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Morphological characterization of the Reticulate Knifefish *Papyrocranus afer* (Gunther 1868) from Lekki Lagoon

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Abstract
Morphological discreteness of *Papyrocranus afer* was studied using truss morphometric measurements utilizing 8 landmarks corresponding to 16 distances on the body, 14 traditional morphometric characters, 10 meristic counts and form factor to ascertain the population characteristics in Lekki Lagoon. Sample (n=1,156) for the study ranged from 5.2 – 75.9 cm total length and weighed 10.9 - 1958.4 g. Two Principal Components (PC) were extracted from Principal Component Analysis both accounting for 82.81% of total variance in size-corrected truss morphometric variables. The PC1 showed high loading (72.8%) for measurements on the posterior region of the fish, while PC2 showed low loadings (9.1%) for variables in the head region. The lower variation accounted for by PC2 suggests conserved variables that could be of taxonomic importance in this species. Form factor of males and females (0.001) confirmed eel-like body form for *P. afer* in Lekki Lagoon.

Keywords: *Papyrocranus afer*, form factor, Morphomerty, Lekki Lagoon

1. Introduction
The first step in any fish conservation and successful management is accurate identification and species characterization; morphology of fish is the main source of information. Fish populations are recognized by using morphological character [5, 12]. These characters are categorized into morphometrics, which denote measurable structures on fish body including head length, body depth, fin length, eye diameter *et cetera*, or ratios between such measurements) and meristic (virtually all countable body structures namely fin rays, scales and gill rakers) characters. Morphological characters are most important in fisheries biology for species characterization and understanding the function of diverse morphological forms in ecology among various taxonomic categories [14, 25]. Morphometric analysis of fish is an indispensable tool for evaluating and characterizing strains stocks of a species by detecting insidious shape variation that are independent of size [14]. In spite of advances in molecular techniques that directly examine biochemical and molecular genetic variations [32], both morphometric and meristic characterization studies are still actively relevant today. To this extent, truss network system is increasingly used for fish morphometric measurements with the purpose of species and/or stock differentiation because it covers the whole fish body in uniform network, and increases the possibility of extracting morphometric differences within and between species [24, 30]. Morphometric variations among stocks of fish species are recognized as an important basis for identifying stocks [23, 26].
In order to evaluate the significant changes in body shapes of fish from different populations or species, and in a particular region, the form factor is an important tool [15]. It is one of the most important biological parameters for management and conservation of natural populations [15, 16]. There is dearth of information on form factor of indigenous fish species including the knife fish in Nigeria. However, there exist several documented studies on population/stock structures in fishes using morphological traits in Nigeria.
Studies on length-weight relation of any fish species remain an imperative requirement for the study of its population [20]; it enables the comparison of the same species from different environment. Like any other morphometric characters, length-weight relationship can be used as a character for the differentiation of taxonomic units although this relationship changes with various developmental events in life such as metamorphosis, growth and onset of maturity [20].

The length-weight relationship of fish also provides a means for calculating weight from length of fish and can indicate taxonomic differences and events in the life history of fish [19, 20].

Understanding the morphometrics of the fish species will enhance the development of cost-effective aquaculture protocols and thus increase in productivity [19]. There is dearth of information on morphometry and form factor of the reticulate knife fish, *Papyrocranus afer* (Gunther, 1868) in Nigeria. Studies on length-weight relationship of this species are also scanty [11, 18, 27]. Therefore, this study provide baseline date on morphometry, form factor and length-weight relationship of *Papyrocranus afer*, an emerging ornamental fish of interest in from a freshwater tropical lagoon in Nigeria.

2. Materials and methods

2.1 Study area

Lekki Lagoon is located in Lagos and Ogun states of Nigeria. It lies on longitude 4˚00' and 4˚15' E and latitude 6˚25' and 6˚37' N (Figure 1). The lagoon is a large expanse of freshwater habitat perhaps due to the maximum impacts of the Rivers (Oni, Oshun and Saga) discharging into it. It supports a major fishery and the knife fish, *Papyrocranus afer* has been observed to occur throughout the year in it.

