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Age, growth and mortality of *Chrysichthyes nigrodigitatus* (Lacépède, 1803) from Lake Akata, Benue State, Nigeria

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ABSTRACT

Age, growth, mortality and exploitation rate of *C. nigrodigitatus* from Lake Akata were determined over a period of 12 months (May2012-April 2013) using the fisheries dependent method. Estimation of age and growth were obtained using Bhattacharya's length frequency distribution assortment method with determination of the von Bertalanfy growth parameters. Length frequency distribution generated three age groups: 1+ years (mean ± SD standard length: 9.32± 6.9cm), 2+ years (25.01±5.25cm) and 3+ years (34.9± 3.56cm). The mean standard length (cm) and weight (g) of *C. nigrodigitatus* were 20.66±0.30cm and 211.7±6.4g, respectively. *C. nigrodigitatus* (K=1.62±0.01) was in good condition with males (1.50±0.02) and females (1.73±0.02) differing significantly in condition while seasonal values were not different: dry season (1.61±0.02) and wet season (1.62±0.02). The growth pattern in both sexes of *C. nigrodigitatus* was isometric (Log W= 2.9569*LogL – 1.7515). The predictive von Bertalanffy growth parameter was $L_t = 37.28$ [1- exp (-0.530 (t –0.85)]. The growth performance index (Φ^1) was 2.87 and total mortality (Z) as estimated from FISAT II using Hoenig's Model I was 1.432/year. Instantaneous fishing mortality (F) was 0.379/year while instantaneous natural mortality was 1.053 /year with an exploitation rate of 0.266 suggesting that exploitation is not excessive.

Key words: Condition, length frequency, mortality, exploitation rate, season

INTRODUCTION

The Claroteidae are a family of catfish found in Africa of which *C. nigrodigitatus* is a prominent member (Nelson, 2006). Family Claroteidae was carved out of the traditional Bagridae to reflect a monophyletic group of African catfishes (Berra, 2001). *C. nigrodigitatus* are important ichthyofaunal components of tropical fresh water ecosystems. They are important ecologically and commercially and are widely exploited. They are abundant and inexpensive, and easily affordable by the low income segment of the population. Distribution includes the Nile River basin and most of west and central Africa south to the tropic of Capricorn, and the East African lakes. Families include *Auchenoglanis, Chrysichthyes, Leptoglanis*, and *Parauchenoglanis*. *C. nigrodigitatus is* found in Africa from Senegal to Cabinda, Angola, (Risch, 1986). The biology of some members of claroteidae family has been studied by (Entsua-Mensa, Osei-Abunyewa and Palomares 1995) who reported *C. auratus* and *C. nigrodigitatus* in Volta River, (Inyang and Ezenwaji, 2004) in Lake Agulu, (Offem, Akegbejo-Samsons and Omoniyi 2008) in Cross River, (Ayotunde and Ada, 2013) in Cross River and (Ikongbeh, Solomon and Ogbe 2013) in Lake Akata. Among studies of fisheries stock assessment for rational exploitation and conservation of resources, growth studies are an essential instrument in the sustainable management of fisheries resources because these studies contribute to estimates of production, stock size, recruitment and mortality of of production, stock size, recruitment and mortality of fish population (Issac, 1990; Abohweyer and Falaye, 2008). Age, growth, mortality and exploitation rate of some species have been investigated. Ofori-Danson, De Graaf and Vanderpuye (2002) reported population parameter estimate for *C. auratus* and *C. nigrodigitatus* (Pisces: Claroteidae) in Volta Lake, Ghana. Ogbe, Kappo and Cheikyula (2003) reported population parameters for *A. occidentalis* in Lower River Benue. Abowei and Hart (2007) reported for *C. nigrodigitatus* in Nun River, Niger Delta, Nigeria. Chukwu and Deekae (2010) reported for *P. barbarus* in New Calabar River, Nigeria. Salem, El-Aiatt and Ameran (2010) reported for *S. aurita* in the East Mediterranean Sea (North Sinai Coast) and Amrollahi *et al*., (2011) reported for *P. argenteus* in the Northern Persian Gulf.

This work aims at providing information on the age, growth and mortality and exploitation rate of *C. nigrodigitatus* from Lake Akata, since no information is currently available on their population dynamics. Knowledge of population dynamics and fisheries parameters is necessary for management and conservation of fish stock.

