Journal of Agriculture, Environmental Resource and
Management
ISSN2245-1800(paper) ISSN 2245-2943(online)
4(2)402-422-; Dec.2019

www.saerem.com

COHORT ANALYSIS OF *Chrysichthys nigrodigitatus:* BAGRIDAE (LACEPEDE, 1803) IN LOWER CROSS RIVER, SOUTHEASTERN NIGERIA

[1]John E. Ukpatu and [2]Okon M. Udoidiong

[1]Department of Fisheries and Aquaculture, Akwa Ibom State University,Faculty of Agriculture

Obio Akpa Campus, Oruk Anam, Nigeria

[2]Department of Fisheries and Aquatic Environmental Management, Faculty of Agriculture, University of Uyo, Uyo, Nigeria.

E-mail: etitigwun@yahoo.com

ABSTRACT

A cohort analysis was carried out on an annual cycle (November 2015- October, 2016) length frequency data of ***Chrysichthys nigrodigitatus (Lacepede, 1803)*** *(silver catfish) from the Lower Cross River, Nigeria. The study was necessitated to generate growth parameters that would be used for conservation and sustainable management of the stock in the Nigerian Aquatic ecosystem. The modal progression analysis using Bhattacharya's method incorporated in FiSAT 11 (FAO-ICLARM Stock Assessment Tools) software was used to analyze the 12 months' data. A total of 6,846 specimens of* ***Chrysichthys nigrodigitatus*** *were used for the cohort analysis. Bhattacharya's Modal Class Progression Analyses depicts three distinct peaks representing age groups 1+ to 3+. These three cohorts were decomposed from the composite length frequency samples. The residual of the Gulland and Holt plot, from the length at age derived from the linking of cohort means gave the value of the amplitude of seasonal growth oscillation C as 0.75 and the Winter Point (WP) as 0.5 or 1st July. The amplitude of seasonal growth oscillation and the winter point derived from the cohort analysis are of paramount importance in the stock assessment and ultimately management of the resource as they revealed the strength of growth oscillation along with the period of slowest growth which can be inferred as the most susceptible period for the stock. Overexploitation of the stock during the vulnerable time can lead to the collapse of fishery. Management effort should be directed towards controlling fishing pressure on the fish stock in the water body. Therefore, exploitation should be minimized in the period (June - September) for resource sustainability of the stock in the Lower Cross River system of Nigeria.*

Key words: ***Chrysichthys nigrodigitatus,*** Cohort analysis**,** Bhattacharya's method, amplitude of seasonal growth oscillation (C), the winter point (WP), susceptible period, Lower Cross River, Nigeria

INTRODUCTION

A cohort is a batch of all fish of approximately the same age and belonging to the same stock. It is assumed that a cohort of all fish has the same age at a given time thereby attaining recruitment age at the same time (Beverton and Holt, 1957). The average length of a cohort is therefore used to describe growth and recruitment pattern. For several decades, assessing tropical fish stocks has been hindered by the difficulty of obtaining reliable estimates of growth parameters. However, the development of length-frequency analysis by Pauly and Morgan (1982) has represented substantial progress in the aspects of Population Dynamics and estimation of growth parameters. Beside the detailed analysis of length-frequency data, mark-recapture studies, direct observation of captive fish and Progression Analysis (MPA) are methods applied routinely to draw inferences on growth of tropical fishes (Pauly, 1987). The Modal Progression Analysis (MPA) involves several length-frequency samples plotted sequentially, where the apparent shift of modes is used to infer growth. MPA refers to a methodology that infers growth from the apparent shift of the modes or means in a time series of length-frequency samples, and involves three stages: (i) decomposition of composite distributions into their components to identify means, (ii) subjective identification and linking of the means perceived to belong to the same cohorts, and (iii) using the growth increments and length-at-age (relative) data resulting from the linking to estimate growth parameters. The critical issue is the linking of means perceived to belong to the same cohort. The growth parameters estimates are essential tools in the management of exploited fishery resource. In FiSAT II, two methods are provided to decompose composite length-frequency distribution.

Bhattacharya's method (Bhattacharya, 1967) is useful for splitting a composite distribution into separate normal distributions NORMSEP (Normal Separation) (Pauly, 1987; Gayanilo, *et al;* 2002) when there are several fish cohorts (age groups; age-years classes) in the same sample. The silver catfish, *Chrysichthys nigrodigitatus* (Lacepede, 1803) is a highly cherished freshwater fish species among the dominant commercial catch exploited in the major rivers of Africa. In Nigeria, Silver catfish, *Chrysichthys nigrodigitatus* Family: Bagridae), is an important fish species occurring in estuarine water bodies (Goli *et al.* 2019). According to Eyo *et al.* (2013), the fish is highly appreciated by consumers for its taste and meat quality, mostly in smoked form, and is used in traditional and continental dishes.

The fish is caught with drag net, hook and line, bottom-set gillnet and bottom-set traps because of its bottom dwelling habit. There is acute reduction in the population of this species in Nigeria because of the over-exploitative nature of indigenous fishers and the degradation of the habitats of this species. The *Chrysichthys nigrodigitatus* fishery of the Lower Cross River, Nigeria is exploited at a commercial artisanal manner, being characterized by the use of ancient and modern gear. Also, the silver catfish is a target species of the artisanal fishery in Nigeria and are popularly sought for as source of food and income. No information is available on the cohort analysis of *Chrysichthys nigrodigitatus* in the Cross River system. Therefore, a cohort analysis of the length-frequency data of this species was done in order to generate growth parameters that would be used for conservation and sustainable management of the stock in the Lower Cross River of Nigeria.

Materials and Methods

Description of the Study Area

The study was conducted within approximately 40km of Lower Cross River (from Itu) located in the South-Eastern part of Nigeria (4°25′ – 7°01′ N; 7°15′ – 9°3′ E, Fig. 1). This stretch of the river sampled lies within the rainforest zone of southern Nigeria, where the weather is wet for many months of the year (April to mid November), with an annual rainfall of up to 2500 mm (Ekanem, 2010). The mean annual temperature for the area is about 27°C, with the mean annual maximum approximately 30°C recorded in April or May, and a minimum of about 22°C recorded in January, giving a narrow range of about 8°C. This narrow range is attributed to the nearness of the area to the sea, which tends to prevent extremes of temperature fluctuations. The dominant factor influencing the climate in the area is the movement of the Inter-Tropical Front which gives rise to two seasons: the wet and dry seasons. The dry season, during which the cold, dry and dusty harmattan winds occur, lasts for only a short period, beginning in mid-November and ending in March.

