UTTAR PRADESH JOURNAL OF ZOOLOGY

43(2): 19-29, 2022
*ISSN: 0256-971X (P)*

# AGE AND GROWTH OF *Papyrocranus afer* (GUNTHER 1868), AN EMERGING ORNAMENTAL FISH IN NIGERIA

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**AUTHOR'S CONTRIBUTION**
The sole author designed, analysed, interpreted and prepared the manuscript.

***Article Information***

DOI: 10.56557/UPJOZ/2022/v43i22892

Editor(s):
(1) Rakpong Petkam, Khon Kaen University, Thailand.
Reviewers:
(1) Philemon E. Nsinda, Tanzania Fisheries Research Institute, Tanzania.
(2) Levent Bat, University of Sinop, Turkey.

***Received: 20 November 2021***
***Accepted: 26 January 2022***
***Published: 28 January 2022***

***Original Research Article***

## ABSTRACT

*Papyrocranus afer* are threatened by increasing collection from the wild for aquaria, especially the juveniles. Age, growth and growth derived parameters of *P. afer* Lagoon based on analysis Length Frequency Distribution (LFD) and interpretation of annual growth marks hard structures (namely scales, otoliths, opercula and cleithra). In total, 1, 154 individuals of *P. afer* were sampled monthly during Jan. 2010 to Dec. 2011 from Lekki Lagoon. The mean lengths-at-ages from LFD were 13.45 cm (Age $0^+$) 34.45 cm (Age $1^+$), 49.50 cm (Age $2^+$) and 61cm (Age $3^+$). The von bertalanffy growth function was used to model the observed length-at-age data: $L_t = 77.6 (1 – e^{-0.33(t +0.46)})$. Length at first maturity ($L_m$) was 41.1cm while length at optimum yield ($L_{opt}$) was 49.5cm. Preponderance of immature fishes (38 cm) in the catch suggests growth overfishing. Interpretable annual growth marks on hard parts showed ages 1, 2 and 3 years; the mean lengths at these ages were 33.1, 44.6 and 58.4cm (cleithra), 29.1, 40.0 and 60.4 (scale) and 29.1, 40.0 and 60.4 (operculum). No interpretable growth marks on otoliths. Growth overfishing underline vulnerability of *Papyrocranus afer* to over-exploitation, hence the need for its conservation in Lekki Lagoon.

**Keywords:** Size-at-maturity; age-at-length; von-baterlannfy growth; population dynamics; growth mark; Lekki Lagoon.

## 1. INTRODUCTION

Juveniles of the reticulate knifefish, *Papyrocranus afer* (Gunther, 1868) has commercial importance as aquarium species. The fish could attain a maximum size of 80 cm total length (wet weight = 1956g); it is likely good as food fish that attracts high market values. However, there has been considerable decline in their abundance in Nigeria waters possibly due to habitat degradation, loss of catchment area, destructive fishing practice and even pollution [1]. Intensive fishing pressure coupled with international demand resulting from foreign exchange earning potentials of ornamental fishery have led to substantial decrease in population of several indigenous ornamental fish species in developing

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countries [2,3]. In the prevailing trends of growing local and international ornamental fish demands, the sustainability of the fish stock is not guaranteed. International Union of Conservation of Nature [4] categorized *P. afer* as Least Concern (LC). Lalèyè and Moelants[5] reported further that the available information on the species is fragmented in spite of the fact that the species is harvested for human consumption, and for the aquarium trade. Consequently, the evaluation of the effective productive potentials and sustainable use of these fishes requires basic information on their biology [6].

Yearly variations in productivity of fish stocks are functions of age composition and growth patterns. Consequently, age and growth studies and their derived growth parameters are indispensable for optimal and rational exploitation of a fishery both in the wild and in culture enclosure. Campana [7] affirmed that information on age and growth rates are critical in monitoring and assessment of the population status of a fishery; and for understanding the life history and population biology of a species [8], through such attributes as growth, size at maturity, size at optimum yield, recruitment, longevity, mortality [9]. Ample knowledge of all these parameters is crucial in fishery production. They also furnish quantifiable baseline data from which decision on conservation and impact assessment can be made.