2.2 Sample collection

Monthly samples of *Papyrocranus afer* were purchased from landing site of Fishermen from Lekki Lagoon at Epe Jetty, also called Chief Landing site. The artisanal fishermen employ set and floating net of myriads mesh sizes, assorted traps and hooks and lines for fishing. Collected samples were transported in ice-chest to the laboratory, and preserved by deep freezing prior to examination. In the laboratory, samples were sorted and identified using keys, catalogue and diagrams [29, 17].

2.3 Data collection

2.3.1 Morphometry of *Papyrocranus afer*

Truss morphometric measurement [4, 31] using eight landmarks (Figure 2) corresponding to sixteen distances on the body form were used for species characterization of *P. afer*. Landmarks were (1) anterior tip of snout at jaw, (2) most posterior aspects of the nuerocranium (beginning of scale nape), (3) origin of dorsal fin, (4) insertion of dorsal fin, (5) point of insertion of the caudal fin, (6) origin of anal fin (7) insertion of pectoral fin and (8) points of maxillary. Morphometry measurements were made on graph paper graduated in centimeter.

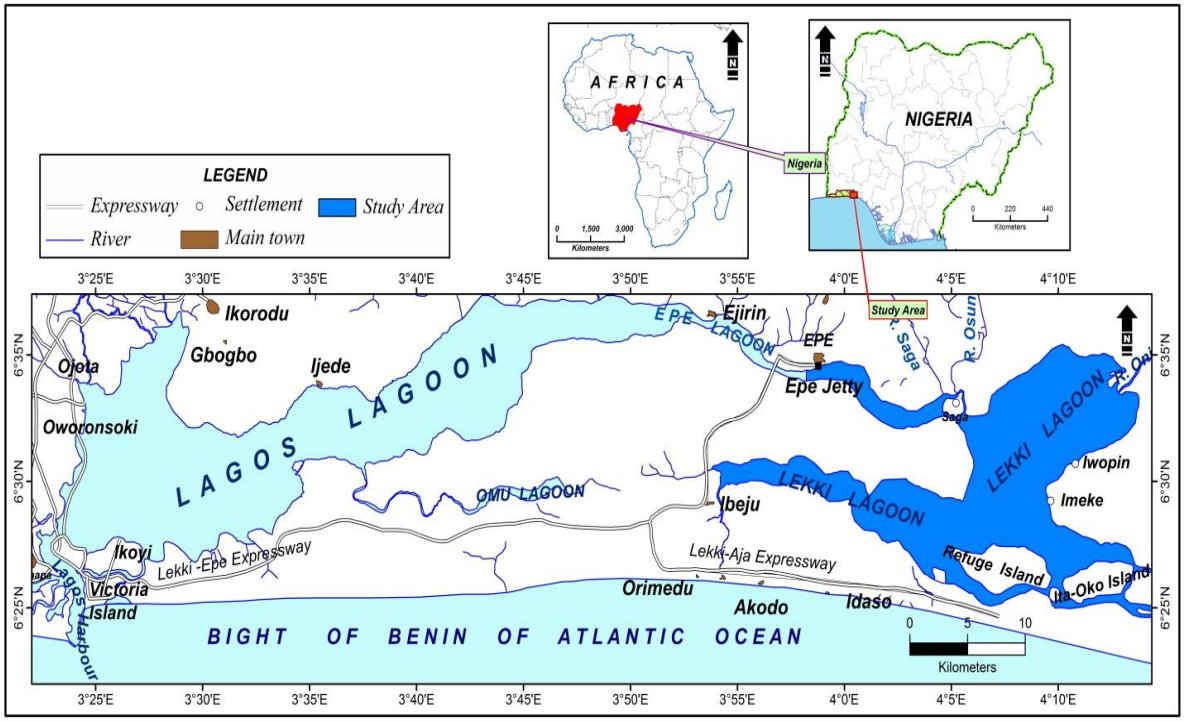


Fig 1: Map of lagoon complex of western Nigeria showing study area ( ). Insert: Map of Africa showing location of Nigeria. Administrative Map of Nigeria showing the study area