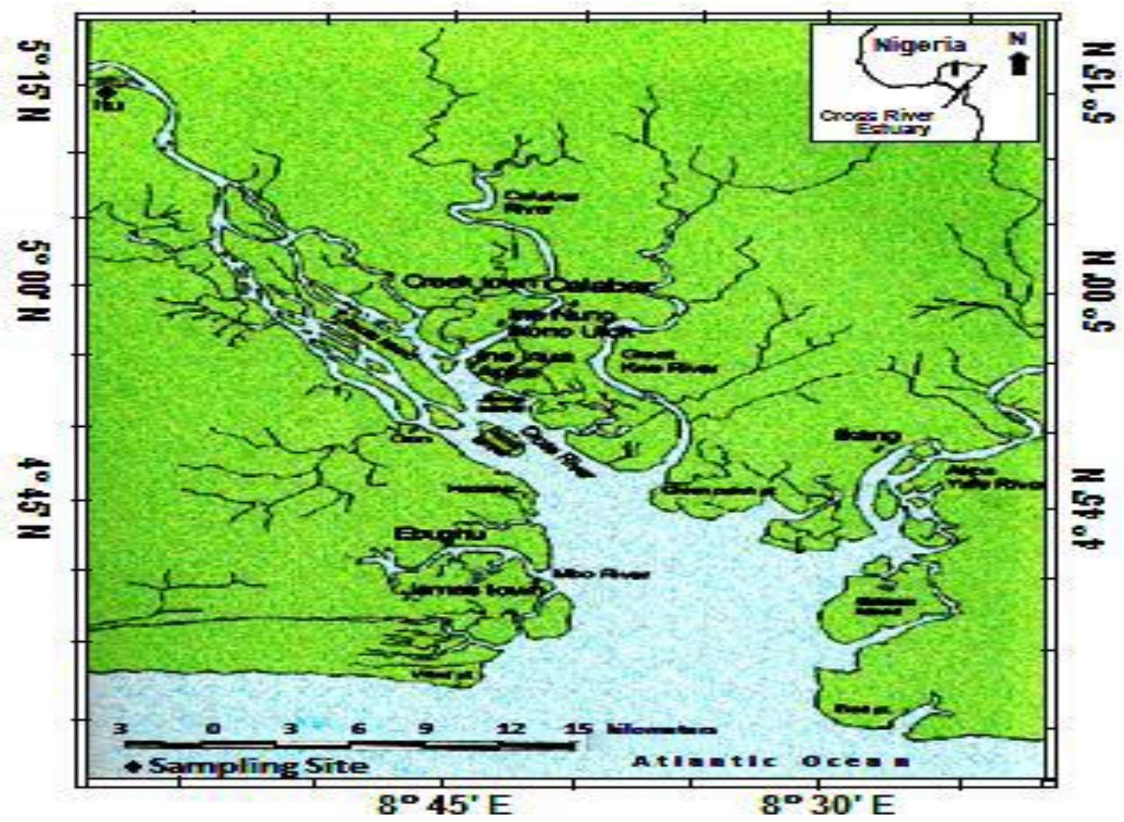

Fig. 1: Map of the Cross River, Southeastern Nigeria showing Itu (Sampling area)

Data Collection

The fish is caught with bottom-set gillnet (22-76mm stretch mesh size) and bottom-set traps because of the bottom dwelling habits (Offem, *et al.,* 2008). A total of 6846 samples (combined sex) were randomly measured from the artisanal fishers using wooden canoes at Itu beach near Calabar. The field sampling period was from October 2015 to November 2016 covering the dry and the wet seasons (12 months sampling). Total length (TL) from the orbital notch to the tip of the caudal fin of individual specimen was recorded with a measuring board. These measurements were made to the nearest 0.01 centimeter (cm) accuracy. Fish samples were identified using FAO species identification sheet (Fisher and Bianchi, 1982 and Olaosebikan and Raji, 1988).

Cohort analysis

Bhattacharya's (1967) method in FiSAT (Gayanilo *et al.,* 1997 and 2002) software was used in the decomposition of composite distribution of the length-frequency data into cohorts. This method splits composite distribution into separate normal distributions, each representing a cohort of *Chrysichthys nigrodigitatus* from the overall distribution in the sample starting from the left side of the total distribution. The process starts with the selection of the sample to analyze and identification of the first and last data points that identify a group (cohort). Once the first normal distribution has been determined, it is removed from the total distribution. The same procedure is repeated as long as it is possible to separate normal distribution from the total distribution. The process is continued until all groups are identified.

The separation of length-frequency samples into their components is an iterative process until every identified component is subtracted from the remainder of the sample using the Gaussian function. The results were saved as a mean and standard deviation file which was later linked to form growth increments or length-at-age (relative) data. Age (length) is denoted 'relative' because it is not known. Gulland and Holt (1959) plot also in FiSAT based on preliminary estimates of von Bertalanffy Growth Function (VBGF) parameters (asymptotic length ($L\infty$) and growth coefficient (K)) was used for growth increments estimation, whereas the residual of the plot was used for inference on seasonality of growth.