Growth in fishes is indeterminate [10, 11, 12]. Knowledge of growth rate of fish is a prerequisite for effective management. This requires determination of fish ages in order to establish a relationship between age and size of fish. Age and growth studies in fish species may be accomplished either directly through recognition, reading and interpretation of annual growth marks on hard parts (scales, otoliths, vertebrae, cleithra and opercula of specimens) on specimens; and indirectly by analysis of length frequency distribution of individuals to obtain mean length of each age group [13, 14], moreover plots of data in a sample of the entire population consecutive ages given lengths aggregate together separating the various age groups. In the formal method, growth marks are formed during period of alternative fast and slow growth; such growth marks often indicate fluctuating environmental and internal factors [9].

In temperate environment, age determination of fish on hard parts is somewhat accurate due to definite growth marks resulting from definite changes in seasons. Determining the age of tropical fishes is of particular concern as it is often difficult because there are no definite demarcated seasons and hence no clear annual rings on the hard structures [15, 16, 17]. However, there are periodically recurring growth rings which once their periodicity has been established with the use of daily increments, could be used for age determination [18, 19, 20]. A combination of the various methods would give more conclusive result than any single method [21, 22]. This is necessary for ageing tropical fishes where there are no abrupt seasonal changes to necessitate temporary cessation of growth of the hard parts of fishes.

There is paucity of biological data as regards age and growth attributes of *Papyrocranus afer* despite its increasing importance as an aquarium species. Fragmental available information on this species reflects food and feeding habits [23, 24, 25], morphometric and faunal composition [25, 26] and length-weight relationships [27, 28]. These do not provide insight for understanding species-specific population characteristics and dynamics for *P. afer*. Hitherto, this paper acquaints the readers with information on aspects of the age and growth of *P. afer* from Lekki Lagoon, Nigeria.

## 2. MATERIALS AND METHODS

### 2.1 Study Area

The study area is Lekki Lagoon (Fig. 1). Lekki Lagoon is a large expanse of fresh water body located on longitude 4˚00’ and 4˚15’ E and latitude 6˚25’ and 6˚37’ N. Rivers Oni, Oshun and Saga flowed and emptied into the lagoon at the north-eastern and north-western parts respectively. The lagoon is one of the largest sources of freshwater fish production in this region; and it is also used for sand mining, transportation and recreation.

### 2.2 Collection of Samples

Monthly samples of *Papyrocranus afer* was collected during January, 2010 to December 2011 from the landing sites of artisanal fishermen from Lekki Lagoon at Epe Jetty. The fishermen employed utilized gears including cast and gill nets, traps and hook and lines in fishing. Samples procured were transported in ice chest to Hydrobiology and Fisheries Research Unit, Department of Zoology, University of Ibadan, where there were preserved by deep freezing ($-4^0C$) prior to analysis.

### 2.3 Laboratory Procedures

The preserved specimens were allowed to thaw, mopped and wiped dried with tissues paper before laboratory procedures. Fish specimens were identified following description of Idodo-Umeh [26], measured

