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Age and growth of catfish *Synodontis schall*, (Bloch and Schneider, 1801) in the Lower Benue River, at Makurdi, Nigeria

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Abstract
The age and growth of *Synodontis schall* in River Benue at Makurdi were studied over a 24- month period (January, 2009-December, 2010). A total number of 635 specimens comprising of 329 males and 306 females with the size range of 6.1 - 30.40 cm (mean = 12.04 ± 0.11) were studied. The weight ranged from 53.0 - 864g (mean = 57.71 ± 2.26). Asymptotic length ($L\infty$) was 30.05cm, 30.00cm and 28.50cm in the females, males and combined sexes respectively. Growth rate ($K^{1\text{-}yr}$) was found to be 0.580, 0.570 and 0.430 while the growth performance index (Ø') was 2.756, 2.645 and 2.946in the females, males and combined sexes respectively. The t_0 (a time in the growth history of fish at which the fish would be zero sized) values were all positive as follows 0.830 in the females, 0.39 in the males and 0.00 in the combined sexes.

Keywords: Asymptotic length, growth rate, growth performance index, *Synodontis schall,* River Benue.

1. Introduction

The genus *Synodontis* is the most common of the three genera of the *Mochokidae* family. It is among the most favoured edible fish in northern Nigeria (Reed *et al*., 1967) [35], owing to their overwhelming abundance in the artisanal fisheries. The genus consists of 23 species in the Nigerian waters (Idodo–Umeh, 2003) [22]. *Synodontis* species only occur in Africa and apart from the species present in River Nile; they are restricted to water systems within the tropics (Willoughby, 1974) [42]. The genus is commercially important in the inland waters of West Africa and in River Benue at Makurdi. *S. schall* is one of the species that can be seen in the fish markets throughout the year.

Hard parts such as scales, otoliths, spines, opercular bones, fin rays and vertebrae are used in age and growth determination by many authors. The age and growth of some scale-less fishes have been determined by the use of otoliths, opercular bones, spines, fin rays and vertebrae by Fagade (1979) [16], Araoye *et al*., (2002) [8] and Nargis (2006) [29]. Adeyemi and Akombo (2012) [6] used scales and opercular bones to determine the age and growth of dominant Cichlids in Gbadikere Lake, Kogi state, Nigeria. Despite the commercial importance of *S.schall* in River Benue at Makurdi, its age and growth have not been studied in order to access its production potentials. This paper therefore aims at determining the age and growth of *S.schall* in River Benue at Makurdi using opercular bones and length frequency data methods.

2. Materials and Method

The study was carried out in the Lower Benue River at Makurdi, Nigeria. The Lower Benue River is the portion of the Benue River that is contained within the Benue and Kogi States of Nigeria. River Benue originates from the Adamawa Mountains of Cameroun and flows west across East-Central Nigeria. It is the largest tributary of the Niger which it joins at Lokoja in Kogi State, Nigeria.

The River has extensive alluvial plain stretching for many kilometers, which covers a distance of approximately 187 kilometers. The extensive flood plain forms breeding grounds for many fish species (Beadle, 1974) [12]. The highest water levels are in August to September and the Lowest are in March to April.

2.1 Sampling method
The *S. schall* specimens were purchased from fishermen at Wadata fish landing site, Makurdi, which is one of the landing sites on the bank of River Benue. The fishes were caught with gill nets, cast nets, hooks and lines as well as other fishing gears. They were procured fortnightly for 24 months and transported to the Biology Laboratory in Benue State University, Makurdi for identification and measurements. Identification was done using the keys by Reed *et al*., (1967) [5, 30] Holden and Reed (1972) [21], Babatunde and Raji (1998) [9] and Idodo-Umeh (2003) [22].

2.2 Length-Weight Measurements
The standard lengths (SL) of the fish samples were measured using a measuring board. The anterior tip of the fish was placed against a stop at the beginning of the measuring scale with its mouth closed. SL was taken as the length from the tip of the fish's snout to the end of the caudal peduncle and this was measured to the nearest 0.1 centimeter. The total weight (TWT) was measured using a digital electronic weighing balance (Adam AFP 4100L). This was read to the nearest 0.1 gramme.