RESULTS

Length frequency distribution

The length frequency distribution of *Chrysichthys nigrodigitatus* from the Lower Cross River was binomial and prominent in Mid Length class of 44.5 and 54.5 (Fig. 1)

Cohort identification

Monthly length-frequency annual cycle data (November 2015-October 2016) of *Chrysichthys nigrodigitatus* are presented in Table 1. The 12 months samples were decomposed into cohorts and the number of cohorts per sample ranged from 1 to 3. Three distinct peaks were separated by Bhattacharya's using length frequency data (Figure 2). Mean lengths of the cohort age group were 19.2, 36.3 and 57.5 cm for age 1+ to 3+ respectively. Age group 3+ dominated followed by age group 2+ while age group 1+ was the least. Samples that had only one cohort were three namely No. 10 (August), No. 12 (October) and No. 2 (December). Two cohort samples were represented in No. 9 (July), No. 11 (September) No. 7 (May) and No. 3 (January) (see Table 1). Three samples No. 4 (February), No. 6 (April) and No. 8 (June) had three cohorts. Figures 2-4 are examples of the decomposed samples. The decomposition results (cohorts mean lengths) are in Table 2 and these were used to plot growth increments representing the progression through time of the mean length of the cohort as shown in Fig 5a, while Fig. 5b shows the linking of these different cohorts that form incremental data for use in the Gulland and Holt plot. The length frequency analysis applied in two seasons (wet and dry) allowed the recognition of three main cohorts: one of them appearing before the fishing season in January, the second at the beginning of rainy season in April and the last at the beginning of the dry season in November. Three cohorts were identified in Fig. 5b.

The Gulland and Holt plot estimated growth parameters from growth increments based on the von Bertallanffy growth function (VBGF), in which growth rate declined linearly with increase in length reaching zero at $L\infty$. The $L\infty$ and K are preliminary estimates of growth parameters and these were (120.23cm) and 1.50 yr^1 respectively. The residuals of the plot were used for inference on seasonality of growth and the seasonal growth oscillation or amplitude of growth oscillation (C) estimated was 0.75 while the Winter point was 0.5 or 1st July.

Age and growth

The application of *Bhattacharya's* method through FiSAT determined model lengths of *Chrysichthys nigrodigitatus* from 26.15cm in August to 82.23cm in May with satisfactory separation index (Table 3). Two dominant modal groups were identified, reflecting different annual cohorts. Therefore, the monthly size frequency distributions suggested that the population consisted of three age groups (cohorts) with modes at approximately 15cm, 45cm and $\geq$ 109cm total length. Thus, the sizes attained by *Chrysichthys nigrodigitatus* were 21.6cm, 47.6cm, 76.4cm, 97.0cm, 109.8cm and 119.1 cm at the end of 2, 4, 6, 8, 10 and 12 months of age, respectively. The absolute increase is presented in Fig. 7. Table 3 shows the length and age relationships of the estimated Bertalanffy's model using growth parameters $L\infty$ = 120.23cm, K = 1.50yr^{-1} and t_o = 0. The total lengths correspond to the relative age since the value of t_o = 0. Therefore, the actual age could not be calculated based on length data only.

Discussion

Knowing the age of a fish provides a clue to its longevity, age at first maturity, age of recruitment, and growth (Goli *et al.* 2019) **.** When organisms cannot be aged individually, length-frequency data can be used to produce seasonalized length-converted catch curves which would be equal or similar to age-structured catch curves. Sparre and Venema (1992) showed that the growth of a cohort of fish and crustaceans conform to the von Bertallanffy growth function, hence justifying the use of length frequency analysis tools incorporated in FiSAT 11 for cohort analysis.

Length –frequency data is a source of obtaining basic information required to assess and manage exploited fish and aquatic invertebrate stocks (Pauly,1987; Pauly and Morgan, 1989). It is most suitable in the tropics than in the temperate region because of conspicuous growth marks on the temperate species. Modal progression analysis (MPA) infers growth from apparent shift of the modes or means in the time series of length frequency samples. Out of the 12 samples decomposed, three cohorts were identified by the linking of means over time. The component distributions in the mixture decomposed into component structures revealed normal distribution or natural selection of cohorts (age groups). Bhattacharya (1967) reports that up to 10 age groups can be identified per sampling period, but separation is generally unreliable when the separation index (SI) is below 2. Thus, the SI of 2.01 and above indicates the reliability of the separation process. Also the standard deviations increased with lengths. This implies that growth rate declines linearly with increase in length, reaching zero at $L\infty$, and that the species grows according to the von Bertallanffy function (Fig. 5). The estimate of longevity of 2 years for the species indicates that the species are short lived organisms.

The Gulland and Holt plot also showed that growth rate declines linearly as length increased reaching zero at $L\infty$ (Fig 6). The residual of the Gulland and Holt plot from the length at age derived from the linking of means, gave the value of the amplitude of growth oscillation C = 0.75. Growth oscillation is influenced by temperature fluctuation. This is also in agreement with the assertion by Pauly (1984) that aquatic animals are well known to exhibit the phenomenon of seasonal growth which is especially linked to the seasonal oscillation of temperature. Moreover, Pauly and Ingles (1981) and Pauly (1989) showed that virtually all natural fish stocks, including those in tropical waters, display seasonally oscillating growth. Pauly

(1982, 1987) demonstrated a direct relationship between the highest and lowest mean monthly temperature to which fish are exposed to during one year , suggesting that growth oscillation is mainly due to temperature changes. The mean annual temperature difference of 8^{o}C in the Lower Cross River (Etim and Brey,1994) could account for the value of C estimated for *Chrysichthys nigrodigitatus* in this study to be (0.75). The amplitude of oscillation indicates that growth does strongly decrease in July for *Chrysichthys nigrodigitatus* as the winter point (WP) estimated was 0.5 or 1st July. The VBGF has a component that qualifies the seasonality of growth and it is advantageous because it deals with length – growth oscillation and so avoids the problem of shrinkage which occurs in growth. Growth oscillation C in the VBGF is the empirical constant that indicates the amplitude of growth oscillation, while the other constant, Winter Point (WP) indicates the time of the year when growth is slowest (von Bertalanffy, 1938).

Further, the sizes attained by *Chrysichthys nigrodigitatus* of the Lower Cross River, Nigeria indicate that the body size is a function of age. The size is an exponential function of age. Fish increases in length as they grow older, but their growth rate (the increment in length per unit time), decreases when they get older, approaching zero when they become very old (Fig 6). The differences in the growth parameters could be explained with the postulation of Sparre and Venema (1992) that growth parameters of a particular species may take different values in different parts of its range.

