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Morphometric adaptation of Bobo Croaker, *Pseudotolithus elongatus* (Bowdich, 1825) (Sciaenidae) in the Cross-River estuary, Nigeria

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ABSTRACT

This study was carried out to assess the morphological adaptation of the Bobo croaker (*Pseudotolithus elongatus*) in different portions of the Cross River Estuary. A total of one hundred and twenty fish specimens were collected from landings (Ikang, Nsidung, Oron and Ibaka beaches) of the artisanal fisheries from September to November, 2018. Fifteen traits including standard length, body depth/width, head and fin characteristics were measured to the nearest 0.1cm using Veneer Callipers and measuring board. Spatial data were analyzed using one-way analysis of variance (ANOVA) which showed ten significant traits between habitats. Derived discriminant functions with ten standardized morphometric traits identified nine traits as significant contributors (Wilk's Lambda at $P<0.001$) among which body width (BW) contributed most (Wilks' Lambda=0.430) while orbital length (OL) was the least (Wilk's Lambda=0.819). The derived classification functions correctly classified up to 77.5% of original grouped cases; the remaining 22.5% could be attributed to other factors rather than morphology. While the best classification success was derived for Ibaka group (96.7%), the lowest success was for Ikang group (60%). All pair-wise Mahalanobis distance (D^2) values in the different groups correlated significantly ($P<0.05$) to the approximate pair-wise geographic distance value. The plot of first two canonical variables (CDF I and II) was able to significantly separate the samples into four distinct groups implying morphological adaptation of *P. elongatus* to discrete habitats. Hence different management strategies should be used to maintain these morphologically separated stocks.

INTRODUCTION

Fish morphology is the study of the shape and external structures of fish. Morphometric studies involve the quantitative evaluation of the external morphology of an organism in order to understand their variability in size and shape using measurable indices such as different body parts relative to their total length or weight (Mojekwu and Anumudu, 2015). Several researchers have observed, described and analysed these on different fish species in order to evaluate the importance of the variations of shape within a species for taxonomic studies, speciation and adaptation. Morphometric studies of fish include the works of Sedaghat *et al*. (2012) on *Paracobitis malapterurus* in the Zarrin-Gol River, Northern Iraq, Gogoi and Goswami (2015) on *Amblypharyngodonn mola* in the Assam River, Manorama and Ramunujam (2016) on *Pethia shalynius* in the Umiam River, Northeast India, Langer *et al*. (2013) on *Tor putitora* in the Jhajjar stream, India.

Bobo croaker (*Pseudotolithus elongatus*) are sciaenids found mostly along the West African coast. They are commercially important due to high demand as food fish with high market value. They constitute up to 40% of the total fish landings on the Nigerian coast (Gaffer, 1994) and 43.4% of the total catch by artisanal fishermen in the Cross River estuary (Etim *et al*., 1994).

Estuaries are known to be subjected to varying environmental factors which are always at their extremes. Thus, these factors may interact with each other to influence the morphological traits of resident fish, making them particularly relevant for understanding the sources of morphometric variation between fish populations. Most fish species have been recognized for their ability to evolve various morphological and behavioural adaptations which allow them to tolerate a wide range of ecological parameters both in capture and culture fisheries (Idowu *et al*., 2012).

Also, since fish populations inhabiting different habitats may be impacted differently by local force, the present study is designed to investigate whether populations of *P. elongates* inhabiting different portions of the Cross River estuary have undergone any significant morphometric divergence. The results of this study can help in understanding the stock structure so that proper management technique could be applied to conserve discrete stocks.

MATERIALS AND METHODS

Study area

The Cross-River Estuary is relatively the biggest estuary in the Gulf of Guinea, situating between latitudes 04˚10' and 05˚10'N and longitudes 008˚15' and 008˚35'E. Three main rivers, namely;

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Cross River, Great Kwa River and the Akpa Yafe River, empty into this estuary. It is also a very highly productive system in terms of fish catch supporting a wide variety of shell and fin fishes (Nawa, 1986). The mean annual fish catch from the artisanal fisheries of this system within Nigeria had been estimated at 65,000 tons making it one of the most productive estuaries in tropical Africa (Moses, 1987).

Collection of samples

Four landing sites (Ikang, Nsidung, Oron and Ibaka beaches) of the artisanal fisheries were selected for the study. A total of 120 fish specimens (Total length: 14.30cm-55.40cm), 30 from each station, were collected from September to November, 2018.