2.3 Sex determination
The different sexes of *Synodontis* species were identified after dissection. Thus the fishes were dissected and the gonads were inspected using the keys of Nikolsky (1963) [27]. According to him, in the young males, testes are thin, thread like with very small projections, whitish in colour and extend to about 1/3 of the abdominal cavity. In adult males, the testes are creamy in colour with very conspicuous granules. The young females have thin, pink to white tubular gonads occupying about 1/5 of the abdominal cavity. In adult females, that are about to spawn eggs are readily discernable in the ovaries which increase in size and fill most of the abdominal cavity (Bagenal, 1978; Halim and Guma'a, 1989) [10, 19].

2.4 Length-Weight relationship (LWR)
The LWR of the fishes were calculated using the equation

$$\mathbf{W = aL^b} \text{ - - - - - - - - - - - - } \mathbf{(1)}$$

Where W = the observed total weights of the fishes.
L = the observed standard lengths.
a and **b** are constants (Bagenal, 1978) [10].
b is the slope usually between 2 and 4 and ***a*** is the intercept on the length axis (Bagenal, 1978) [10]. The logarithmic transformation of the equation (1) gives a straight line relationship.

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

When $\mathbf{Log_{10}W}$ is plotted against $\mathbf{Log_{10}L}$, the regression coefficient is **b**, and **Log a** is the intercept on the Y axis.

2.5 The Condition Factor (K)
The condition factor (K) was computed from the equation:

$$K = \frac{100W}{L^b} \text{ - - - - - - - - - - } (2)$$

Where W = the observed total weight for each fish.
L = the observed standard length for each fish.
K= the Condition Factor (Bagenal, 1978) [10].

2.6 Age and Growth
In aging, opercular bones were used in conjuntion with length frequency, length-weight relationships, length at age and Von Bertallanffy's growth model available in LFA/FiSAT computer programmes.
Treatment of the opercular bones was done as in Nargis (2006) [29]. The left opercular bones from the specimens were removed using a knife and immediately put in hot water for 2-3 minutes and washed. The bones were allowed to dry, then put in numbered envelopes and stored. The age rings on the boneswere observed under a microscope projector to detect the growth marks.
Photographs of clear growth marks were made, and the opercular radius and the radius of the growth marks were measured.
Scatter diagrams of opercular radii against fish length were made. This relationship is always linear, but does not intercept at the origin, therefore back calculations of the length at specific ages were computed using the formula:

$$\mathbf{ln = \frac{Sn(l - a)}{S}}$$

Where
Ln = length of fish when annulus "n" was formed
l= length of fish when opercular sample was taken
Sn= radius of annulus "n"
S= total opercular radius
a= intercept at the length axis
(Bagenal, 1978[10]; Araoye *et al*., 2002) [8].
The maximum distance between the centre of the bone and its margin was taken as the length of the bone. The relationship between bone length (Y) and SL (X) was established and the age groups were considered as 0+, 1+, 2+, 3+ etc. The yearly increase in length for each of the age groups was found by subtracting the mean length of each group from the next older age groups.
The growth parameters describing the fish populations were estimated from length frequency,length-weight relationships, and length at age using the Bhattacharya's,Von Bertallanffy's,Powell-Wetherall and Ford-Walford methods. All of these are available in the length frequency based stock assessment computer software programme FiSAT II (1996).

2.7 Length at Age
The length at age was calculated using the Von Bertallanffy's growth model in the LSA/FiSAT computer programmes.
The Von Bertalanffy's growth model of (1957) described growth curves as expressed by the formula:

$$\mathbf{L(t) = L_\infty(1 - e^{-k(t-to)})}$$

WhereL(t) = length at age t
L_∞ = asymtotic or maximum attainable length, assuming fish growth is indefinite.
k = rate at which the asymtotic length is approached.
t_o = a time in the growth history of fish at which the fish would be zero sized.
e = exponential and
t = age in years.
Growth curves were fitted to the Von-Bertalanffy model and tested with Walford plots (Ricker, 1975) [37]. From the Walford plots, trials L∞ were obtained.

From the trial $L\infty$, five values were obtained by successive addition of 1 to the trial $L\infty$ twice and subtraction of 1 twice from it. Trial plots of ($L\infty$ -Lt) against age were done using the method of Ricker (1975) [37], where the line of best fit was selected by eye to obtain the true $L\infty$.
The gradient $Log_e\ L\infty + Kt_0$, is the intercept, then

$$t_0 = \frac{Y\text{–}Intercept - Log_e\ L\infty}{K}$$

K is the gradient of the line of best fit from the trial plots of $Log_e\ (L\infty - Lt)$ against age.
By these the Von-Bertalanffy growth parameters $L\infty$, K and t_0 were obtained.