MATERIALS AND METHODS

Study area

The study area, Lake Akata is an ox-bow lake of the

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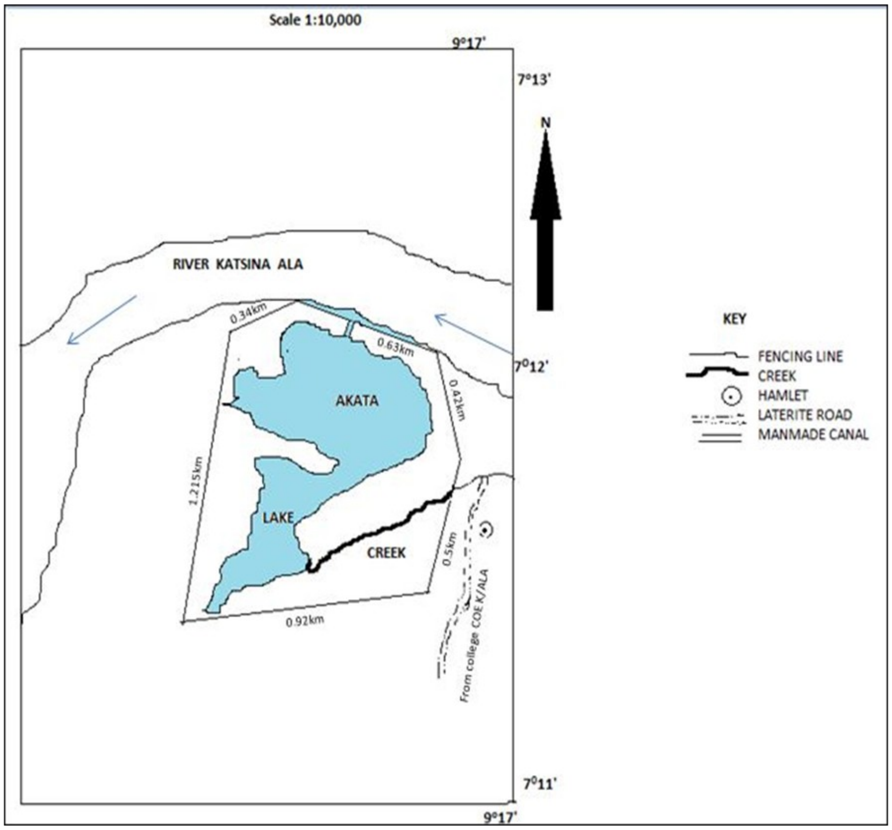

Figure 1. Map of Lake Akata (Source: Ministry of Agriculture and Natural Resources, Makurdi, Benue State.)

River Katsina-Ala and lies between longitude 9°16´ and 9°17´ East and latitude 7°11´ and 7°13´ North (Figure 1). The host town, Katsina-Ala is a riverside resort with a unique feature and the scenic beauty of savannah landscape, supplemented by the famous River Katsina-ala with extensive fadama flood plain covered by numerous lakes scattered over the flood plain one of such lake is the Lake Agbo (MANR Makurdi, unpublished).

Sample Collection

A total of 920 individuals of *C. nigrodigitatus* were randomly sampled monthly for one year and usually in the mornings between 7.00am – 9.00am. The period of the study was from May, 2012 to April, 2013. The fish specimens used for the study were obtained from fishermen operating along Lake Akata. These fishermen use various fishing gears including hand nets, cast nets and gill nets of various standard mesh sizes (20.2, 25.4, and 30.5mm) while dug-out canoes were used as fishing craft. Length and weight measurements were taken directly from the landing sites. Samples were preserved in ice chest and taken to the laboratory for identification.

The total and standard lengths were measured with a meter rule on measuring board according to (Olatunde, 1977). Since *C. nigrodigitatus* has a forked tail like *B. docmac* and *C. nigrodigitatus*, the two lobes were pressed together to give the maximum length measurement. These data obtained when pooled together were used to determine age growth and mortality as described by (Ogbe, Obande and Okayi 2006).

The total body weight was determined using the Mettler tabletop loading electronic weighing balance (model 59174). The sex of each fish sample was determined by visual observation using genital evidence. The length-weight relationship for the species was computed using the equation described by (Bagenal, 1978).