The largest specimen of *Chrysichthys nigrodigitatus* recorded in this study measured 119.1cm. This contrasts with the 30.0cm sample recorded by Reed *et al*., (1967) in Northern Nigeria. The reasons for this smaller size may be attributed to location, food abundance, genetic make up and environmental factors as asserted by Moses (1988) that differences in size composition of fish species from different water bodies could be attributed to genetic make-up, availability of food and other environmental factors in the water. King (1996) also noted that maximum size attainable in fishes is generally location specific, stating however, that this could also be due to noise from outboard engines and industrial activities.

The minimum length of 15.0cm (TL) and maximum length of 119.1 cm TL recorded in this study are at variance with 14.0cm (min) and 91.90cm (max) recorded by Abowei and Hart (2007) for Nun River, Niger Delta, Nigeria. This smaller size reported by Abowei and Hart (2007) may imply that fishing pressure is severe at the Nun River than the Lower Cross River. It could also be that the mesh size used in the Nun River does not allow juveniles to escape, resulting in recruitment over-exploitation, which is not healthy for the sustainability of the fishery. It also shows that greater mortality of the available stock from the Nun River was caused by over exploitation, while the minimum and the maximum lengths (or probability of capture in the Lower Cross River) indicate the promising nature of the fishery to make significant contribution to national food security and socio-economic development.

Moreover, the occurrence of more juveniles in the months of April – July (Table 1) (peak of rains) varied with the report from Reed *et al* (1967) who had recorded the abundance of juveniles in January and February for *Chrysichthys nigrodigitatus* from Northern Nigeria. However, the occurrence of more juveniles in the months of April – July is in accord with the report of Offem *et al* (2008) who recorded the breeding period of this species in the Cross River, Nigeria between April and August. The linear decline in growth with increase in length, reaching zero at length infinity ($L\infty$), is in accord with the report of Abowei and Hart (2007) which noted that growth rate of *Chrysichthys nigrodigitatus* from Nun River, Niger Delta, decreased progressively with age.

Conclusion

Modal progression analysis (MPA) was applied to decompose distribution into their components called cohorts. The cohort analysis of *Chrysichthys nigrodigitatus* produced three cohorts or age groups. The paramount parameters, the amplitude of seasonal growth oscillation and the winter point were derived from the cohort analysis. These represent the prominent factors in the stock assessment and ultimate management of *Chrysichthys nigrodigitatus* resource of the Lower Cross River, Nigeria. These parameters revealed the strength of growth oscillation along with the period of slowest growth which can be inferred as the most susceptible period for the stock. Thus, fishing mortality should be minimized in this period, April - August for resource sustainability. Incidentally, this period coincides with the period of migration of the species from the estuary up the Cross River for spawning in the numerous wetlands and headwaters of this river.

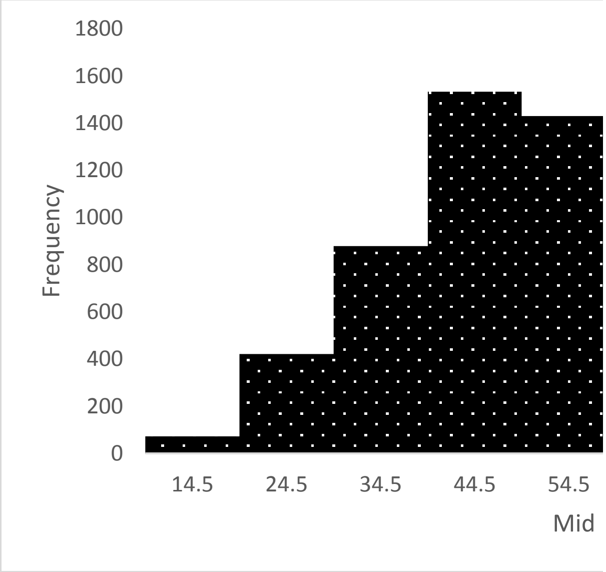

Fig1. Length-frequency distribution of *Chrysicthys nigrodigitatus* in the Lower Cross River, Nigeria

Table 1. **Length – frequency data of *Chrysichthys nigrodigitatus* from lower Cross River, Nigeria between November 2011-0ctober 2012; n = 6,846, *Size class=10cm***

Mid length (ML)	**No. 1 2011 Nov 14/11/2015**	**No. 2 Dec. 15/12/2015**	**No. 3 2012 Jan. 13/1/2016**	**No. 4 Feb. 16/2/2016**	**No. 5 Mar 12/3/2016**	**No. 6 Apr. 14/4/2016**	**No. 7 May 17/5/2016**	**No. 8 June 13/6/2016**	**No. 9 Jul. 15/7/2016**	**No. 10 Aug. 16/8/2016**	**No. 11 Sep. 14/9/2016**	**No. 12 Oct. 16/10/2016**
14.5						2	20	14	24	13		
24.5	26	2	4	3	27	12	76	148	88	31		4
34.5	116	14	24	8	116	14	148	222	122	20	51	24
44.5	201	181	144	17	211	18	135	248	148	128	73	30
54.5	108	188	181	133	148	188	44	117	118	45	46	114
64.5	140	178	18	118	122	149	35	187	113	56	35	19
74.5	110	111	3	122	59	49	10	30	20	54	23	10
84.5	95	71	2	92	30	38	9	17	4	23	9	8
94.5	38	3	1	41	4	2	7	14	4	9		
104.5	2	1		4				0	1			
114.5	0							1				
SUM	**836**	**586**	**559**	**588**	**828**	**472**	**484**	**997**	**632**	**379**	**276**	**209**