2.9 Growth Performance Index

The growth performance index Ø'(Phi-Prime) was calculated using the formula of Pauly and Munro (1984) [34].

$$Ø' = LogK + 2LogL\infty.$$

Where, K and $L\infty$ are parameters of VBGF.

3. Results

A total number of 635 specimens of *S.schall* comprising of 306 females and 329 males were examined. The results of the morphometric, growth parameters and mortalities were as shown in table1.

Table 1: Morphometric and Growth Parameters of *S.schall* in the Lower River Benue at Makurdi.

PARAMETER	SEX		
	♀	♂	COMBINED SEX
No. Sex Ratio	306 1	329 1.1	635 1:1.1
Length Range (cm)	6.6 – 30.4	6.1 – 21.5	6.1 – 30.4
Mean Length (cm) ± SE	12.29 ± 0.175	11.81 ± 0.134	12.04 ± 0.110
Weight Range (g)	8.4 – 864.5	5.3 – 406.9	5.3 – 864.5
Mean Weight (g) ± SE	63.37 ± 4.04	52.36 ± 2.14	57.71 ± 2.26
a	-1.0458	-1.0198	-1.2072
b	2.5290	2.4979	2.6749
r	0.9333	0.9308	0.9411
K^1	2.874	2.838	2.855
$L\infty$ (cm)	30.05	30.00	28.50
K ($^{1\text{-yr}}$)	0.580	0.570	0.430
t_0 (cm)	0.830	0.330	0.000
Ø	2.756	2.645	2.946

a = intercept on x-axis, b = slope, r = Coefficient of Regression, K^1 = Condition Factor, ***L****∞ = Asymptotic length, K = Growth curvature, t_0 = length at time 0, Ø = Growth performance index.*

The correlation coefficient **r** for the females, males and combined sexes were positively correlated at 0.05% level (p<0.5%), while the regression coefficient **b** were all below 3 indicating a negative allometric growth pattern as shown in table 1 above..
The fishes were in good condition throughout the period of study with the average K^1values of 2.874, 2.838 and 2.855 in the females, males and combined sexes respectively. The asymptotic lengths ($L\infty$) from the Walford plots were 30.05cm, 30.00cm and 28.50cm for the females, males and combined sexes respectively. Growth rate ($K^{1\text{-yr}}$) was slightly higher in the females (0.580) than the males (0.570), though there was no significant difference ($p > 0.05$) between the two. The growth performance indices (Ø') were 2.756, 2.645 and 2.946 for the females, males and combined sexes respectively. This was also slightly higher in the females than the males without a significance difference ($p > 0.05$).
The photographs of the opercular bones of a two year (2+) and five year (5+) are shown in plates 1 and 2 respectively. The periods of slow growth are represented by the dark bands, while the periods of faster growth are represented by light bands which are wider. The growth marks were observed between July and October when water level was high due to the flood. As can be seen by the wider gaps in the first year, growth is rapid in the first year and slows down gradually in the subsequent years.
The relationship between the standard length and opercular radii for the females, males and combined sexes are presented in figures 1-3 below. The relationship is linear, but does not intercept at the origin. Therefore, back calculations of the length at specific ages were calculated (Table 3 below).