The relationship was transformed into a linear form using the logarithm equation:

$$\text{Log } W = a + b*\text{Log}L$$

Where,

W = weight of fish (g)
L = standard length of fish (cm)
a = intercept
b = regression co-efficient/exponent.

For males and females and both combined sexes by least square regression method.

The condition factor is a measurement of the degree of well-being of a fish. This was calculated monthly for males and females using the equation of Fulton's condition factor of (Ricker, 1975). The condition factor, (k) was determined using the equation:

$$K = 100W/L^3$$

Where,

K = the condition factor.
W = Weight of fish in (g).
L = Standard Length of fish in centimeters.

Lengths were grouped into 1cm classes and smoothed (x3) to reduce sampling error (Rosenberg and Beddington, 1988). Bhattacharya's method as provided in the FAO-ICLARM stock assessment tools (FISAT) (Gayanilo, Sparre and Pauly 1996) was used to decompose composite length frequency distribution.

Theoretically, growth parameters were calculated using the (von Bertalanffy, 1934) equation expressed as:

$$L_t = L\infty\ [(1-\exp(-k\ (t - t_o))] \qquad (7)$$

Where,

L_t =Predicted length at age t
$L\infty$ = Maximum length predicted by the equation or mean length (asymptotic length).
e = Base of the natural log.
t_o= The time at which the organism would theoretically be zero length or initial condition parameter
t = Time (Age).
K = Curvature parameter or the growth co-efficient (instantaneous growth rate), which determines how fast the fish approaches $L\infty$.

Total Mortality (Z) was estimated from FISAT II using Hoenig's Model 1. This model requires only t_{max} i.e. the maximum age (in years) observed in a given stock. This is related to Z through the equation:

$$\ln Z = 1.44 - 0.984 \ln t_{max}.$$

Natural Mortality (M) was estimated from FISAT II using Pauly's M equation:

$$\text{Log}M = -0.0066 - 0.279\text{Log}L_\infty + 0.6543\text{Log}K + 0.4634\text{Log}T$$

Where:

T = Mean annual habitat temperature (Assumed to be 25°C)
K = VBGF growth constant
L_∞= Asymptotic Length.

This formula was used to obtain the estimate of (M), given the asymptotic length, K (the growth constant), and T (the mean annual surface river temperature, taken as 25.0°C).

Once Z and M were obtained, then fishing mortality (F) was derived from the relationship: $Z = M + F$ and Exploitation Rate (E): $E = F/Z$

Where,

F = Fishing mortality and Z = Total mortality and M = Natural mortality

RESULTS

Growth pattern and condition factor

The predictive equations for computing standard lengths (L) of known weight (W) of *C. nigrodigitatus* was Log W= 2.9569 LogL – 1.7515. The growth pattern in both sexes of *C. nigrodigitatus* was isometric. (Figures 2 and 3) illustrate the monthly mean variation in standard lengths and weights of *C. nigrodigitatus.* The highest monthly mean standard length 26.56±1.46cm and mean weight 298.6±41.0g were obtained in the month of April respectively while the least standard length 17.01±1.17cm and weight 110.8±23.1g were recorded in March. The variation in the monthly mean standard lengths was not significant in males ($p>0.05$) and females ($p>0.05$). Male specimens had slightly bigger mean sizes than female in the months of May, September, December, and April, while the female were slightly bigger in July, October, November, and March.

(Figure 4) shows the monthly mean condition factor of *C. nigrodigitatus.* The monthly condition K-values ranged from 1.58 to 1.43 in September and April, respectively for males and 1.76 to 1.66 in May and April, for females respectively. There was a significant difference between the condition factors of male (1.50±0.02) and female (1.73±0.02) of *C. nigrodigitatus* ($p<0.05$). There was no difference between the dry season (1.61±0.02) and wet season (1.62±0.02) values ($p>0.05$).