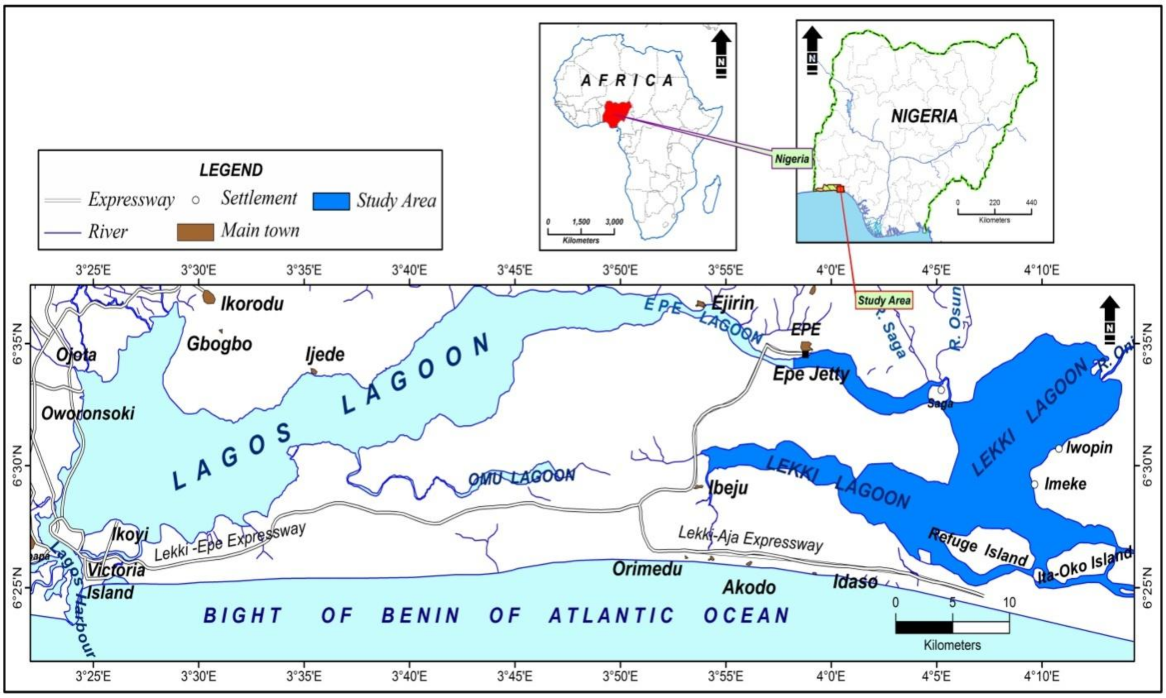



**Fig. 1. Map of lagoon complex of western Nigeria showing study area ( )**
*Insert: Map of Africa showing location of Nigeria.*
*Administrative Map of Nigeria showing the study area*

**Fig. 2. *Papyrocranus afer***

to the standard and fork lengths using fish measuring board nearest 1 cm and weight in grams of individual fish using an electric balance to the nearest 0.01g (Pro-Explorer Model 1106).

### 2.3.1 Growth and Age Studies by Indirect Approach

**Length Frequency Distribution and Growth Derived Parameter:** The length frequency distribution of sample was analyzed using FishBase Length Analysis Wizard to obtain mean length-at-age, which was assumed to represent cohort (age group) and to create the model yield (biomass) curve of the sample. The mean length-at-age data obtained were used to estimate growth parameters using von Bertalanffy [29] and Gulland and Holt [30] plots. The fish growth was described by von Bertalanffy growth function (vBGF) [29] represented by the equation:

$$Lt = L\infty\ (1\text{-}e^{(-K)}\ (t\text{-}t_0)$$

Lt = predicted length at time t, $L_\infty$ = asymptotic length, e = base of the natural log t, T = time, $t_o$ = a small negative or positive number representing the age a fish would have at zero length and K = growth coefficient. The parameters L∞ and K were obtained from the Guland-Holt plot of the growth rate against the mean length at ages. The interception at the mean length axis gave the parameter L∞. Length at maturity ($L_m$) was the average length at which fish of a given population mature for the first time. The value and its standard error are calculated from an empirical relationship between length at first maturity and asymptotic length $L_{inf}$ according to Froese and Binohlan[31]. Length at maximum yield ($L_{opt}$) was the length class with the highest biomass in an unfished population, where the number of survivors multiplied with their average weight reaches a maximum in line with Beverton[32]; $L_{opt}$ and its standard error are estimated from an empirical relationship between $L_{opt}$ and $L_{\infty}$ [33]. The life span ($T_{max}$) was the approximate maximum age that fish of a given population would reach. Following Taylor[33], it was calculated as the age at 95% of L∞., using the parameters of the von Bertalanffy growth function as estimated above, viz.: $T_{max} = t_0 + 3 / K$.

The growth performance index ($Ø^1$) was computed from the formula described in Getabu [34] as follows: $Ø^1 = \text{Log } K + 2 \text{ Log } L_{\infty}$ where K and $L_{\infty}$ = parameters of the Bertalanffy's growth equation while Total mortality (Z) was estimated according to Beverton and Holt [35] as:

$$Z = (K (L_{\infty} - L_x)) / L_x - L^1$$

Where

K and $L_{\infty}$ = parameters of the Bertalanffy's growth equation
$L_x$ = mean length in the catch (cm)
$L^1$= smallest length that was fully represented in the catch samples

Exploitation ratio (R) was the ratio of Total mortality (Z) to von Bertallanffy growth coefficient (K).

## 2.3.2 Age Studies by Direct Method

**Interpretation of Annual Growth Marks:** A direct method of counting growth marks on hard parts of fish namely cleithra, scales and opercula was also used for the age studies. These processes comprised the collection, preparation, examination, interpretation and measuring of growth marks on the hard parts.

*2.3.2.1 Scales study*

Key scales were taken below the 27th groove of the lateral line on the left side of the fish with the head was facing left using forceps. Scales were cleaned in tepid water and examined under a binocular microscope for age determination [36], then photographed with digital camera. The length (radius) of scale were measured with graph paper and recorded. When examination was not made on the same day, the scales were put in between two slides and held with cellotape.

