Comparative Morphology of *Ethmalosa fimbriata* (Bowdich, 1825) From Three Estuaries Adjoining the Gulf of Guinea, Nigeria

Ochuko Joshua Eriegha[1,2]*, Jerimoth Kesena Ekelemu[1], Oster Francis Nwachi[1]

[1]Department of Fisheries and Aquaculture, Delta State University
Abraka, Nigeria
[2]Department of Fisheries and Aquaculture, Nigeria Maritime University
Okerenkoko, Delta State, Nigeria
Email: ochukodegreat@gmail.com; ochuko.eriegha@nmu.edu.ng

Abstract

Environmental interactions have long been considered an important factor in morphological differentiation in fish species. This study evaluated the morphological variations in Ethmalosa fimbriata from three water bodies (Qua Iboe estuary, Escravos estuary, and Lagos lagoon) adjoining the Gulf of Guinea, Nigeria. Fish samples were collected with the assistance of fishers using nets and were taken to the laboratory, where they were identified. Morphological evaluations were thereafter made on a total of 450 samples, comprising 150 random samples from each water body. Fish from the Qua Iboe estuary and Lagos lagoon shared the most morphometric characteristics (weight, standard length, dorsal fin base, and caudal peduncle length) that were significantly different (P< 0.05) from those in the Escravos estuary. The length-weight regression of E. fimbriata can be described by the following equation: $W = 0.163TL^{2.7078}$, $W = 0.1915TL^{1.4322}$, *and* $W = 0.2039TL^{1.4394}$ *for Qua Iboe estuary, Escravos estuary, and Lagos lagoon, respectively. The regression coefficient b revealed that all three populations of E. fimbriata had a negative allometric growth pattern. Fish samples from the Lagos lagoon had the highest condition factor (1.01±0.02) while those from the Escravos estuary had the least (0.79±0.02). Conclusively, the study revealed that E. fimbriata from the Escravos estuary was less fit compared with the other water bodies. This may be attributed to crude oil pollution, overfishing, and frequent water disturbance by vessels. The data generated is critical to understanding population dynamics and further contributing to sustainable fisheries practices, management, and conservation efforts.*

Keywords: *morphometric, meristic, Ethmalosa fimbriata, Qua Iboe estuary, Escravos estuary, Lagos lagoon.*

Introduction

Nigeria has rich and varied fisheries resources of freshwater, brackish, and marine origin (Bolarinwa *et al.,* 2015) and has been proclaimed as the third most biologically diverse country in Africa with about 800 known fish species (Olaoye and Ojebiyi, 2018). However, in recent years, Nigeria's fisheries production from the capture fisheries has been on a steady decline (Ekpo and Essien-Ibok, 2013; Onuche and Ogbe, 2021). The decline has been attributed to some challenges such as unregulated fishing practices, failure to observe closed seasons, inadequate storage facilities, use of obnoxious/destructive fishing methods, climate change, and environmental degradation among others (Olopade *et al*., 2017; Eriegha and Sam, 2020; George *et al*., 2021). For sustainable exploitation and conservation of fisheries resources, a comprehensive understanding of the stock composition and characteristics is important. The first step in any fish conservation and successful management is accurate identification and species characterization (Kuerzel *et al*., 2022). Fish populations can be recognized by using morphological characters (Mahmoud *et al.,* 2016). These characters are categorized into morphometric [which denote measurable structures on fish bodies] and meristic [virtually all countable body structures] (Soliman *et al*., 2018). Morphometric and meristic characters are considered authentic and the easiest methods for the identification of specimens termed morphological systematics (Olopade *et al*., 2018).

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. Morphometric analysis of fish is an indispensable tool for evaluating and characterizing strain stocks of a species by detecting insidious shape variations that are independent of size (Kaur *et al*., 2019). Despite the recent advances in molecular technology that directly examine biochemical and molecular genetic variations, both morphometric and meristic characterization studies are still actively relevant today (Nwachi and Egbuchunam, 2021; Naser *et al.,* 2023). While

*) Corresponding author

https://ejournal.undip.ac.id/index.php/ijms
DOI: 10.14710/ik.ijms.29.2.211-221
Received : 11-02-2024
Accepted : 21-03-2024

molecular tools offer greater precision and resolution in specific areas, morphological techniques remain valuable for their cost-effectiveness, direct observation capabilities, and applicability to historical specimens (Fischer, 2014). Morphometric variations among stocks of fish species are recognized as an important basis for identifying stocks (Omoniyi *et al*., 2010). The plasticity of fish species in their growth, survival, and other life history characteristics is key to their ability to adapt to environmental changes and makes them suitable indices for assessing the impact of climate variability on aquatic ecosystems (Baldé *et al*., 2019).