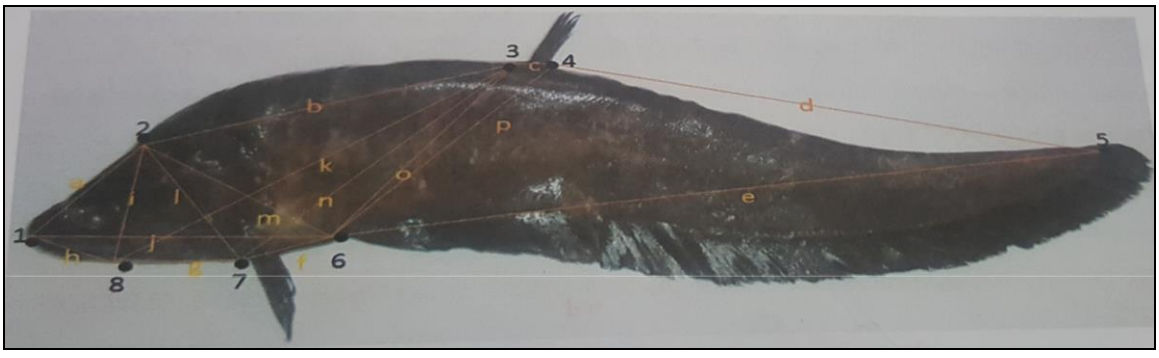


Fig 2: Location of eight landmarks ( ) on *Papyrocranus afer* for constructing truss networks and morphometric measurements (alphabets)

Size-dependent variations from all truss measurement were removed by using the allometric formular:

$M_{adj} = M (L_s/L_o)^b$ [8]

In addition, fourteen traditional morphonetric characters were measured (Table1). All the measurements were made with the head of the fish pointing left (Figure 2). Ten meristic characters were counted for species characterization of *P. afer*; these characters included numbers of branchiostegal rays, nasal barbells, pyloric ceaca, gill raker (lower arch), dorsal fin

Table 1: Morphometric measurements for description of *Papyrocranus afer*

Morphometric parameter	Description
Total length	Distance from the tip of the upper jaw to the end of caudal fin
Standard length	Distance from the tip of the upper jaw to the base of caudal fin
Total weight	Total weight of the fish including gut and gonads
Head length	Distance from the tip of the snout to the posterior margin of the operculum
Body Depth	Distance from the base of the dorsal fin to the base of the anal fin
Eye length	Horizontal diameter of the orbicular cavity
Snout length	Distance from the upper lip to the fleshy anterior end of the eye orbit
Post-orbital length	Distance from the posterior margin of the eye to the end of the operculum
Gape	Vertical measurement of the mouth when completely opens
Dorsal fin length	Distance from the longest dorsal fin ray to the base of the dorsal fin
Anal fin length	Distance from the base of the anal fin to the tip of the anal fin
Pectoral fin length fin	Distance from the tip of the longest pectoral fin ray to the base of the pectoral
Caudal fin length	Distance from the upper lobe of the caudal peduncle to the most posteriorpoint of the caudal fin
Ventral serration	Distance from the beginning point of the ventral spine to the last

rays, pectoral fin rays, ventral serrations, vertebrae and the number of lateral line scale. The pectorals were counted on the left side of the head. Where two rays, have a common root, they were counted as one [34]. Vertebrae counts were made after drying at 60 ^OC in an electric-oven TEK Model TFO-10 for 12 hours to enable the flesh around the skeleton to be easily pulled out in one piece on either side; the counts included the atlas and the urostyle.

2.3.2 Length-weight relationship
The relationship between length and weight of the species (male, female and combined sex) was described by the equation: $W = aL^b$ [20]. This was logarithmically transformed into a linear form by the equation Log W = a + b Log L where W = weight of fish in grams, L = standard length of fish in centimeters and 'a' and 'b' are regression constants. Correlation coefficient (r) was determined from regression analysis.

2.3.3 Form factor ($a_{3.0}$)
The form factor ($a_{3.0}$) was calculated using the equation $a_{3.0} = 10^{\log a - s (b-3)}$ [13].