*2.3.2.2 Cleihtra study*

Cleithra bones were removed from the left side of the fish, boiled in water for 3 minutes for easy removal of soft tissue on them, and the bones air dried [37]. They were immersed in glycerine and first examined with a hand lens, followed by observation under a dissecting microscope under direct light; the growth marks were then counted. The length of cleithra were measured in cm using a graph paper and recorded.

*2.3.2.3 Opercula study*

Opercular bone was removed from left side of the body, cleaned in 5% ammonium hydroxide solution for 2 hours, washed in distilled water and stored in paper envelope until examination [38]. Growth marks were counted and interpreted. The length of each opercular bone was measured with graph paper and recorded. Photomicrographs of all hard parts were taken.

*2.3.2.4 Otolith study*

Otoliths were removed from fish by dissection of their heads opened lengthwise to expose the brain using a dissecting blade. Otoliths were prepared and processed [21,39] on glass plate in a successive carborundum powder having grit sizes of 400, 600 and 800 µm.

All the hard parts were preliminary viewed with the aid of a hand lens using reflected light and a dark background. Subsequently, low power binocular dissecting microscope and/or reflected light were required to aid in the discernment and assessment of growth marks. Clearly defined growth (annular) marks were carefully examined at appropriate magnifications, and counted only when a mark was uninterrupted on the entire hard part. All marks questionable in this regard were excluded.

The relationships between standard length of fish and hard parts (opercular length, scale radius cleithra length and otolith radius) were described by the regression equation:

$$Y = a + b X$$

Where

L = Standard length of fish (cm),
X = Hard part length opercular length.

Correlation Coefficient (r) was calculated from regression analysis.

## 2.4 Back Calculation

The procedure for back-calculation of lengths at various ages was done according to Fraser [40] and Lee [41]; the Fraser-Lee equation:

$$Lt = c + (LT - c)(S_t/ST)$$

Where:

Lt = Length at age t,
LT=Total fish length,
$S_t$=Scale radius length at age t,
ST=Total scale radius and
c=Carlander's constant

## 2.5 Statistical Analysis

Data were analyzed using descriptive statistics by means of Microsoft Excel 2007 (Microsoft, Redmond, WA, USA), and presented as means ± standard deviation (S.D.). Pearson correlation coefficient was used to establish relationship between body length and hard part lengths. FishBase Length Analysis Wizard was used to validate modes from length frequency distribution.

## 3. RESULTS

## 3.1 Size Distribution

### 3.1.1 Length-frequency distribution

In all, 1,154 specimens ranging in size from 3.2-75.1 cm (34.86±17.2cm) standard length and body weight 7.9-1,958.8g (249.12±28.56g). Four modes were revealed by analysis of length frequency distribution (Fig. 3) of *P. afer* in Lekki Lagoon. Mean length at each mode and ages (cohorts) were 13.45 (Age $0^+$), 34.45 (Age $1^+$), 49.50 (Age $2^+$) and 61 cm (Age $3^+$). The most frequently caught age group was Age $1^+$ which constituted 78% of the samples. The percentage of mature specimens was 23.8% (276) while the percentage of specimens with optimum yield (Lopt) was 13.6% (158). Based on the length frequency distribution, the yield (biomass) (Fig. 4) indicated that small *P. afer* (approximately 20cm and less) virtually did not contribute to the total yield. The most frequently caught length is 34.5cm; the length at optimum yield was 49.5cm while the length at first maturity was 41.1 cm.

### 3.1.2 Von Bertalanffy Growth function and other growth derived parameter

The growth constant, K, and the asymptotic length, (L∞) from Gulland – Hold plot (Fig. 5a) were 0.33 cm/yr and 77.6 cm respectively; hypothetical age the fish would have had at zero length ($t_o$) was - 0.46/yr by von Bertalanffy curve (Fig. 5b). The fastest growth rate, 21cm/yr was between ages $0^+$ and $1^+$. The slowest growth rate, 12.5 cm/yr was between ages $2^+$ and $3^+$. The mean length of *P. afer* in the lagoon, which was 34.cm, fell within the age group $1^+$ Empirical estimated growth performance index ($Ø^1$), life span and total mortality of *P. afer* in Lekki Lagoon were 3.29, 9 years and 0.65/ yr.