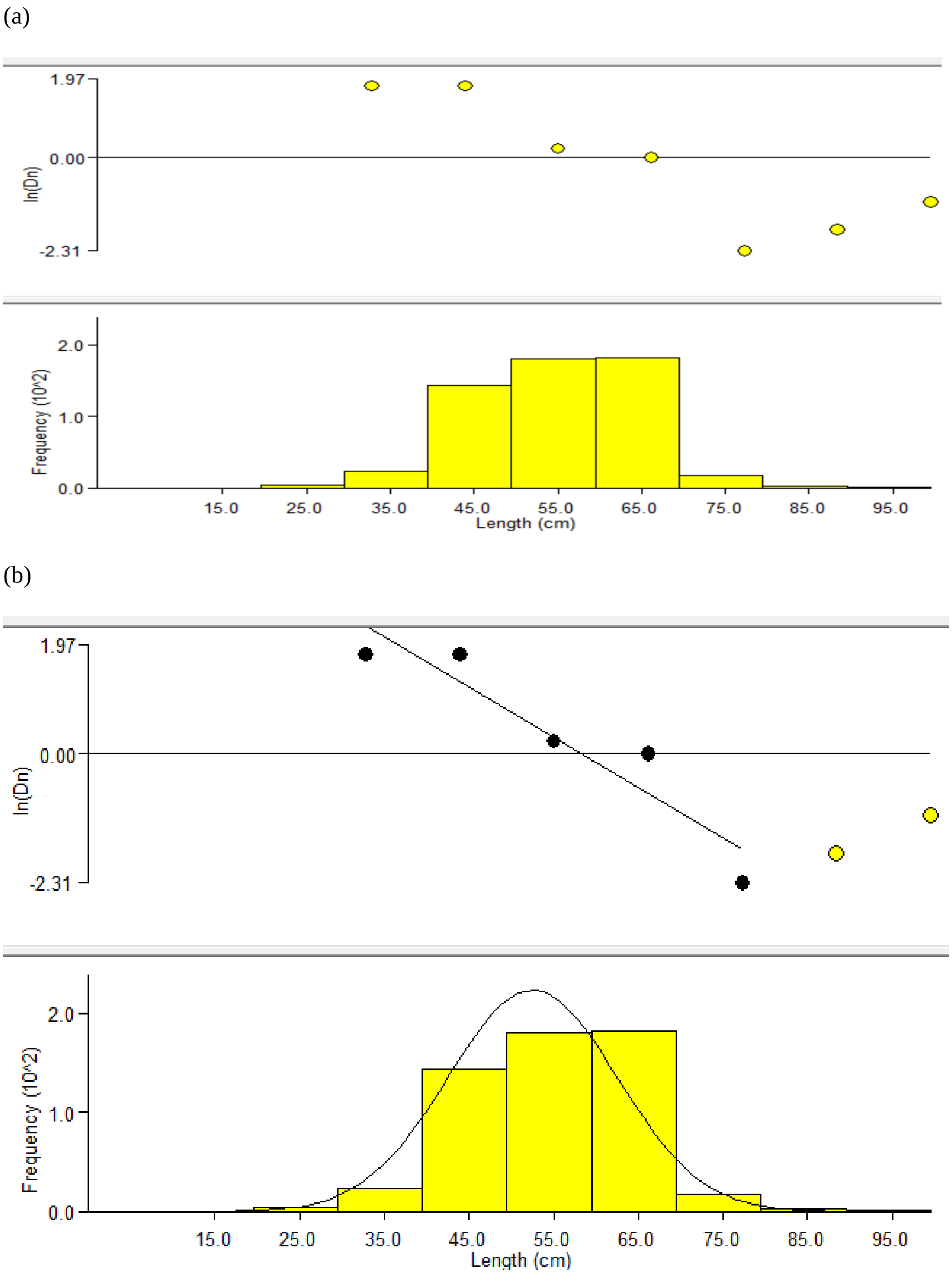

Figure 2 a-b. One cohort Bhattacharya's Decomposition of composite Distribution of *Chrysichthys nigrodigitatus* for sample No. 2. (a) The upper part of the figure is the log-plot of the slopes between successive frequencies while the lower part is the resulting distribution. (b) Upper part of the figure shows the first and the last data points that identified a group, lower part of figure shows the decomposed distribution into its composite cohort