Plate 1: Opercular Bone of Two Year *S.schall*

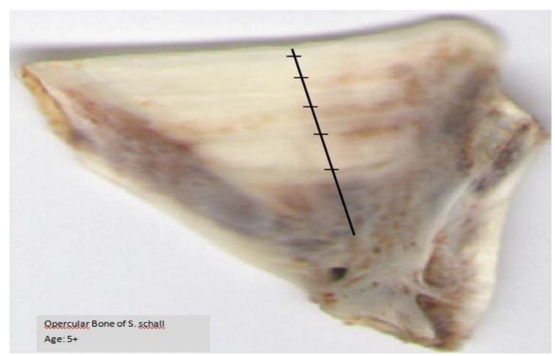

Plate 2: Opercular Bone of Five Year *S.schall*

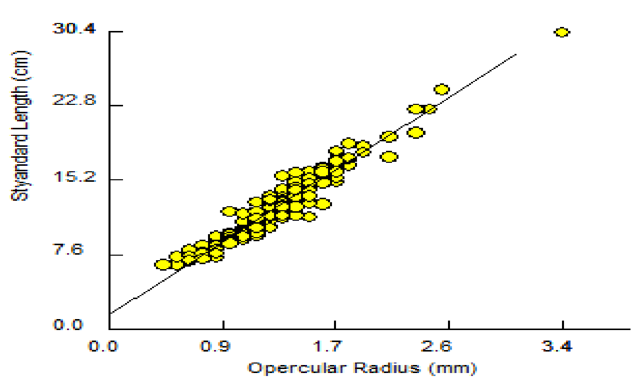

Fig 1: Opercular-Standard Length Relationship of *S.schall* – Female

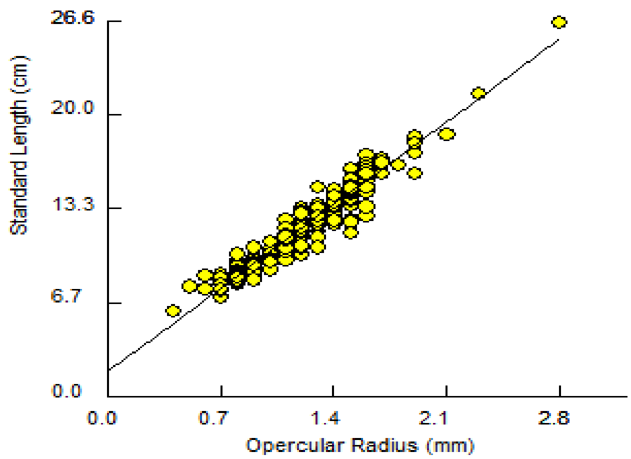

Fig 2: Opercular-Standard Length Relationship of *S. schall* – Male

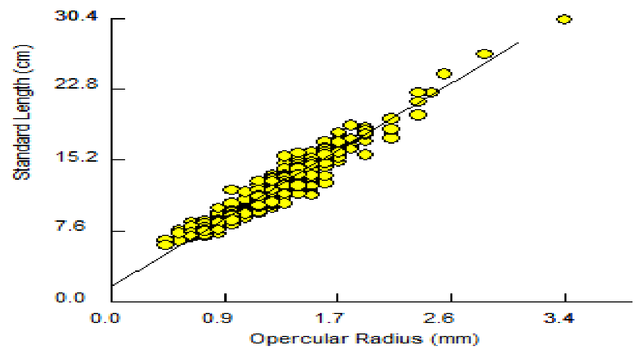

Fig 3: Opercular-Standard Length Relationship of *S. schall* - Combined Sexes

The slope relationship is described by the regression equations in table 2 which are all positive.

Table 2: Regression Equations for the Opercular Radius-Standard Length Relationship of *Synodontis schall* in the lower River Benue at Makurdi.

Species	Sex	N	Regression Equation	Regression Coefficient (r)
S.schall	♀	306	SL = 1.5279 + 8.7105 OR	0.9371
	♂	329	SL =1.8049 + 8.4237 OR	0.9296
	Combined	635	SL = 1.6735 + 8.5662 OR	0.9327

SL = Standard Length, OR = Opercular Radius, ♀ = Female, ♂ = Male.

Table 3: Back-Calculated Lengths of *Synodontis Schall* in Lower River Benue

Sex	Age	No of Fish		Length at Age					
				L_0	L_1	L_2	L_3	L_4	L_5
♂	0+	7		5.98					
	1+	207			6.55				
	2+	96			6.04	6.55			
	3+	11			7.53	11.81	13.68		
	4+	13			10.06	16.76	20.36	21.85	
	5+	-							
Mean				5.98	7.55	11.71	17.02	21.85	
Av. Ann. Increment				5.98	1.57	4.16	5.31	4.83	
% Growth Increment				9.33	2.45	6.47	8.28	7.53	
♀	0+	10		5.98					
	1+	157			6.04				
	2+	102			6.94	10.42			
	3+	12			7.90	12.76	14.55		
	4+	19			11.03	18.34	22.73	24.72	
	5+	1			6.98	17.94	23.92	26.91	27.91
Mean				5.98	7.78	14.87	20.40	25.82	27.91
Av. Ann. Increment				5.98	1.80	7.09	5.53	5.42	2.09
% Growth Increment				7.49	6.45	25.40	19.81	19.42	7.49

4. Discussion

In the temperate waters, it was assumed that during the cool months of winter when temperatures were low, the life functions of most fishes decreased to a minimum in which case growth was also reduced. Gado (1999) [17] explained that annual fluctuations of metabolic level and of water temperatures were the major factors explaining the occurrence of annuli in the hard parts.