## 3.2 Age of *Papyrocranus afer* using Hard Parts

There were incomplete (false) and complete (true) growth rings on the cleithra, scale and opercular bone (Plates 1a, b and c). A total of 301 specimens were aged using these hard parts out of which 60.5 % (182) recorded well-defined and clear annual growth marks on the hard parts. Fish specimens between: 29.7 cm - 36.4 cm (mean=33.05 ± 1.8cm), 39.1 cm – 52.5 (mean=44. 57 ± 1.6), and 53.2 – 64.1 (mean=58.4 ± 1.7) had 1, 2 and 3 true annuli on all the hard parts respectively. There were no clear annuli that would have facilitated ageing from otoliths.

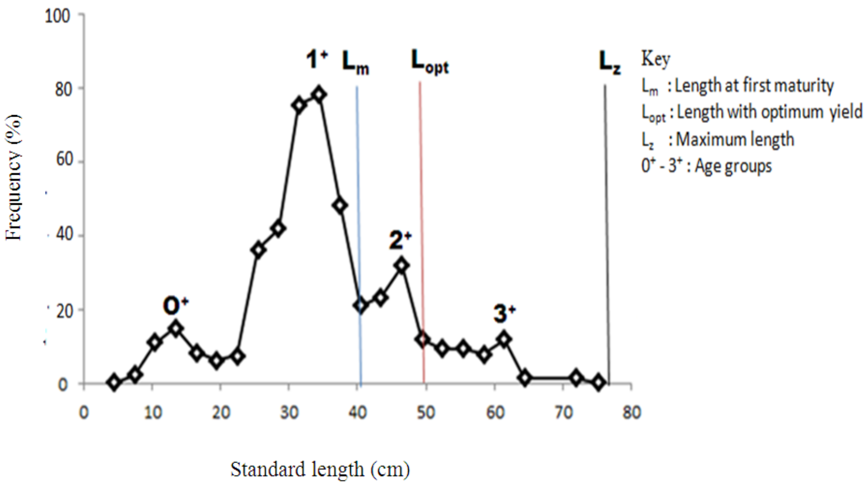



**Fig. 3. Length frequency distribution of *Papyrocranus afer* from Lekki Lagoon**

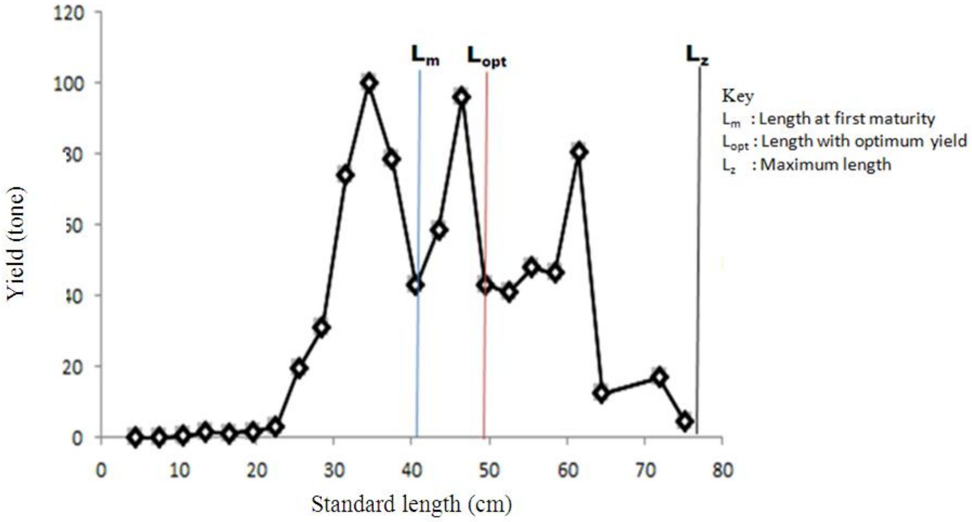
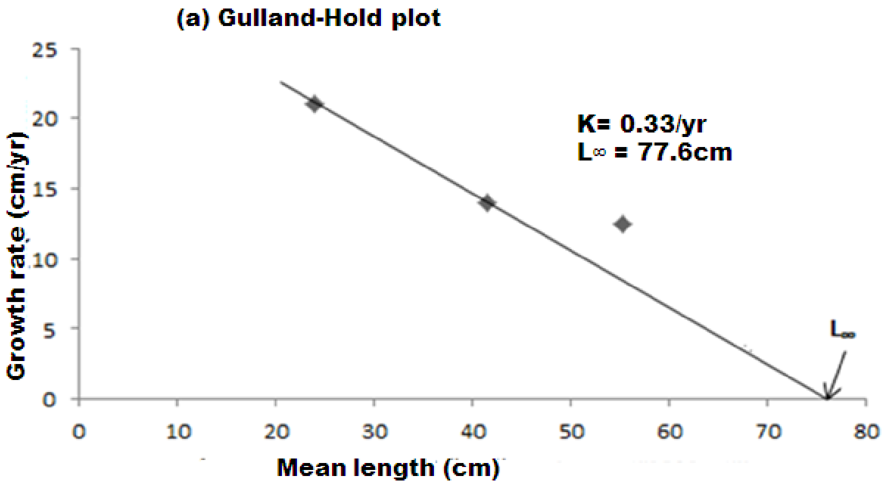