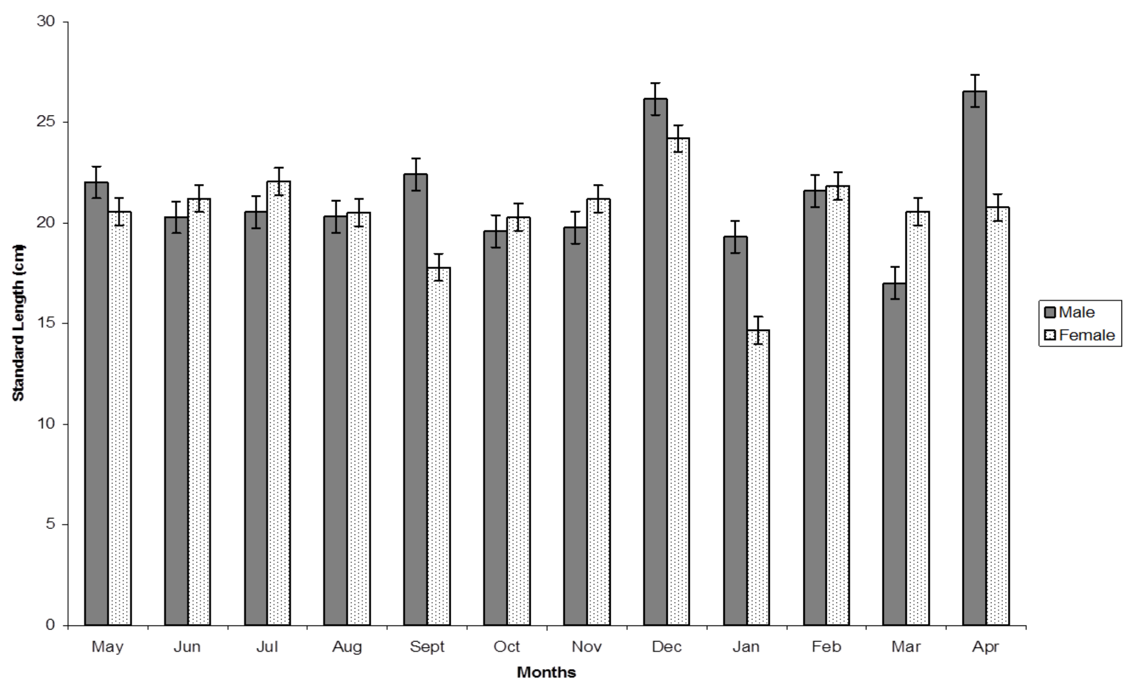

Figure 2. Monthly Mean Variation in Standard Length of *Chrysichthyes nigrodigitatus* from Lake Akata.