Morphometric measurements

Fifteen traits including standard lengths, body depth/width, head and fin characters (Fig. 1) were measured to the nearest 0.1cm using Veneer Callipers and measuring board. Except for standard length (SL), each morphometric trait was correlated with total length, and parameters that correlated significantly at $p<0.05$ were transformed to eliminate size effect using the allometric formula given by Elliot *et al*. (1995):

$$M_{adj} = M\left(\frac{L_s}{L_o}\right)^b, \quad (1)$$

where: M_{adj}= Adjusted measurement, M= Original measurement, L_o= Total length of fish specimen, L_s= Overall mean TL for all fish specimens in all taxonomic groups b= slope of regression line of logM against $\log L_o$

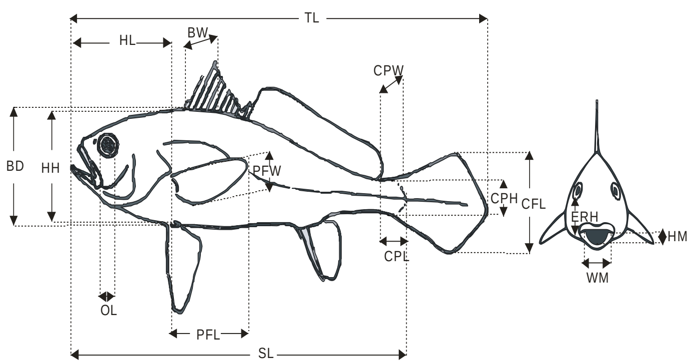

Fig. 1. Schematic diagram of *Pseudotolithus elongates* showing morphometric description: total length (TL), standard length (SL), body depth (BD), body width (BW), head length (HL), head height (HH), orbital length (OL), relative eye height (ERH), pectoral fin length (PFL), pectoral fin width (PFW), caudal fin height (CFH), caudal peduncle length (CPL), caudal peduncle height (CPH), caudal peduncle width (CPW), mouth width (WM) and mouth height (HM).

RESULTS

Statistical analysis

Spatial data were analyzed using one-way analysis of variance (ANOVA) and those traits that flagged significant differences were further separated using Duncan Multiple Test of difference. Of these, apart from total and standard lengths, 10 morphometric traits (HL, OL, WM, HM, BW, PFW, CPL, CPW, CPH and CFL) showed significant variation between habitats (Table 1) and were further subjected to Principal Component Analysis (PCA) in order to evaluate the relationship between different factors and morphometric traits. The trend in distribution across different habitats was measured using Canonical Discriminant Function Analysis (DFA) as described in Negi *et al*. (2015) and Nofrita *et al*. (2015).

The mean (±SD) standard lengths of *P. elongatus* from the Cross River Estuary were as follows: 22.49±8.76,17.64±4.60,24.65±5.44 and 15.38±1.23 cm in Ikang, Nsidung, Oron and Ibaka beaches respectively. The results of the Principle Component Analysis indicate that PC1 accounted for 53.00% of the total morphometric characteristics and positively correlated with all linear dimensions of size, which indicated low size effect on the morphometric characteristics of the analyzed populations. PC2 and PC3 accounted for 25.37% and 7.53% of the total variation respectively being positively correlated with some variables and negatively correlated with others (Table 2). However, PC1 and PC2 with Eigenvalues > 1 were able to account for total variance observed.

Table 1. Morphometric characteristics of *Pseudotolithus elongatus* (n = 120, Mean±SD)