**Fig. 4. Yield (Biomass) of *Papyrocranus afer* from Lekki Lagoon**



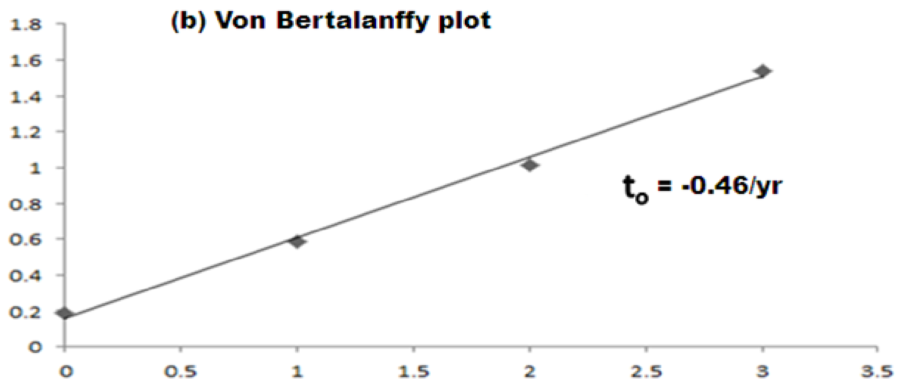




**Fig. 5. Von Bertalanffy growth parameters for *Papyrocranus afer* determined using Gulland and Hold (a) and von Bertalanffy (b) plots**

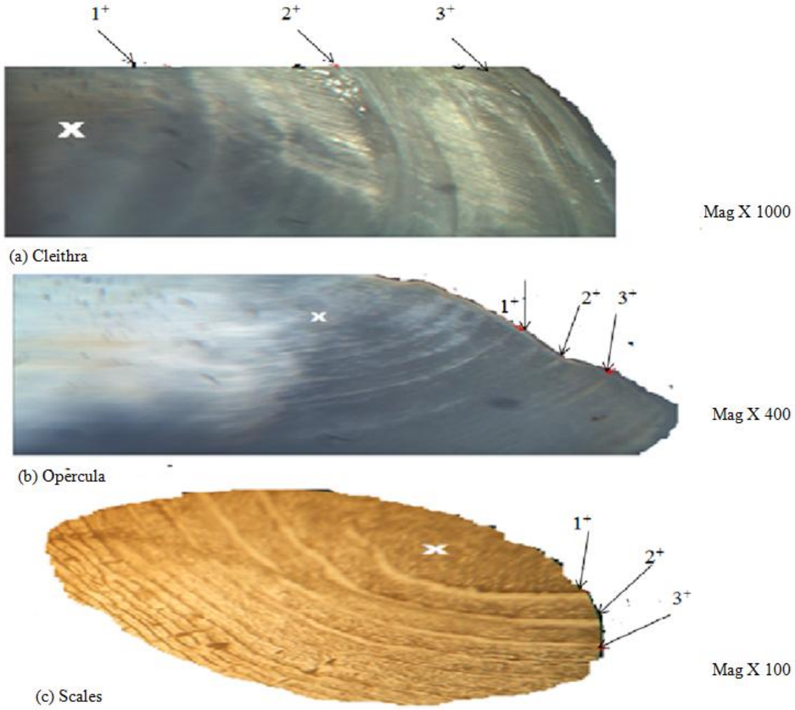



**Plate. 1a, b and c: Cross section of hard parts of *Papyrocranus afer* showing annuli for years 1-3. The point X was the centre of growth of part: a=cleithra, b=operculum and c=scale**

### 3.3 Back Calculation of Length-at-age from Hard Parts

The predictive regression equation for the relationship fish length and hard parts (Fig. 6) were linear and proportional, having a positive intercept on the ordinate. This indicated that the growth annuli on hard parts could be used for back calculation of body length at different ages. Back calculated length at the ages $1^+$, $2^+$ and $3^+$ were 33.2, 42.3 and 58.1 cm for operculum, 31.1, 40.4 and 57.6 cm for cleithra and 29.7 38.1 and 57.0 cm for scale respectively. Positive correlation (r) coefficients were obtained for scale radius (r=0.59), cleithra (0.88), and opercula lengths (0.93) with fish length (Fig. 6).