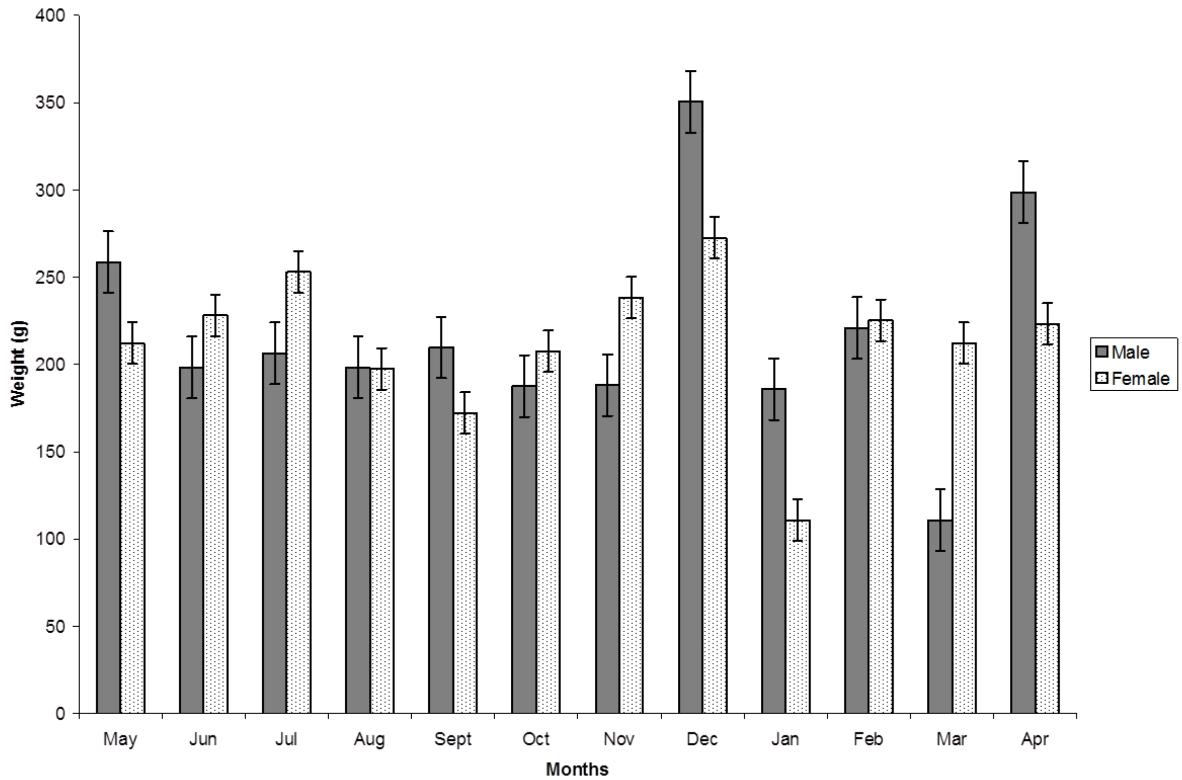

Figure 3. Monthly Mean Variation in Weight of *Chrysichthyes nigrodigitatus* from Lake Akata.

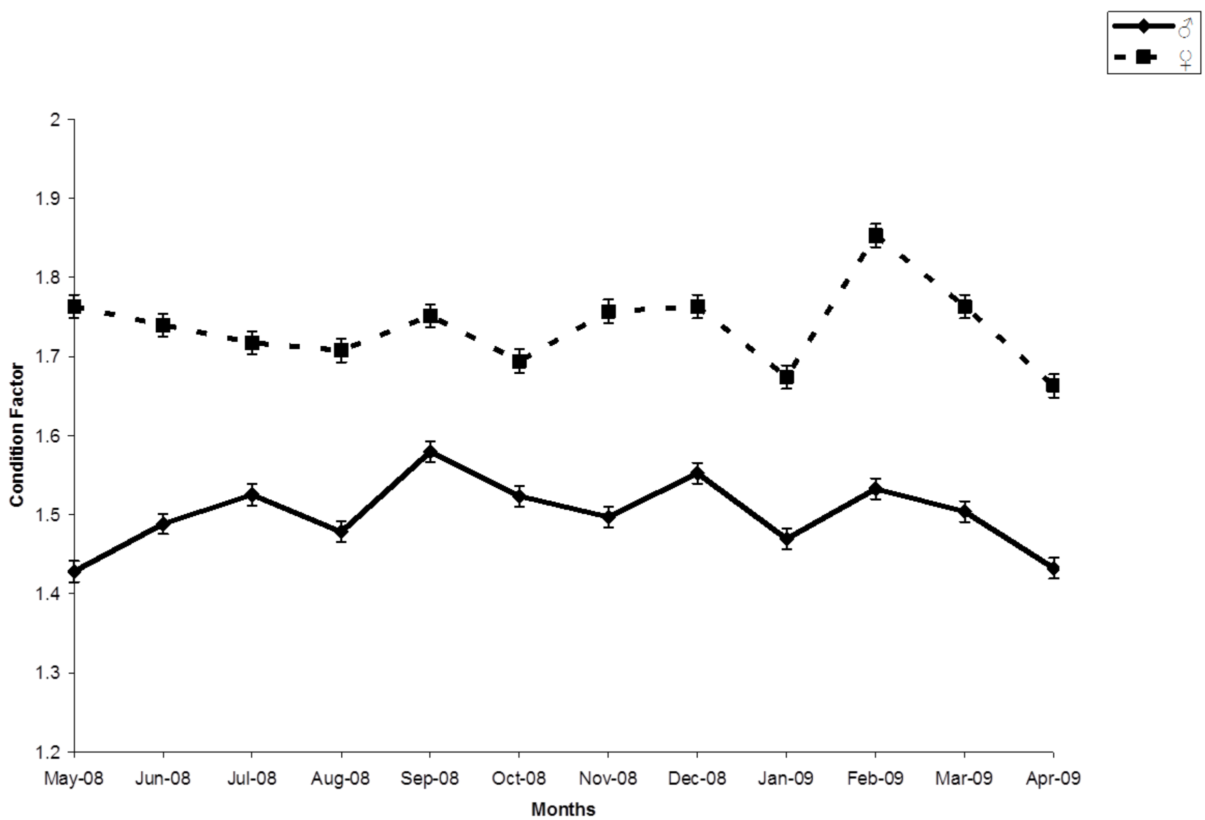

Figure 4. Monthly Variation in Condition Factor of *Chrysichthyes nigrodigitatus* from Lake Akata in Katsina-Ala.