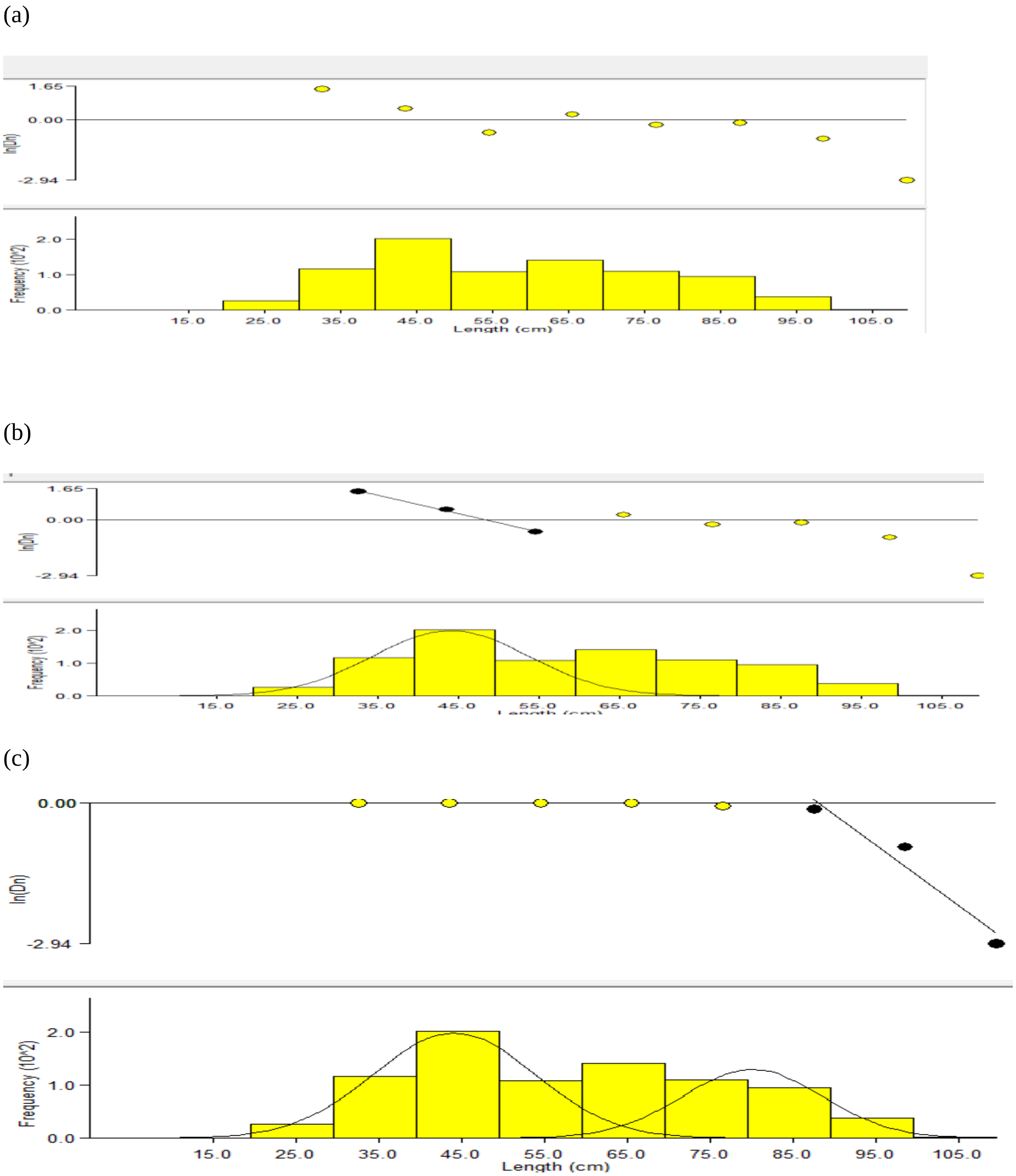

Figure 3a-c. Two cohort Bhattacharya's Decomposition of composite Distribution of *Chrysichthys nigrodigitatus* for sample No. 9. (a) The upper part of the figure is the log-plot of the slopes between successive frequencies while the lower part is the resulting distribution. (b) Upper part of the figure shows the first and the last data points that identified a group, lower part of figure shows the decomposed distribution into its composite cohort. (c) Upper part of the figure shows the first and last data points of second cohort identified, lower part of the figure shows the decomposed distribution into its composite cohorts.

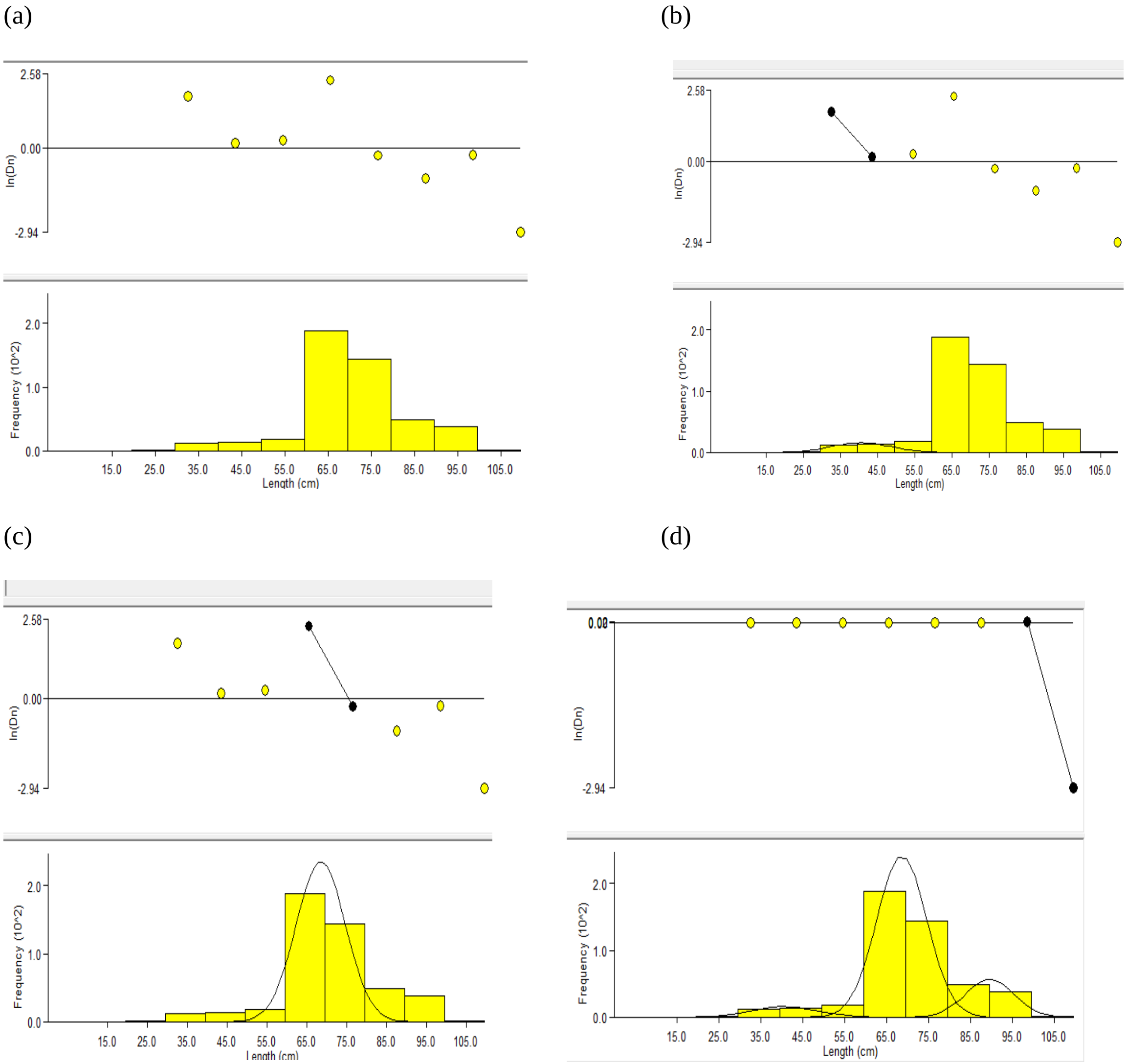

Figure 4a-d: Three cohort Bhattacharya's Decomposition of composite Distribution of *Chrysichthys nigrodigitatus* for sample No. 4. (a) The upper part of the figure is the log-plot of the slopes between successive frequencies while the lower part is the resulting distribution. (b) Upper part of the figure shows the first and the last data points that identified a group, lower part of figure shows the decomposed distribution into its composite cohort.(c) Upper part of the figure shows the first and last data points of second cohort identified, lower part of the figure shows the decomposed distribution into its composite cohorts and (d) Upper part of the figure shows the first and last points of the third cohort identified, lower part of the figure shows the decomposed distribution into its composite cohorts.