## 4. DISCUSSION

von Bertallanffy growth coefficient (K=0.33) recorded for *P. afer* in the present study indicate that it is not a short-lived species. Short lived species have K values ≥ 1.0 yrs and attained, maximum length available (asymptotic length) (L∞) in a year or two [42]. The estimated life-span of this species, 9 yrs, suggested that *P. afer* from Lekki Lagoon is relatively a long-lived species. Moreau, Bambino and Pauly [43] reported that environmental condition like temperature leads to rapid juvenile growth (less vulnerable to predation) towards small size in adult, with increase chance of survival) (high growth coefficient (K), low maximum length attainable ($L_\infty$) or slow juvenile growth towards large adult size (low K and high $L_\infty$) as reported for *P. afer* in this study. In addition, Beverton and Holt [35] asserted that L∞ and k are inversely proportional to each other. It implies that fishes with high L∞ have lower k suggesting the reliability of the estimated von Bertalanffy growth parameters for *P.* afer in the present study.

The estimated von Bertalanffy parameters, maximum length attainable (L∞) and growth coefficient (K) recorded for *P. afer* in this study are higher than those reported by King [44] (L∞, 57.1, K=0.289) in Cross River, south eastern Nigeria, perhaps due to ecological differences. Physiological conditions of fish, fishing pressure and sampling may also affect values of L∞ and K [45]. The slight difference between the maximum length observed for *P. afer* and the asymptotic length suggested that this species in Lekki Lagoon could grow to full potential. To maintain a fishery population in equilibrium, it is of paramount importance to give each fish the chance of reproducing at least once in its lifetime to recruit the stock [45]. Hence, the length at first capture should be bigger than the length at maturity. The percentage of the total catch was less than the size at first maturity (41.1cm) in this study was 77.2%; suggesting growth overfishing. This may cause a great reduction of this fish catch in future due to the continuous removal of pre-spawning fishes.