2.4 Statistical analysis
Fish data were subjected to descriptive statistics using Microsoft Excel ® Statistical Tool Pack (2010). Truss measurements were analyzed by Principal Component Analysis using SPSS ® (2006) version 15 statistical package to determine morphometric measurement of highest variations. Pearson correlation coefficient (r) and linear regression was used to establish the relationship between length and weight.

3. Results
One thousand one hundred and fifty six specimens of *Papyrocranus afer* examined ranged in total length from 5.2 – 75.9 cm and weighed 10.9 – 1 958.4g. Seven hundred and fifty-four specimens were characterized using truss measurements. Kaiser-Meyer- Olkin measures of sampling adequacy indicate sample size (n=754) adequacy for characterization of *P. afer* using truss morphometrics. The present value of 0.91 was found to be sufficiently high for truss morphometric measurements. Principal components analysis reduced the size-corrected truss measurements into two principal components, PC1 and PC2 both accounting for 82.81% of total variance within *P. afer* sampled (Table 2). Overall 1,156717 *P. afer* were analyzed for 13 morphometric measurements and 10 meristic characters from Lekki Lagoon. The means, standard deviations and ranges of variation of the morphological measurements of *P. afer* from Lekki Lagoon are presented in Tables 3 and 4. Branchiostegal ray, barbels and pyloric caeca recorded no variation; they are useful for this species identification (Table 4).

Length-weight relationship
The logarithmic transformations of the length-weight relationship of male, female and combined sexes are illustrated in Figures 3. These are represented by the following regression equations:

- Male: Log W = 0.49 + 2.54 Log L (r = 0.79, n = 384)
- Female: Log W = 0.381 + 2.674 Log L (r = 0.94, n = 242)
- Combined sexes: Log W = 0.531 + 2.94 Log L (r = 0.94, n = 1,154).

The value of b (< 3) indicates negative allometric growth in *P. afer*.

Form factor
The estimated form factor for males and female were 0.001 and 0.003 respectively.

Table 2: Rotated (variance) components matrix showing components' scores and percentage variance for truss measurement on *Papyrocranus afer* (n = 754) from Lekki Lagoon

Truss measurements	Components (Principal Components)	
	PC1	PC2
k: distance between point of anterior insertion of dorsal fin and most posterior point of the maxilary.	0.956	
g: distance between most posterior point of the maxillary and point of insertion of the pectoral fin.	0.887	
l: distance between end point of the neurocranium and point of insertion of the pectoral fin	0.852	
o: distance between anterior point of insertion of the dorsal fin and anterior beginning of the anal fin	0.834	
p: distance between anterior beginning of the anal fin and posterior insertion point of the dorsal fin	0.827	
j: distance between the anterior tip of snout on upper jaw and beginning of the anal fin	0.820	
b: distance between end point of the neurocranium and insertion point of the dorsal fin	0.809	
n: distance between anterior point of insertion of the dorsal fin and point of insertion of the pectoral fin	0.807	
d: distance between posterior point of insertion of the dorsal fin and end of the caudal fin	0.784	
e: distance between beginning of the anal fin and the end of the caudal peduncle	0.743	
m: distance between end point of the neurocranium and point of insertion of the anal fin	0.705	
f: distance between point of insertion of the pectoral fin and beginning of the anal fin	0.655	
i: distance between end point of the neurocranium and insertion point of the pectoral fin		0.796
a: distance between the anterior tip of snout on upper jaw and end point of the neurocranium		0.947
h: distance between the anterior tip of snout on upper jaw and most posterior point of the maxilary.		0.867
% Variance	72.836	9.76
Cumulative Variance	72.81	82.81

