Nigeria. Archives of Fisheries and Marine Resources, 42, 1, 63-74.

Etim, L., Enyenihi, U. K. (1991): Annual Cycle of Condition and Flood Season Spawning in *Galatea paradoxa* (Born 1777) from the Cross River in Nigeria. Tropical Freshwater Biology, 2, 234-248.

Etim, L., Uwe-Bassey, B. U., Brey, T. (1994): Population Dynamics of the West African Croaker *Pseudotolithus elongatus* in the Cross River Estuary, Nigeria. Marine Sciences, 58, 4, 315-321.

Ezenwa, B. (1981): A Study of the Reproductive Biology of the catfish *Chrysichthys nigrodigitatus* (Lacépčde 1803) in Nigeria. Ph.D. Thesis, University of Lagos, Lagos, Nigeria, 32pp.

Ezenwa, B. I., Ugwumba, O. A., Anyanwu, P. E. (1987): Cultivable Fish Seeds in Nigerian Coastal Waters. A research survey (second phase 1978-1985). Proceedings of the Fisheries Society of Nigeria (FISON), Port Harcourt, River State, 99-112.

Falaye, A. E. (1981): Brackish Water Culture of Catfish *Chrysichthys nigrodigitatus* (Lacépčde) Nigeria. M.Sc. Thesis University of Ibadan, Nigeria, 56pp.

Fischer, W., Bianchi, G. (1984): FAO Species Identification Sheets for Fishery Area, 34, 47pp.

Francis, A., Elewuo, U. (2012): Aspect of the Biology of trap caught *Chriysichthys nigradigitatus* (Lacépčde 1803) from the New Calabar River, Nigeria. International Journal of Fisheries and Aquaculture, 4, 6, 99-104.

Francis, A., Samuel, E. E. (2010): Fish Mortalities and Management Measures of Fish Species of the Andoni River, Niger Delta, Nigeria. Research Journal of Biological Sciences, 5, 2, 171-176.

Froese, R. (2004): Keep it simple: three indicators to deal with overfishing. Fish and Fisheries, 5, 86 - 91.

Froese, R. (2006): Cube law, condition factor and weight–length relationships: history, meta-analysis and recommendations. Journal of Applied Ichthyology, 22, 241–253.

Froese, R., Binohlan, C. (2000): Empirical relationships to estimate asymptotic length, length at first maturity and length at maximum yield per recruit in fishes, with a simple method to evaluate length frequency data. Journal of Fish Biology, 56, 758–773.

Froese, R., Pauly, D. (2015): FishBase. World Wide Web electronic publication. http://www.fishbase.org. Accessed on: 9th April, 2015.

Gayanilo, Jr. F. C., Pauly, D. (eds.) (1997): The FAO-ICLARM Stock Assessment Tools (FiSAT) Reference Manual, FAO Computerized Information, Series 8, (Fisheries), FAO, Rome. 262pp.

Gayanilo, F. C., Spare, P., Pauly, D. (2002): The FAO–ICLARM stock Assessment Tools (FISAT-11) User's guide . Computerized Information series FAO, Rome, Italy.

Gulland, J. A. (1971): The fish resources of the oceans. Fishing News, Farnham.

Jones, R., (1984). Assessing the Effects of Changes in Exploitation Pattern Using Length Composition Data (with notes on VPA and cohort analysis), FAO Fisheries Technical Paper, (256), (FAO), 118pp.

Lawal, M. O., Sangoleye, O. J., Seriki, B. M. (2010): Morphometry and diet of *Chrysichthys nigrodigitatus* (Lacépčde 1803) in Epe Lagoon, Nigeria. African Journal of Biotechnology, 9, 46, 7955-7960.

Mohamed, K. S. (1996): Estimates of Growth, Mortality and Stock of the India Squid (*Loligo duvauceli*) exploited off Mangalore, Southwest Coast of India. Bulletin of Marine Sciences, 58, 2, 393-403.

Moses, B. S. (1987): The Influence of Flood Regime on Fish Catch and Fish Communities of the Cross River Flood-Plain Ecosystem, Nigeria. Environmental Biology of Fishes, 18, 51-65.

Moses, B. S. (1997): Artisanal Fisheries of Southeastern Nigeria: Catch Rates, Population Dynamics, Potential Yields and Resources Management. Ph.D. Dissertation, University of Uyo, Uyo, 334pp.

Moses, B.S (2001): The Influence of Hydroregime on Catch Abundance and Recruitment of the Catfish, *Chrysichthys nigrodigitatus* (Bagridae) and the bonga, *Ethmalosa fimbriata* (Clupeidae) of Southeastern Nigeria's Inshore Waters. Environmental Biology of Fishes, 61, 99-109.

Nural Amin, S. M., Arshad, A, A., Siraj, S. S., Sidik, B. J. (2008): Population Structure, Growth Mortality and Yield per recruit of Segestid shrimp, *Acetes japonicus* (Decapoda: Sergestidae) from the Coastal Waters of Malacca, Peninsular Malaysia. Indian Journal of Marine Sciences, 38,(1), 57 – 68.

Nwosu, F. M., Wolfi, M. (2006): Population Dynamics of the Giant African River prawn *Macrobrachium vollenhovenii* Horklot 1957 (Crustacea, Palaemonidae) in the Cross River Estuary, Nigeria. West African Journal of Applied Ecology, 9, 12-19.