Estuaries are dynamic habitats marked by considerable swings in environmental conditions because they are the meeting location of freshwater from rivers and saltwater from the sea (James *et al*., 2007). The unique feature of this water, in combination with other factors (such as food availability), usually influences the growth rate and abundance of fish (Abdul *et al*., 2023). However, just like in other water bodies, the fish biodiversity in the estuaries is rapidly depleting (Atique and An, 2022). There is therefore a need to study the population structure of fish species. *Ethmalosa fimbriata* (Bonga Shad) has often been used as a model for studies of morphology and evolution (Samba *et al*., 2016).

The *E. fimbriata* is an estuarine and coastal clupeid found in abundance in Nigeria (Döring *et al*., 2017; Ndibukke *et al*., 2020). It is the most widespread member of the family, Clupeidae inhabiting the brackish waters of the West African coastal estuaries and can live in a wide and varying range of salinity (Abowei, 2009; Baldé *et al*., 2018). *Ethmalosa fimbriata* is overexploited in Nigeria as a result of an increased number of fishers, increased fishing efforts, and modernization of fishing gear and craft (Ama-Abasi *et al*., 2004). Several studies have been carried out on growth and population dynamics (Soyinka, 2013), sex ratio and length-weight relationship (Ajah and Asuquo, 2017; Abdul *et al*., 2023; Eriegha and Eyo, 2023), and fecundity (Ama- Abasi, 2004) of *E. fimbriata* from different Nigerian water bodies. Despite the global significance of *E. fimbriata*, the comparative morphological diversities of this fish are still mostly unknown. The findings of this study will bridge the aforementioned research gap and will also contribute to scientific literature so that future studies can be compared. Therefore, this present investigation aimed to compare the morphometric characteristics, meristic profile, length–weight relationship, and condition factor of *E. fimbriata* from Qua Iboe estuary, Escravos estuary, and Lagos lagoon. These water bodies were selected based on species richness and distance from each other.

Materials and Methods

This study was carried out in three water bodies that have connections to the Gulf of Guinea, Atlantic Ocean. They were the Qua Iboe estuary, Escravos estuary, and Lagos lagoon (Figure 1.). The sites were also characterized by landing sites with high species richness and availability of economically important fish species. The Qua Iboe estuary which is located in Akwa Ibom State lies within the tropical region in South Eastern Nigeria. It is located at latitudes $4^{o}39^{1}$ and $27^{o}61^{1}$ N and longitudes $7^{o}52^{1}$ and $42^{o}18^{1}$E. It drains it catchment area of about 7.092 km^2 and the river course covers a distance of 151 km from its source at Umunike in Imo State to where it discharges into the Atlantic Ocean at the Bight of Bonny close to Ibeno (Essien-Ibok and Isemin, 2020). The Escravos estuary is located in Delta State and lies within the tropical region in South Southern Nigeria. Located in latitude 5° 34' 56" N and longitude 5° 10' 49" E, the Escravos estuary is noted for shipping and inland waterborne transportation and is the preferred route for ocean-going vessels engaged in the oil and gas industry (Nwaogbe *et al*., 2023).

The vegetation is dominated by red mangroves (*Rhizophora racemosa* and *Rhizophora mangle*). Some other plant species are *Paspalum viginatum* and *Achrostichum aureum* (Onyena *et al*., 2022). The Lagos Lagoon is the largest of the four lagoon systems of the Gulf of Guinea and lies in latitude 6° 26' 59.99" N and longitude 3° 22' 59.99" E. Fresh water from the upland is fed into the lagoon from the northern part of the system by Ogun River, with a host of other smaller rivers as well as tidal creeks. It discharges in the south into the South Atlantic Ocean through the Lagos harbour (Ajao and Fagade, 1990; Alademomi *et al*., 2020). The three water bodies provide ample fishing opportunities for the riparian communities, waterways transportation, and offshore oil exploration.