The periods of low growth are imprinted on the skeleton and scales in the form of rings or stripes, while the periods of faster growth are characterized on the scales and skeleton by wide fields or rings (Lagler, 1977) [26].

Even though there are small seasonal temperature and other environmental changes prevailing in the tropics, growth marks on the hard parts of tropical fishes can also be used in aging fishes. On the other hand, different hard parts are most appropriate for aging different species of fish. Thus, in this study the opercular bones were used in aging the *Synodontis schall*. Growth marks were observed on many opercular bones as can be seen in plates (1-2). These growth marks according to Araoye *et al*., (2002) [8] were usually formed between July and October when water level was high due to the flood. Blake and Blake (1978) [13] reported the presence of growth rings on the scales and opercular bones of *Labeo senegalensis* from Kainji Lake. They however commented that the scale marks were often indistinct and difficult to interpret while they observed at least two check marks per year on the opercular bones. Haruna (1992) [16] observed growth rings on the opercular bones of cichlids from Jakara Lake, Nigeria. Gado (1999) [17] used opercular bones to age many species of fish in the Hadeijia Nguru wetlands including *Synodontis* species. Araoye *et al*., (2002) [8] also used opercular bones to age *S. schall* in Asa Lake, Ilorin. Nargis (2006) [29] reported that opercular bones method was superior to several other methods of determining age and growth of Carp (*Cyprinus carpio*), while Khan and Khan (2009) [23] showed that opercular bones were the most suitable structures for ageing *Catla catla* and scales were the most suitable in *Labeo rhoheta* in India.

Fagade (1974) [16] attributed the growth marks on hard structures in tropical fish as a result of factors such as reproductive activity, feeding intensity, lower salinity, increased turbidity and reduced temperature during the rainy season in the Lagos lagoon. Abowei and Davies (2009) [2] attributed growth fluctuations in tropical and sub-tropical fishes to many factors such as environmental changes, food composition changes, competition with the food chain, changes in the physical and chemical properties of aquatic medium. The growth marks observed in this study may also be attributed to high turbidity, low oxygen and reduced feeding intensity during this period as this also coincided with the period of spawning.

The readings on the opercular bones in this research revealed that growth was slowed during certain period of the year and faster at other times. The period of slow growth coincided with the period of flooding which is from July to October in this part of country (Araoye, *et al*., 2002) [8]. This is also the period of spawning of these species in this area. The flooding of the river brings about changes in the hydrological, chemical and physical characteristics of the water body especially temperatures. Olaosebikan *et al*., (2006) [32] observed that seasonal changes in temperature and day length were less pronounced in tropical latitudes, therefore, suitable environmental conditions were governed more by the change in rainfall and water level, forming a sequence of wet and dry seasons than by physiological process.

From the opercular readings and the back calculations, it was observed that growth rate was rapid during the early years and gradually declined during the preceding years. Araoye *et al*., (2002) [8] explained that this was a usual phenomenon in some fishes in which wider gaps between the annular marks on the opercular of the fishes in their early years was an indication. This is due to the fact that the younger fishes were more involved in feeding activities than the matured ones which might be more engaged in reproductive activities and territorial protection, hence slowly declining growth curves for most fishes. However in piscivorous fishes such as *Lates niloticus* and *Clarias gariepinus* the growth rate could approach a straight line even up to 10 years Araoye *et al*., 2002) [8].

The highest L_∞ was 30.05cm in the females while the maximum length of 30.40cm was recorded in a female also. There was not much difference between the L_∞ and the maximum length of fish obtained indicating that the values obtained were reasonable for the species in the river.