(a)

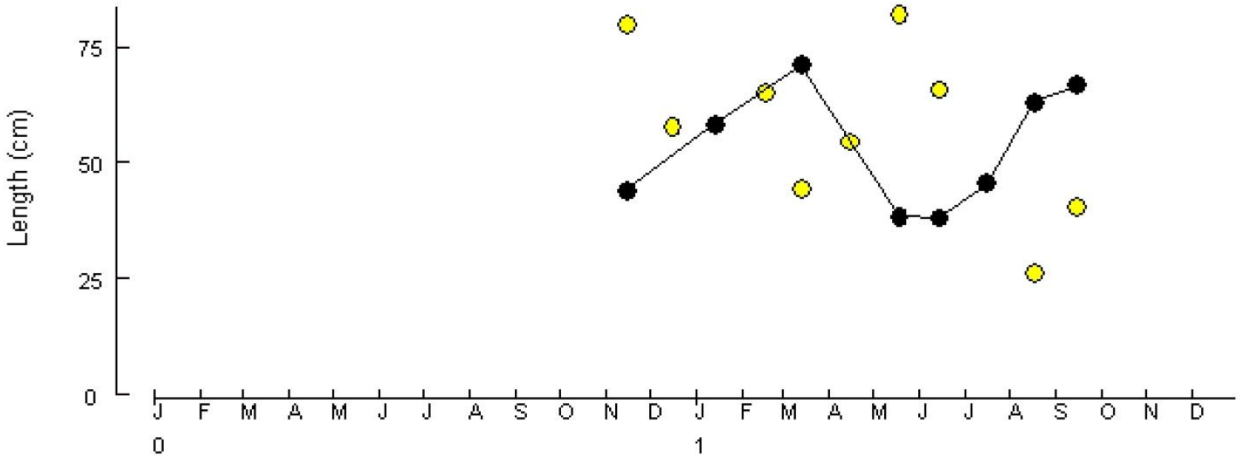

Figure 5. (a) Mean lengths of different cohorts linked over time representing the growth of the cohorts of *Chrysichthys nigrodigitatus* from the Lower Cross River, Nigeria.

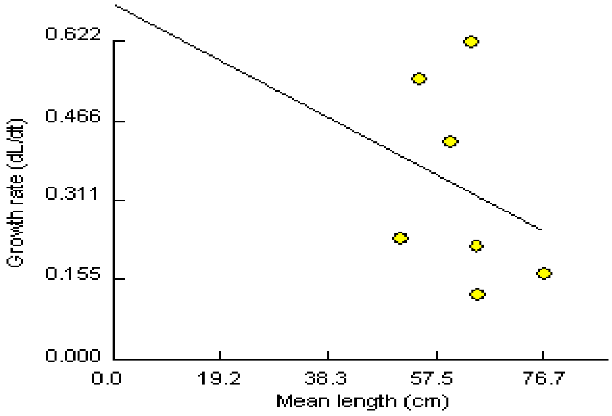

Figure 6. Plot of growth rate against mean length which declines linearly as length increases, reaching zero at L∞ for *Chrysichthys nigrodigitatus*

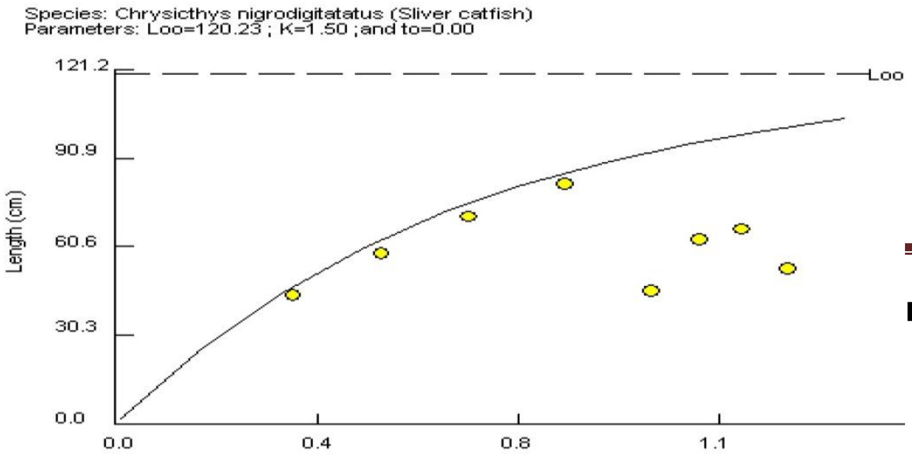

Figure 7. Munro's plot of length at age data

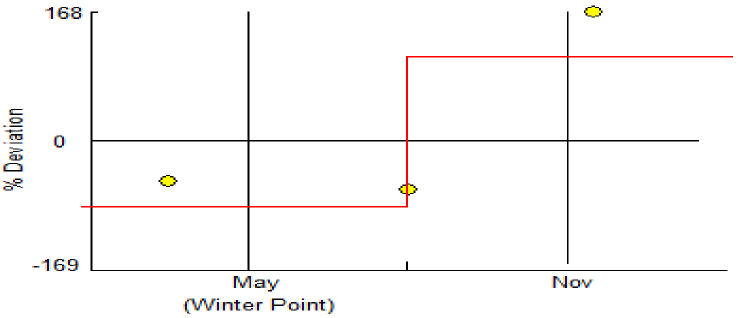

Figure 8. Residuals, re-expressed in percentage and plotted against the mid range of time for *Chrysichthys nigrodigitatus*