Table 1. Mean Lengths at Age (year) of *Chrysichthyes nigrodigitatus* Determined from Bhattacharya's Method of Separating Length Frequencies Distribution.

Fish Species	Age Groups	Mean Standard Length (cm)	Standard Deviation of Mean Standard Length	Population	Separation Index
Chrysichthyes nigrodigitatus	1+	9.32	6.86	664	n.a.
	2+	25.01	5.25	196	2.44
	3+	34.90	3.56	60	2.07

S.I should be 2 or more than 2 for groups to be meaningfully separated. Key: n.a. = Not applicable

Age and growth

The length frequency distribution of *C. nigrodigitatus* and assortment into composite distributions or age groups is presented in Figure 5. The mean standard lengths for different age groups are shown in (Table 1). There were three age groups of *C. nigrodigitatus,* the age (years) range of 1+ years (mean ± SD standard length is 9.32± 6.9cm) to 3+ years (mean± SD standard length is 34.9± 3.56 cm) was observed in the species. The highest (32.43cm) standard length was observed in age 3+, while age 1+ had the lowest (23.30cm) standard length (Figure 6). The predictive von Bertalanffy growth parameter for C. *nigrodigitatus* were L∞ (37.28cm), K (0.530), and t_o (0.85year) = Lt = 37.28 [1- exp (-0.530 (t –0.85)]. While the growth performance index (Φ^1) was 2.87 and the instantaneous natural mortality (Z/year) estimated from the Hoenig's model I was 1.432/year (Table 2), and the environmental average temperature for Katsina-Ala (25.0°C) was used to compute the natural mortality (M) of 1.053/year and the instantaneous fishing mortality (F) was 0.379/year. The exploitation rate was 0.265.

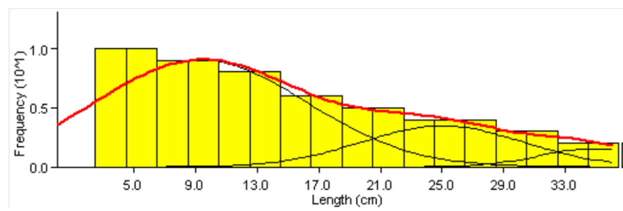

Figure 5. Age Group Decomposition of *Chrysichthyes nigrodigitatus* from Lake Akata Using Standard Length Frequencies (Bhattacharya's Method).