A total of 450 fish samples, comprising 150 random samples of *E. fimbriata* were collected each from Qua Iboe estuary, Escravos estuary, and Lagos lagoon through indigenous fishers operating in the various water bodies, using purse seine and gill nets (mesh size ranging from 20–50 mm). Morphological measurements and meristic counts were carried out on fresh samples after a thorough species identification using Idodo-Umeh (2003).

Measurement for length (cm) and weight (g) were determined using a meter rule and an electronic weighing balance (OHAUS Corporation, Model SPX622, 600g Max, USA) respectively. All fresh samples of *E. fimbriata* from the three water bodies were examined for 17 morphometric characteristics and 5 meristic counts each. Except for weight, all other 16 morphometric measurements (described in Figure 2.) were measured to the nearest 0.1cm using the meter rule. Length measurements were taken parallel to the antero-posterior body axis. The meristic characters counted were the number of rays on the pectoral fin, pelvic fin, anal fin, dorsal fin, and caudal fin. Counting was made with the head pointing left. Counts were taken as one where two rays originate from a common root.

Determination of length-weight Relationships and condition Factor. The raw data for all the specimens were log-transformed to reduce the effects of non-normality. The relationship between the length and weight of a fish is usually expressed by the equation described by Ricker (1973); $W= a.L^b$. The values of constant "a" and "b" were estimated from the log-transformed values of length and weight i.e. log W=log a + b log L, via least square linear regression. The condition factor (K values) was calculated, using Fulton's condition factor formula (Pauly, 1984); $K= 100W.L^{-3}$.

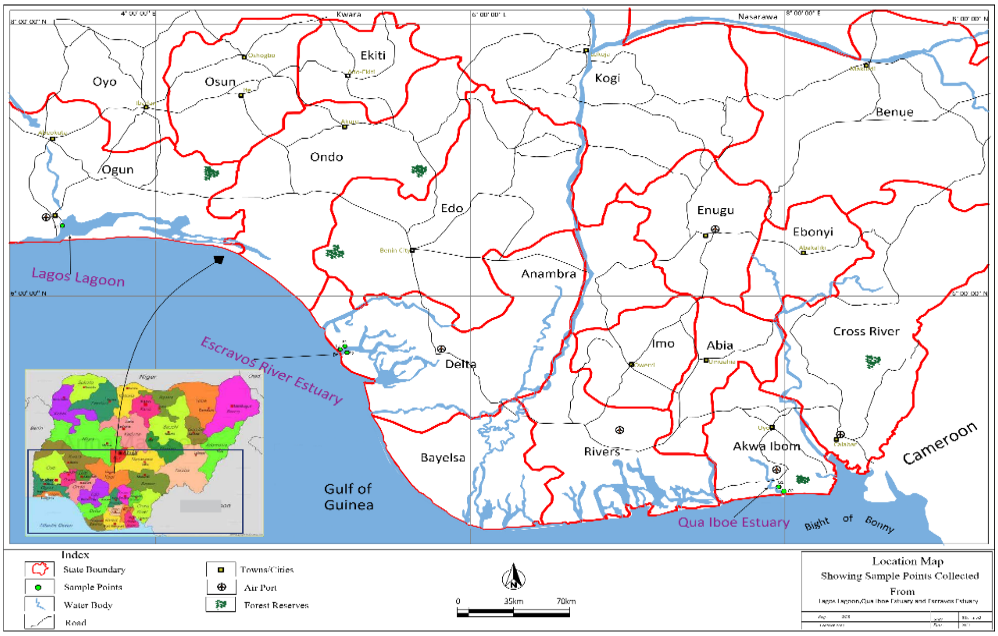

Figure 1. Map of Nigeria showing Qua Iboe estuary, Escravos estuary and Lagos Lagoon