S/N	Measurements (cm)	Variable code	Ikang	Nsidung	Oron	Ibaka
1	Total length	TL	26.50±8.84[a]	21.56±4.48[b]	28.56±5.40[a]	18.87±1.35[b]
2	Standard length	SL	22.49±8.76[a]	17.64±4.60[b]	24.65±5.44[a]	15.38±1.23[b]
3	Body depth	BD	4.43±0.77[a]	4.34±0.56[a]	4.63±0.58[a]	4.36±0.39[a]
4	Body width	BW	2.29±0.17[a]	2.21±0.09[a]	2.43±0.10[b]	1.99±0.25[c]
5	Head length	HL	5.14±0.88[a]	5.16±0.49[a]	5.44±0.46[b]	4.64±0.39[c]
6	Head height	HH	3.84±1.07[a]	4.01±0.52[a]	4.30±0.54[a]	3.95±0.23[a]
7	Orbital length	OL	0.65±0.10[a]	0.57±0.08[b]	0.58±0.08[b]	0.56±0.06[b]
8	Relative eye height	ERH	1.45±0.44[a]	1.34±0.23[a]	1.58±0.27[a]	1.33±0.13[a]
9	Pectoral fin length	PFL	3.69±0.51[a]	4.02±0.14[b]	4.25±0.14[b]	3.72±0.45[a]
10	Pectoral fin width	PFW	0.72±0.12[a]	0.63±0.14[a]	0.65±0.15[a]	0.71±0.09[a]
11	Caudal fin height	CFL	4.45±1.05[a]	3.46±0.37[b]	3.72±0.40[c]	3.62±0.40[c]
12	Caudal peduncle length	CPL	2.20±0.65[a]	1.70±0.17[bc]	1.94±0.23[b]	1.63±0.28[c]
13	Caudal peduncle height	CPH	1.41±0.15[a]	1.17±0.15[b]	1.41±0.22[a]	1.16±0.12[b]
14	Caudal peduncle width	CPW	0.86±0.10[a]	0.64±0.14[b]	0.81±0.07[a]	0.54±0.07[b]
15	Mouth width	WM	1.24±0.12[a]	1.02±0.31[b]	1.21±0.29[a]	0.88±0.25[b]
16	Mouth height	HM	1.20±0.42[a]	1.32±0.12[ab]	1.53±0.14[b]	0.98±0.21[c]

Variable code refers to Fig. 1, Mean values in similar row with different letters are significantly different at $p<0.05$

Table 2. Total variance explained by the Principal Component Analysis

Components	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.300	53.00	53.00	5.300	53.000	53.00
2	2.537	25.37	78.37	2.537	25.37	78.37
3	0.753	7.53	85.90			
4	0.393	3.93	89.83			
5	0.246	2.46	92.29			
6	0.227	2.27	94.55			
7	0.186	1.86	96.41			
8	0.164	1.64	98.06			
9	0.128	1.29	99.34			
10	0.066	.66	100.00			

The Kaiser-Meyer-Olkin test gave a KMO coefficient of 0.845 (Table 3) indicating that the samples were adequate enough to explain any morphometric variability between eco-morphs. Derived discriminant functions with ten standardized morphometric traits identified nine traits as significant contributors (Wilk's Lambda at

P<0.001) among which body width (BW) contributed most (Wilks' Lambda=0.430) while orbital length (OL) was the least (Wilk's Lambda=0.819) (Table 4). Canonical discriminant function analysis revealed that CDFI accounted for 95.50% while CDFII accounted for 8.4% percentage of variance with respective Eigen values of 3.19 and 0.29 (Table 5).

Table 3. KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.845
Bartlett's Test of Sphericity	Approx. Chi-Square	1121.592
	df	45
	Sig.	0.00

The derived classification functions correctly classified up to 77.5% of original grouped cases; the remaining 22.5% could be attributed to other factors rather than morphology. While the best classification success was derived for Ibaka group (96.7%), the lowest success was for Ikang group (60%) (Table 6). All pair-wise Mahalanobis distance (D^2) values in the different groups correlated significantly (P<0.05) with the approximate pair-wise geographic distance value (Table 7). Plot of 1st canonical discriminant function (CDFI) against 2nd canonical discriminant function (CDFII) showed that samples from different stations (Ikang, Nsidung, Oron and Ibaka) were highly isolated (Fig. 2).

Table 4. Tests of Equality of Group Means

Traits	Wilks' Lambda	F	df1	df2	Sig. (P<0.001)
HL	0.649	20.921	3	116	0.000
OL	0.819	8.563	3	116	0.000
WM	0.549	31.802	3	116	0.000
HM	0.455	46.251	3	116	0.000
BW	0.430	51.279	3	116	0.000
PFW	0.915	3.570	3	116	0.016
CPL	0.754	12.625	3	116	0.000
CPW	0.460	45.381	3	116	0.000
CPH	0.666	19.398	3	116	0.000
CFL	0.768	11.699	3	116	0.000

Table 5. Total variance explained by the Discriminant Function Analysis

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	3.187[a]	91.5	91.5	0.872
2	.291[a]	8.4	99.8	0.475
3	.006[a]	0.2	100.0	0.079

First 3 canonical discriminant functions were used in the analysis.