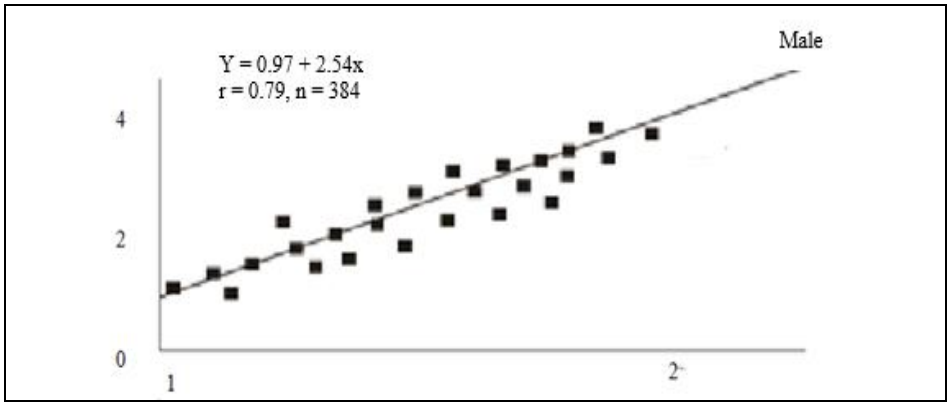
Key: k, g, i, o, p, a, b, n, d, e, m and f are posterior body morphometrics while i, j and h are anterior body morphometrics

Table 3: Summary of morphometric measurement describing *Papyrocranus afer* from Lekki Lagoon

Morphometric measurement	Range	Mean ± Standard deviation
Total length (cm)	5.2 - 75.9	36.8± 11.4
Standard length (cm)	3.2 – 71.4	34.9 ± 11.2
Total weight (g)	10.9 - 1958.3	293.7 ± 79.7
Head length (cm)	2.3 - 12.5	6.5 ± 1.6
Eye diameter (cm)	0.6 - 1.9	1.2 ± 0.3
Pre-orbital length (cm)	0.3 – 2.2	2.0 ± 0.3
Post orbital length (cm)	1.2 – 8.1	4.5 ± 1.3
Body depth (cm)	2.4 -14.4	6.8 ± 1.8
Gape (cm)	0.6 – 5.6	2.4 ± 0.8
Dorsal fin length (cm)	0.5 – 5.2	28.1 ± 9.0
Anal fin length (cm)	3.9 – 58.2	3.9 ± 1.2
Pectoral fin length	1.1 – 7.7	2.7 ± 0.4
Ventral serration (cm)	1.1 – 4.9	5.3 ± 1.1

Table 4: Meristic features of *Papyrocranus afer* from Lekki Lagoon

Meristic Count	Range	Mean ± Standard deviation
Branchiostegal ray	-	7±0
Barbels	-	2±0
Gill rakers (lower arch)	6 - 10	9±1
Dorsal fin ray	4 -9	6±2
Pectoral fin ray	4 -15	9 ± 5
Ventral serrations	23 -43	36 ± 3
Vertebrae	76-77	77 ±1
Scale on opercular	11 - 15	13 ± 1
Lateral line scale	132 - 145	132 ± 5
Pyloric caeca	-	2 ± 0