Nwosu, F. M., Holzohner, S., Enin, U. I. (2007): The Exploited Population of the Brackish River Prawn (*Macrobrachium macrobrachion* Horklots 1851) in the Cross River estuary, Nigeria. Scientia Marina, 71,1,115 – 1221.

Offem, B.O., Akebejo-Samsons, Y., Omoniyi, I. T. (2008): Diet, Size and Reproductive Biology of the silver catfish, *Chrysichthys nigrodigitaus Siluriformes*: Bagridae) in the Cross River, Nigeria. Revista de Biology_Tropical, 56, 4,166-178.

Ofori-Danson, P. K., de Graaf G. J., Vanderpuye, C. J. (2002): Population Parameter Estimated for *Chrysichthys auratus* and *Chrysichthys nigrodigitatus* (Pisces: Claroteidae) in Lake Volta, Ghana. Fisheries Research, 54, 2 , 267-277.

Olaosebikan, B. D., Raji, A. (1988): Field guide to Nigerian Freshwater Fisheries. Federal College of Freshwater Fisheries Technology. New Bussa, Niger State, Nigeria.106pp.

Pauly, D. (1980): A selection of simple methods for the assessment of tropical fish stocks. FAO Fish. Circ., No 729, Rome, FAO, 54pp.

Pauly, D. (1984): Fish population dynamics in tropical waters: A manual for use with programmable calculators. ICLARM, Studies and Reviews 8, 325pp.

Pauly, D. (1987): A Review of the ELEFAN system for Analysis of Length - Frequency Data in Fish and Aquatic Invertebrates. pp. 7-34. In: Pauly, D and G. G. Morgan (Eds). Length-Based Methods in Fisheries Research. ICLARM Conference Proceedings 13, 468.

Pauly, D. (1990): Length Converted Catch Curve and the Seasonal Growth of Fishes. Fishbyte, 8, 8, 33-38.

Pauly, D., David, N. (1981): ELEFAN-1 BASIC Program for the Objective Extraction of Growth Parameters from Length Frequency Data. Meereforsch, 28, 4, 205-211.

Pauly, D., Gaschutz, G. (1979): A Simple Method for Fitting Oscillating Length Growth Data, with a Program for Pocket Calculators. International Conservation and Exploration Sea Demersal Fish Comm. ICES 1979/G/24,26p.

Pauly D., Morgan, G. R. (1987): Length – Based Methods in Fisheries Research. International Centre for Living Aquatic Resources Management (ICLARM) Manilla, Conf. Proc., 13, 468.

Pauly, D., Munro, J. L. (1984): Once more on the comparison of growth in fish and invertebrates. Fishbyte, 2, 1 , 21-34.

Pauly, D., Soriano, M. L. (1986): Some Practical Extensions to Berverton and Holts Relative Yield-per-recruit Model. pp.491-496. In: Maclean, J. L., Dixon, L. B., Hovillo, L. V. (Editors), The First Asian Fisheries Forum, Asian Fisheries Society, Manila, Philippines, 496 pp.

Pauly, D., Ingles, J., Neal, R. (1984): Application of objective methods for the estimation of growth, mortality and recruitment related parameters of shrimp stocks from length frequency data (ELEFAN 1 and 2). pp. 220-234. In: Gulland, J. A. and Rothschild, B. J. (Editors), Penaeid shrimps- Their Biology and Management. Fishing News (Books) Surrrey.

Pomeroy, R. S., Pollnac, R. B., Predo, C. D., Katon, B. M. (1996). Impact evaluation of community-based coastal resource management projects in the Philippines. Naga, the ICLARM Quarterly, 19, 9 – 11.

Pope, J. G. (1972): An Investigation of the Accuracy of Virtual Population Analysis. Int. Comm. Northwest. Atlantic Fish Resources Bulletin, 9, 65-74.

Powell, D. G. (1979): Estimation of Mortality and Growth Parameters from the Length – frequency in Catch. Rapports et Procéss-Verbaux des Rēunions du Conseil International Exploration de Mer 175, 167 – 169.

Somers, I. F. (1988): On a seasonally oscillating growth function. Fishbyte, 2, 1 , 21-32.

Sparre, P. Venema, S. C. (1992): Introduction to Tropical Fish Stock Assessment. Part 1 Manual. FAO Fish. Tech. Paper 306 (1), 376p.

Taylor, C. C. (1958): Cod Growth and Temperature. Journal du Conseil International Exploration de Mer 23, 366-876.

Udoh, E. E. (1994): Studies on the occurrences, distribution, growth, mortality and potential yield of catfish of the genus *Chrysichthys* in the Cross River system, Nigeria. M.Sc. Thesis, University of Uyo, Uyo, pp. 371-384.

von Bertalanffy, L .(1938): A Quantitative Theory of Organic Growth. Human Biology, 10, 181-213.

Wetherall, J. A. (1986): A New method for estimating growth and Mortality parameters from length frequency data. Fishbyte, 4, 12-14.

Wolff, M. (1989): A proposed method for the standardization of the selection of class intervals for length frequency analysis. Fishbyte 7, 1, 5.

Yamamoto, T. (1995): Development of a community-based fishery management system in Japan. Marine Resource Economics, 10, 21 – 34.