Table 6. Classification Results of the Canonical Function Analysis

		Stations	Predicted Group Membership				Total
			Ikang	Nsidung	Oron	Ibaka	
Original	Count	Ikang	18	4	8	0	30
		Nsidung	2	21	6	1	30
		Oron	2	3	25	0	30
		Ibaka	0	1	0	29	30
	%	Ikang	60.0	13.3	26.7	.0	100.0
		Nsidung	6.7	70.0	20.0	3.3	100.0
		Oron	6.7	10.0	83.3	0.0	100.0
		Ibaka	0.0	3.3	0.0	96.7	100.0

Table 7. Mahalanobis distance between the two closest groups

S/N	Traits	D^2-Statistic	Between Groups	F-Statistic	df1	df2	Sig. (P<0.05)
1	HM	0.306	Ikang and Nsidung	4.593	1	116.000	0.034
2	CPW	1.920	Ikang and Nsidung	14.278	2	115.000	0.00
3	CPH	1.986	Ikang and Nsidung	9.757	3	114.000	0.00
4	PFW	1.986	Ikang and Nsidung	7.254	4	113.000	0.00

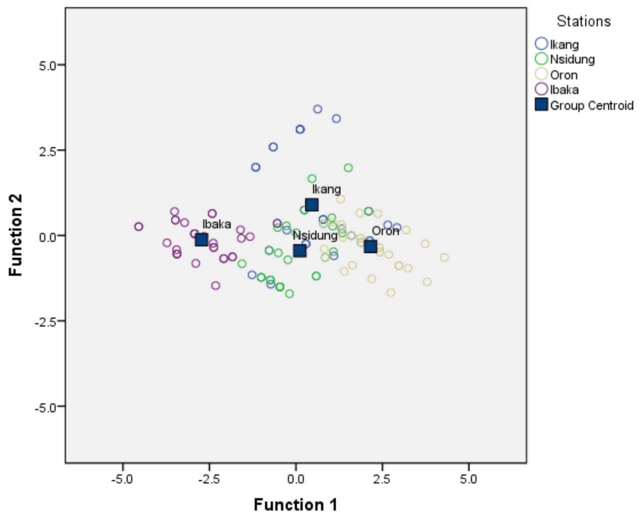

Fig. 2. Plot of Canonical discriminant functions (F1 and F2)

DISCUSSION

The findings of this study agrees with that of Nofrita *et al*. (2015) who reported that successful species that inhabit a particular aquatic habitat whether as resident or opportunistic species had been subjected to varying environmental conditions which could have made them adjust their traits naturally in order to cope with and adapt to the changing environments. In fish and other aquatic organisms inhabiting different eco-regions, their degree of morphometric variations, distribution and abundance relates to some extent with the impact created by local forces, natural or anthropogenic. Estuaries are typical among such regions which are subject to highly variable environmental conditions such as tides, waves and fluvial processes. Other environmental parameters such as water velocity and depth may also influence the morphology of fish species. Also, there was observed meaningful differences in four morphometric traits between stations (P<0.05). The reason behind morphological differences between populations are to segregate them into distinct stocks each possessing similar morphometric attribute (Poulet *et al*., 2004). It has been suggested that the morphological characteristics of fish are determined by genetic, environment and the interaction between them (Pinheiro *et al*., 2005). The observed morphometric distinction in population of *P. elongatus* in the Cross River Estuary can be attributed partly to environmental parameters as reported in the work of (Negi *et al.*, 2015). Water type can hinder gene flow between populations inhabiting different portions of the estuary while each clade develop or modify their phenotype to adapt to the habitat condition. It is well known that morphological characteristics can show high plasticity in response to differences in environmental conditions (Negi *et al*., 2015). The influences of environmental parameters on morphometric characters are well discussed by several authors in the course of fish population segregation (Samaee *et al*., 2006). These morphological differences may be solely related to body shape variation and not to size effects which were successfully accounted for by allometric transformation.

CONCLUSION

The plot of first two canonical variables was able to significantly separate the samples into four distinct groups using four morphometric traits such as mouth height, caudal peduncle width, caudal peduncle height and pelvic fin width. The observed differences could be as a result of both feeding and foraging attributes. Difference in mouth height could be traceable to size of prey, while differences in fin measurements (caudal and pelvic) could be attributed to foraging and swimming propensities. Other traits such as orbital length and body width removed from the canonical matrix could have been due to chance or some environmental parameters rather than morphometric. This implies morphological adaptation of *P. elongatus* to discrete habitats. Hence different management strategies should be used to maintain these morphologically separated stocks.

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