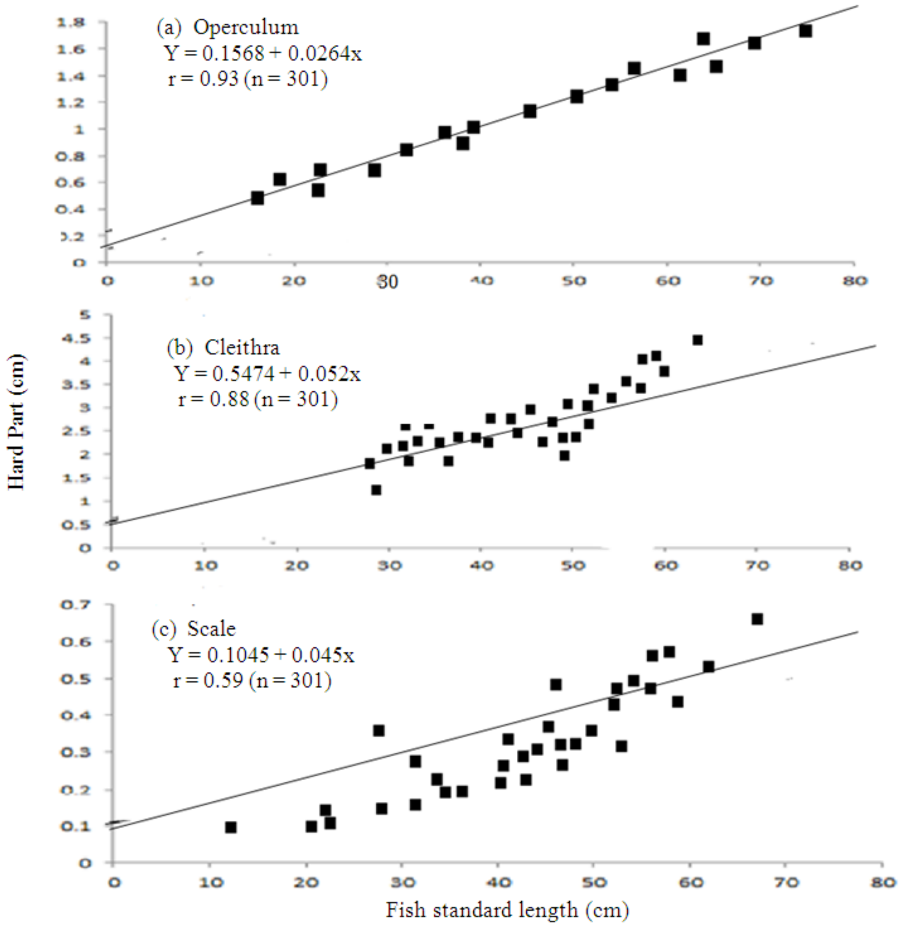



**Fig. 6. Relationship between fish length and hard part length of *Papyrocranus afer* from Lekki Lagoon**

One of the criteria for selection of species for aquaculture based on estimates of growth rates under natural conditions based on growth performance index ($Ø^1$) estimated for *P. afer* is relatively high. This suggests that *P. afer* is suitable for culture in controlled enclosure [46]. Growth performance index recorded for *P. afer* in Lekki Lagoon is higher than $Ø^1$= 2.97 recorded for this species by King [44] in Cross Rivers possibly due to environmental differences, food types and availability. Rapid growth is an important indicator that determines the economic viability of fishery production system. Djama et al. [45] reported growth performance index as useful tool for discriminating the Atlantic coastal stocks off Africa of the clupeid *Sardinella maderensis* in Lobe Estuary, Cameroun. Getabu [33] reported 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.

The exploitation ratio (1.96), which is close to 2, estimated for *P. afer* in the present study is indicative that this species may soon be over exploited. This may be due to increasing demand which is depleting collection from the wild, habitat destruction due to dredging and also sand filling and seasonal availability. In addition, *P. afer* like most ornamental fishes in Nigeria are also consumed as food, and this together with increasing trade in ornamental fishes, there is further pressure on their exploitation. Over exploitation can be the main negative impact of aquarium trade [46]. It not only causes negative ecological consequences, but it also reduces fish production, which leads to negative social and economic consequences [47].

The relationship between natural mortality and von Bertallanfy growth parameter (k) appears to differ from one group of fish to another [35]. A fish which approaches its ultimate length quickly - i.e. has a high value of K - is likely to have a high natural mortality (M) whereas a fish that grows slowly (a low K) is likely to have a low M [35]. Hence, mortality of *P. afer* in Lekki Lagoon could be more of fishing mortality since it approaches its ultimate length slowly because of its low K value.

*Papyrocranus afer* could attain its full potential in Lekki Lagoon but fishing mortality through the operation of the ornamental fish trade and local consumption as food fish may have drastically reduced the optimum performance of this species in Lekki Lagoon. Management effort may use this information for sustainable exploitation of this species which may soon collapse in Lekki Lagoon if exploitation continues without proper management.

A maximum age of three years recorded for *Papyrocranus afer* by length frequency method was in agreement with three years obtained by counting growth marks hard parts. *P. afer* lengths and diameters of its hard parts were positive and were directly proportional. This is in line with one of the basic assumptions inherent in growth studies using skeletal hard parts that size of fish and size of hard part are closely related throughout the entire life cycle [48,49]; hence their suitability for growth studies. In addition, the hard parts used in the present study namely cleithra, opercula and scales exhibited concentric growth marks which increased in number with the size of the fish and were interpreted as annual growth mark. Although the time period of deposition of growth marks were not verified, it is assumed that each annulus is a yearly event [49]. This is the basic assumption of ageing studies in which age validation has not yet been attempted or completed [50]. Scales were the most practical ageing structure in term of ease of collection, processing, legibility, and precision of interpretation. It also recorded the highest linear relationship with fish size.

## 5. CONCLUSION

This paper provides information on age and growth derived parameters including sizes at maturity and optimum yields, as well as population size structure of *Papyrocranus afer* which is a prerequisite for holistic management effort and rational exploitation of this species in Lekki Lagoon. For examples, size at population structure is indispensable for management effort because size is central in understanding growth, reproduction, recruitment; a change in size is often an early signal of perturbation in an environment. High exploitation, growth over-fishing and high proportion of immature fish indicated vulnerability of *P. afer* to over-exploitation, hence the need for its conservation in Lekki Lagoon

## DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

## COMPETING INTERESTS

Author has declared that no competing interests exist.

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