Araoye (1997) [7] computed the L_∞ of *S. schall* in Asa Lake from the observed, back calculated, and integrated methods as 50.4cm, 49.5cm and 50.0cm respectively. Abowei and Hart (2009) [4] reported the L_∞ of *S.schall* to be 38.7cm, *S.clarias* 35.56cm and *S. membranaceus* 43.8cm from the Lower Nun River, Niger Delta. Midhat *et al*., (2012) [27] observed the L_∞ of 62.74cm, 64.24cm and 63.45cm for males, females and combined sexes respectively in *S. schall* in Egypt at Gizza.

The different asymptotic lengths observed in the different localities even in the same species can only be explained by the different environmental conditions in those areas or high fishing pressure. Spare *et al*., (1992) [41] reported that growth of fishes differed from species to species and from stock to stock even within the same species as a result of different environmental conditions. Abowei and Hart (2007)[3] attributed the differences in the maximum size of *Chrysichthys nigrodigitatus* in the Lower Nun River to high fishing pressure, environmental pollution and degradation. King (1991) [21] had shown that the maximum size attained in fishes was generally location specific.

The hypothetical age at which length is zero (t_0) were all positive in *S. schall* male, female and combined sexes. Gado (1999) [17] reported positive t_0 values for the fishes of Hadeijia N'guru wetlands, North-Eastern Nigeria. Abowei and Hart (2007) [3] also reported positive t_0 values for the major cichlids and *Chryschthys nigrogiditatus* from Umuoserche Lake and Nun River respectively. Sambo and Haruna (2012) [38] also reported positive t_0 values for the fishes of Adamu Ibrahim Lake, Kazaure, Jigawa state. These were *O. niloticus* 0.12 for males, 0.66 for females; *S. galilalaeus* 0.30 for males, 0.86 for females and *B. bayad* 0.50 for males, 0.85 for females. Pauly (1983) [34] stated that t_0 values were usually negative. King (1997) [25] reported that with negative t_0 values, juveniles tended to grow more quickly than the predicted growth curve for adults, and with positive t_0 values, juveniles grew more slowly. Schnute and Fournier (1980) [39] stated that L_∞, **K** and t_0 had no direct biological meaning and that values of L_∞ in particular were dependant on adequate sampling in the larger length classes.

The growth rate of this species in the river was 0.580, 0.570 and 0.430 in the females, males and combined sexes respectively. This shows that the rate at which the males and females of *S. schall* approach L_∞ is similar.

The growth performance index of fishes (**Ø'**) compares the growth performance of different populations of fish species in the same or different environments. In this study the growth performance indices of the female, male and combined sexes of *S. schall* were 2.756, 2.645 and 2.946 respectively. These values are in agreement with most values obtained in tropical fishes. Abowei (2009) [1] reported the growth performance index (Ø') of 2.63 in *Hemisynodontis membranaceus* from the fresh water reaches of Lower Nun River, Niger Delta. Abowei and Hart (2009) [4] observed the growth performance indices of 2.71 in *S. schall*, 2.63 in *S. membranaceus*, and 3.23 in *S. clarias* from the Lower Nun River, Niger Delta. Midhat *et al*., (2012) [27] reported the growth performance indices in length of *S. schall* in River Nile at Gizza to be 2.689, 2.692 and 2.709 in the males, females and combined sexes respectively. Adedolapo (2007) [5] observed the growth performance index of 2.62 and 2.51 in *Schilbe mystus* in Asejire and Oyan Lakes respectively. Adedolapo (2007) [5] showed that Phi Prime (Ø') were species specific parameters and gross dissimilarity of Ø' values for a number of stocks of the same species or related species are an indicator of unreliability in the accuracy of estimated growth parameters. Thus the similarity of Ø' related species in different tropical areas is an indication of the reliability of the computed growth parameters in this study. Baijot and Moreau (1997) [11] stated that the Ø' mean values of some important fishes in Africa ranged between 2.32-2.51, which they considered as low. Gatabu (1992) [18] indicated that besides the genetic makeup which determines the growth potential of the species, overfishing, diet type and its utilization could affect the growth performance index of a particular species. Even though the growth performance is a function of L_∞, increase in L_∞ leads to increase in growth performance and vice versa.

5. Conclusion
The study of age and growth of *Synodontis schall* in River Benue at Makurdi showed that opercular bones were a reliable part of the skeleton for the determination of age. The growth rate and the growth performance index were found to be good in the river.

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