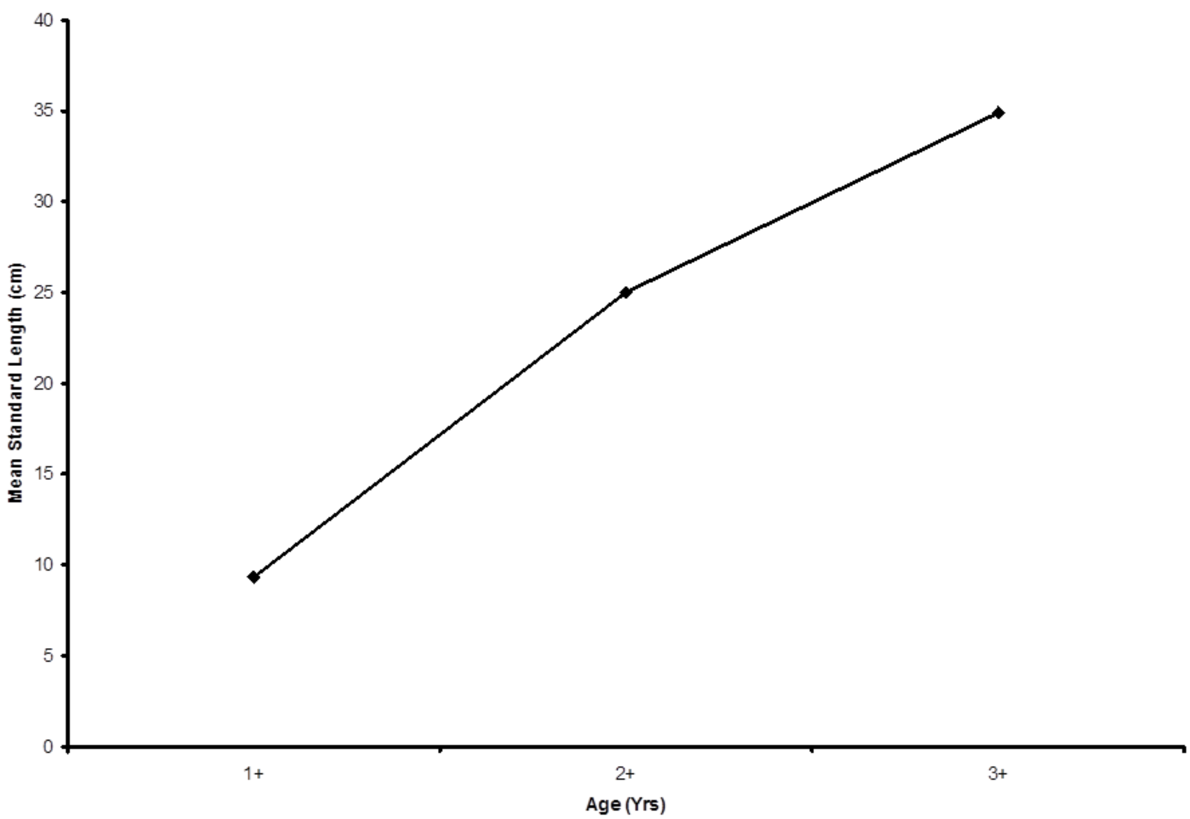

Figure 6. Age and Growth Rate of *Chrysichthyes nigrodigitatus* from Lake Akata, Katsina-Ala

Table 2. Growth Performance, Mortality and Exploitation Parameters

Species	Z/yr(Heonig)	Φ^1	K	L∞ (cm)
Chrysichthyes nigrodigitatus	1.432	2.867	0.530	37.28
	M	F	E	M/K
	1.051	0.381	0.266	1.983

Z/yr = Total Mortality Per year estimated using Hoenig's model I. , Φ^1 =Growth Performance Index., K= VBGF Curvature Parameter, L∞= Asymptotic Length

DISCUSSION

C. nigrodigitatus exhibited isometric growth, similar results were obtained for four dominant fish species-*Heterotis niloticus, Synodontis nigrita, Citharinus citharus,* and *Heterobranchus bidorsalis* in Lake Ona; Ekelemu and Zelibe (2006), Ogbe and Ataguba (2008) also reported isometric growth pattern for *Malapterurus electricus* from Lower Benue River. In a similar study, Offem *et al*. (2008) reported isometric growth for *Chrysichthyes nigrodigitatus* from Cross River. The highest mean standard length obtained for *C. nigrodigitatus* was 20.71±0.44cm. Risch, (1986) reported that *C. nigrodigitatus* attains maximum size of 65.00cm standard length (male/unsexed). Nelson, (2004) reported that *C. grandis* in Lake Tanganyika attained maximum length of about 2m. The condition factor of *C. nigrodigitatus* is favourable. The results of the current study indicated that there was a significant difference between the monthly condition factors of male and female *C. nigrodigitatus* ($p<0.05$). The study was in agreement with the values reported for different cichlid fish in Nigeria (Fagade, 1978, 1983; Dadzie and Wangila, 1980; King, 1994; Junquera *et al*., 1999). There was no significant differences in the condition factor between dry and wet seasons ($p>0.05$). Seasonal variation in condition factor of fish has been reported for *L. lepidus* and *B. nurse* (Karabatak, 1997; Saliu, 2001). The consistently good condition could be an indication of a stable and favourable environmental condition, especially food for sustainable growth of *C. nigrodigitatus.*