Table 2: Bhattacharya's decomposition result for *Chrysichthys nigrodigitatus*

OBSERVATION	DAY	MONTH	YEAR	MEAN	STANDARD DEVIATION
1	14	11	2015	243.99	9.72000
2	14	11	2015	80.06	6.43000
3	15	12	2115	57.67	10.8300
4	13	1	2016	58.29	12.02000
5	16	2	2016	65.31	14.97000
6	12	3	2016	44.32	9.90000
7	12	3	2016	17.08	12.69000
8	14	4	2016	54.50	42.17000
9	17	5	2016	38.42	11.84000
10	17	5	2016	82.23	17.45000
11	13	6	2016	38.03	9.43000
12	13	6	2016	65.79	10.33000
13	16	8	2016	26.15	8.75000
14	16	8	2016	63.11	17.4200
15	14	9	2016	40.59	5.53204
16	14	9	2016	66.81	13.84504
17	16	10	2016	53.21	11.76923
18	15	7	2016	45.54	15.51677

Table 3. Identified age groups from the Length-Frequency analysis of *C. nigrodigitatus* during the monthly sampling, using Bhattacharya's method

Age Groups	Appox Mean	Computed Mean	S.D	Population	Separation Index (SI)
Nov 1	43.99	43.99	9.720	484.00	-
2	80.06	80.06	8.430	272.00	3.970
Dec 1	57.67	57.67	10.830	679.00	-
Jan 1	58.29	58.29	12.020	654.00	-
Feb 1	65.31	65.31	14.970	520.00	-
Mar 1	44.32	44.32	9.900	511.00	-
2	71.08	71.08	12.690	397.00	2.370
Apr 1	54.50	54.50	14.170	474.00	-
May 1	38.42	38.42	11.840	461.00	-
2	**82.23**	82.23	17.450	40.00	2.990
Jun 1	38.03	38.03	9.430	685.00	-
2	65.79	65.79	10.330	303.00	2810
July 1	43.29	43.29	14.840	571.00	-
Aug 1	**26.15**	26.15	8.750	71.00	-
2	63.11	63.11	17.240	242.00	2.820
Sep 1	43.14	41.14	10.070	191.00	-
2	68.58	68.58	15.240	147.00	2.010
Oct 1	40.92	40.92	7.980	66.00	-

References

Abowei, J. F. and Hart, A. I. (12007). Size composition, age, growth mortality and exploitation rate of *Chrysichthys nigroditatus* from Nun River, Niger Delta, Nigeria. *African Journal of Applied Zoology and Environmental Biology*, 9:44-50.

Beverton, R. J. H. and Holt, S. J. (1957). *On the Dynamics of Exploited Fish Population*. U. K. Department of Agriculture, Fisheries and *Food Fisheries Investigations Series* II, Vol. xix, 533pp.

Bhattacharya, C. G. (1967). A Simple Method of Resolution of a Distribution into Gaussian Components. *Biometrics*, 23: 1145-135.

Ekanem, E. M. (2010). Climate characteristics. *In:* (Usoro, E. J. and P. A. Akpan, 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.

Etim, L and Brey T. (1994). Growth, Productivity and Significance for Fishing of the bivalve *Egeria radiata* (Donacidae) of the Cross river Nigeria. Arch . *Fish. Mar. Res.*42(1): 63-74.

Eyo, V. O., Ekanem, A. P., Eni, G. and Edet, A. P. 2013. Relationship between Fecundity and Biometric indices of the silver catfish *Chr ysichthys nigrodigitatus*(Lacepede) in the Cross River Estuary, Nigeria. *Croatian Journal of Fisheries* 71:131-135

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

Gayanilo Jr. F. C. Sparre, P. and Pauly, D. (1997). The FAO-ICLARM Stock Assessment Tools (FISAT) reference manual, FAO Computerized Information. Series 8, (Fisheries), (FAO. Rome), 1997. 262pp.

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

Goli Bi B. E. P., Kamelan T. M. , Berté S. , Kien K. B. ,Ndiaye S. and Kouamelan E. P. (2019). The first data on the population parameters of the main fish species in man-made Lake Buyo (River Sassandra, Côte d'Ivoire). *Egyptian Journal of Aquatic Biology & Fisheries Zoology Department, Faculty of Science,* Ain Shams University, Cairo, Egypt. ISSN 1110 – 6131 Vol. 23(2): 585 - 597 (2019)

Gulland, J. A. and Holt, S. J. (1959) .Estimation of Growth Parameters for Data at Unequal Time Intervals. *J. Cons. CIEM*, 25:47-49.

King, R. P. (1996). Population dynamics of the mud skipper, *Periophthalmus barbarus* (Gobidae) in the estuarine swamps of Cross River, Nigeria. *Journal of Aquatic Sciences*, 11:31-34).

Moses, B. S. (1988). Growth, mortality and potential yield of Bonga fish, *Ethmalusa fimbriata* (Bowdich 1825) of the Nigerian insluore waters, Fisheries Research 6: 233-247.

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

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

Pauly, D. (1982). Fish population dynamics in tropical waters: a manual for use with programmable calculators. ICLARM, Studies and Reviews 8:325.

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

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

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

Pauly, D. and Ingles, J. (1981). Aspects of the growth and natural mortality of exploited coral fishes. *In:* Proceedings of the 4th International Coral Reef system, Manila, Philippines. Gomez E. C. E., Birkeland, R. W., Buddemeyer, R. E., Johannes, J. A., Marsh Jr. and R. T. T. Suda (eds): 1:89-98.

Pauly D, and 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. (1989). Food Consumption by Temperate Fish Populations: Some Generalizations. *Journal of Fish Biology, 35:11-20*

Reed, W. Burchard, T., Hopkin, A. J., Jenness, J. and Yaro, I. (1967). Fish and fisheries of Northern Nigeria. Ministry of Agriculture, Northern Nigeria, 226p.

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

von Bertalanffy, I., (1938). A Quantitative Theory of Organic Growth. *Hum. Biol*. 10: 181-213.

COHORT ANALYSIS OF *Chrysichthys nigrodigitatus:* BAGRIDAE (LACEPEDE, 1803) IN LOWER CROSS RIVER, SOUTHEASTERN NIGERIA