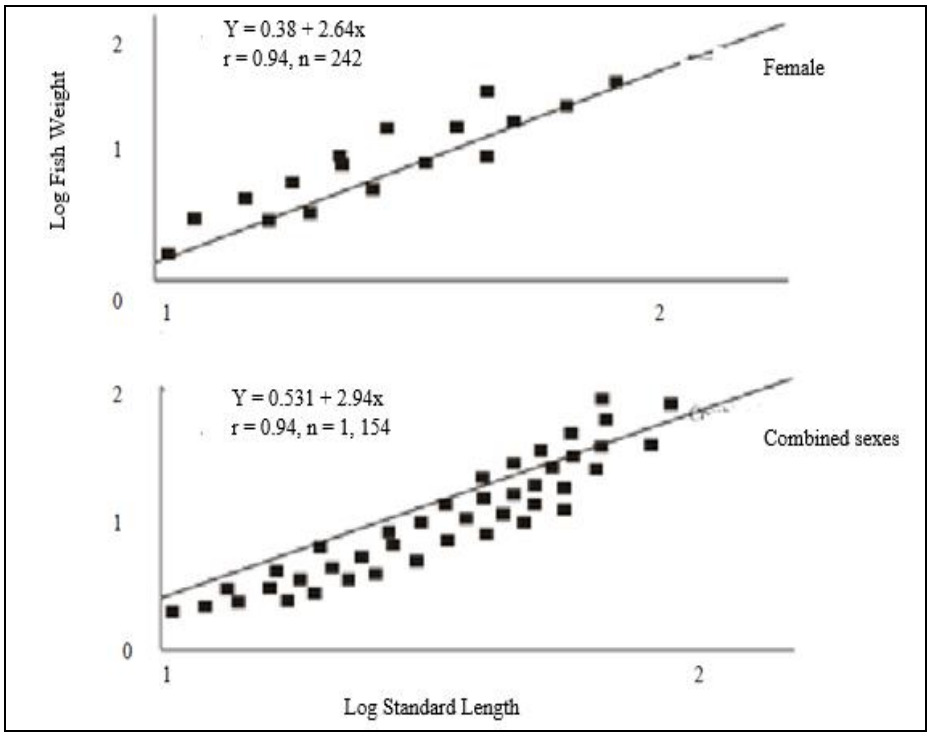


Fig 3: Length-weight relationship of *Papyrocranus afer* from Lekki Lagoon

4. Discussion

In Principal component analysis, principal components (PC) usually indicate which characters contributed significantly to the discrimination of population [21]. The results for PC1 indicate that morphometric differentiation among samples was largely located in the posterior region of *Papyrocranus afer*. The values by PC2 show that these variables showed the least change among individual of *P. afer* suggesting that they were conservative variables. This further suggests their taxonomic relevance since head variables appear conservative or less liable to change across individual samples. A fish body consist of head, trunk and tail [33] but only the head length is frequently measured and use for fish description though, it contains insignificant portion of flesh, contrasting to the bulky trunk and tail, there are few studies that have considered the trunk or the body for their studies in Nigeria [2, 3, 28].

Both standard and total lengths of *Papyrocranus afer* are comparable to those reported in River Osse, (standard length ranged from 13.7 – 38.1) Southwestern Nigeria [8]. Idodo-Umeh [17] reported standard length of 40,5cm in River Asse, Bendel State and standard length of 74 cm at Yanga Market, Ole, Isoko Souht Delta State. It has however been shown that the maximum size attainable in fish is generally location specific [18] which was attributed the differences in maximum size attained by fish in different to industrial activities. High fishing pressure, environmental pollution and degradation have been implicated as the likely causes of difference in maximum sizes of *Chrischthys nigridigitatus* in the lower Nun River, Niger Delta [1].

The number of branchiostegal rays remains constant in all the samples encountered during the present study suggesting they are independent of body size, and there is no change in meristic count with increasing body length [4]. The final counts of most meristic features are set prior to transformation from larval to juvenile stages, for some meristic features, the sensitive period governing the actual number of elements attained may be fixed prior to or after hatching depending on the taxon [22], hence, their bases for taxonomic study.

The value of b, the allometic growth exponent, below 3 indicated negative allometric growths for the species in Lekki Lagoon. This implies that *P. afer* in Lekki Lagoon is lean but not robust; the fish becomes lighter for its length as it grows. Several workers have made similar reports for *P. afer*. Growth exponent b values of 2.99 were recorded for *P. afer* from Anambra River, Southeastern Nigeria [11], and 2.66 in Ikpa River for the same species [18]. Patterns of growth are known to vary with age, maturity and sex [7]; geographical location, environmental condition [10]. Growth exponent for males was lower than female. This suggests that females are heavier than male for any length. It has been reported that lower values for males are common in other species of fish such as *Mormyrus rume*, *Liza klunzingeri*, *Parastromateus* niger, *Clarius batrachus* [6, 8, 19]. The form factor of the individuals fell within eel body shape [13] and indicated the species body form approximated eel or is eel-like. This could account for the negative allometric growth recorded for this species.

5. Conclusion

In conclusion, morphometric features in the head region are conservation, and could be of taxonomic importance for this species. Negative allometric growth (faster growth in lengths than weights) recorded support the values of form-factor (eel-like body) for *P. afer* in Lekki Lagoon. Meristic counts, conventional and truss morphometric measurement as well as length-weight relationship are inexpensive tools for fish stock identification. This study provides baseline data for population assessment of *Papyrocranus afer* in Lekki Lagoon

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