Bhattacharya's method as provided in the FAO-ICLARM stock assessment tools (FISAT) (Gayanilo *et al.*, 1996) Computer programme was used to decompose composite length frequency distribution for various ages, while von Bertalanffy growth model, the most widely used model for describing fish growth was use to parameterize individual growth of *C. nigrodigitatus*. Ogbe, (2002) used Bhattacharya's method to estimate the age structure of the mormyrids in the Lower Benue River and reported a maximum age of 4 years in *M. rume, macropthalmus, and deliciosus* and 5 years in *H. bebe occidentalis*. In another study, (Ogbe *et al*., 2003) reported a maximum of 3 years in *Auchenoglanis occidentalis* in the Lower Benue River. Asila and Ogari (1988) also used this method to estimate the growth parameters of Niger perch in the Nyanza Gulf. Chakraborty (2001) observed that among the methods employed for growth studies, Bhattacharya is relatively less used but established from his studies that overall comparison of growth data M/K ratio and Φ^1 indicated that the growth parameters obtained by Bhattacharya's method were comparable with growth parameters obtained using the other methods for the same species. Growth studies of *C. nigrodigitatus* from Akata Lake, using Bhattacharya's method illustrates that the method can also be used with comparative ease and the results obtained agree with other standard methods available for growth studies. Comparison indicates that there is not much variation in the parameters obtained using Bhattacharya's method as compared to the results obtained using Petterson's method. Values of L∞ (cm SL), K and t_o (years) of the von Bertalanffy growth parameter and growth performance index (Φ^1) were respectively estimated to be 37.28, 0.530, 0.85 and 2.87. Ogbe *et al*., (2003) estimated L∞ for *A. occidentals* as 38.5cm, while Udo, (1994) reported 31.0cm for the same species in Cross River and 44.3cm was reported by Sturm, (1984) in man-made Tiga Lake for *C. auratus,* all in fresh water ecosystem. K-values reported for some siluroid fishes were 0.49cm/year for *A. occidentalis* from Lower River Benue (Ogbe *et al*., 2003), 0.16cm/year (Sturm, 1984) and 0.02cm/year (Udo, 1994) for *C. auratus* caught from manmade Tiga Lake and Cross River respectively, 0.176cm/year and 0.208cm/year for male and female *S. mystus* respectively from Kainji Lake (Olatunde, 1979). According to the Fish Base Species profile (Fish Base, 2003) the k-value of the North African catfish (*C. gariepinus*), is 0.09cm/year. Growth performance index (Φ^1) reported for some *Bagrids* elsewhere were 1.06 and 2.50 for *C. auritus* in Cross River (Udo, 1994) and manmade Tiga Lake (Sturn, 1984) respectively. Growth performance indices (Φ^1) of 3.30 and 3.84 have been reported for *C. nigrodigitatus* by Ezenwa and Ikusemiju, (1981) and Udo, (1994) respectively from River Calabar. King, (1997) reported (Φ^1) of 2.39 for *Schilbeidae* and 3.76 for *Gymnarchidae* for Nigeria fish stock. Ogbe *et al*., (2003) reported Φ^1 of 2.85 for *A. occidentalis* in the Lower Benue River.

Bhattacharya's length-frequency distribution method successfully distinguishes three age groups and their mean lengths and the sorting out of the different sizes into the composite age groups for *C. nigrodigitatus.* The separation indices were all above 2, which indicated empirical conformation that the cohorts were fully sorted into their respective age groups (Clark, 1981).

The total mortality (1.432/year) estimated using the Hoenig's model I which is an age structured model, is quite high. This could be as a result of migration of the species to the bank for feeding where traps and nets are usually set. Total mortality however was estimated to be

0.499/year using the Beverton and Holt length based curve. There is a 65% difference between the Z value obtained using the Hoenig's model compared to the Beverton and Holt model which is length converted catch curve. Pauly, Moreau and Abad (1995) reported that estimates from age-structured catch curve are unbiased because growth in age has no seasonality whereas, from length based method, for example, without considering season, length-converted catch curve often estimate (z) with bias as much as 180% compared to age-structured method. Instantaneous natural mortality (M) of 1.053/year when compared to 1.2/year as reported for *Mugil cephalus* in the estuary of the Senegal River (Sarr, Kabre and Cecchi 2013) is low. With an estimated fishing mortality of 0.379/year, which is lower than natural mortality, the sustainable yield of this species is not optimized (Pauly, 1983). With an estimated exploitation rate of 0.265, the stock is not overexploited.

The exploitation rate (E), is an index which roughly measures whether a fishery is over fished or not. It is based on the assumption that the optimal value of E (E_{opt}) is equal to 0.5. This value of exploitation rate is based on the assumption that sustainable yield is opimised when fishing mortality coefficient (F) is equal to natural mortality (M) (Pauly, 1983). The exploitation of this species is (0.266) quite below the maximum sustainable yield and effort can be increased since protein deficiency is a problem in the locality. Management measures are not critical but monitoring of fishing is vital for sustainability of the stock since data collected can be used to update the exploitation rate and adjust effort accordingly.

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