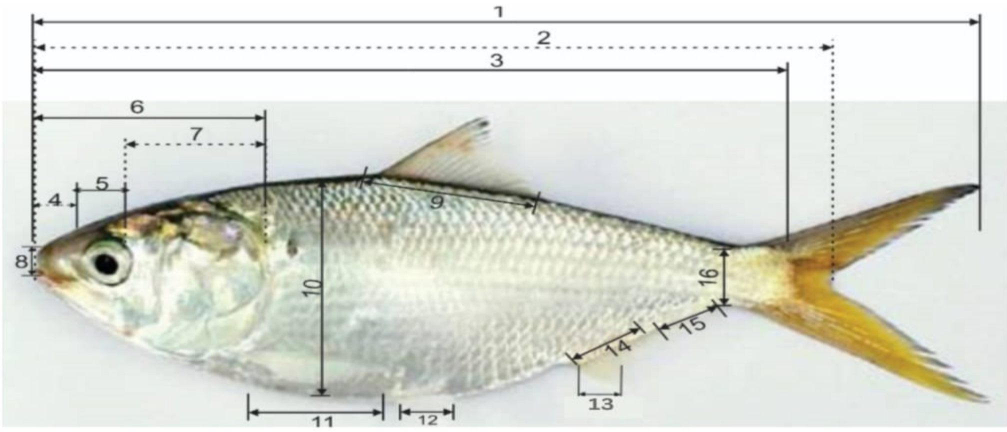

Figure 2. Illustration showing morphometric characters measured in *E. fimbriata*
Note: 1=Total length (TL), 2 = Forked length (FL), 3 = Standard length (SL), 4 = Pre orbital length (PrOL), 5 = Eye diameter (ED), 6 = Head length (HL), 7 = Post orbital length (PoOL), 8=Gape Width (GP, when extended), 9 = Dorsal fin base (DFB), 10 = Body depth (BD), 11= Pectoral fin length (PCFL), 12 = Pelvic fin length (PFL), 13 = Anal fin length (AFL), 14 = Anal fin base (AFB), 15 = Caudal peduncle length (CPL), 16 = Caudal peduncle depth (CPD).

Table 1. Mean values of the morphometric characters of *E. fimbriata* from Qua Iboe estuary, Escravos estuary, and Lagos lagoon (Mean ± S.E)

Measurement	Qua Iboe	Escravos	Lagos Lagoon
Weight (g)	41.88 ± 6.10[b]	23.88 ± 1.57[a]	43.61 ± 5.88[b]
Total length (cm)	16.06 ± 0.55[b]	14.22 ± 0.32[a]	15.20 ± 0.66[a]
Forked length (cm)	13.00 ± 0.46[a]	11.60 ± 0.24[a]	12.28 ± 0.54[a]
Standard length (cm)	12.79 ± 0.44[b]	11.23 ± 0.24[a]	12.94 ± 0.55[b]
Body depth (cm)	3.99 ± 0.16[a]	3.89 ± 0.25[a]	4.02 ± 0.19[a]
Dorsal fin base (cm)	1.81 ± 0.05[b]	1.46 ± 0.03[a]	1.72 ± 0.08[b]
Caudal peduncle length (cm)	1.62 ± 0.36[b]	0.98 ± 0.04[a]	1.19 ± 0.06[ab]
Caudal peduncle depth (cm)	1.27 ± 0.05[b]	1.13 ± 0.03[b]	0.94 ± 0.05[a]
Gape Width (cm)	1.49 ± 0.10[a]	1.71 ± 0.06[ab]	1.97 ± 0.11[b]
Pre orbital length (cm)	0.84 ± 0.05[a]	0.79 ± 0.03[a]	0.81 ± 0.05[a]
Eye diameter (cm)	0.82 ± 0.04[a]	0.78 ± 0.02[a]	0.86 ± 0.04[a]
Post orbital length (cm)	1.49 ± 0.10[a]	1.99 ± 0.06[b]	2.13 ± 0.11[b]
Head length (cm)	3.14 ± 0.17[a]	3.55 ± 0.08[ab]	3.80 ± 0.19[b]
Pelvic fin length (cm)	1.11 ± 0.06[a]	1.21 ± 0.07[a]	2.16 ± 0.13[b]
Pectoral fin length (cm)	2.15 ± 0.11[b]	2.06 ± 0.06[b]	1.31 ± 0.07[a]
Anal fin length (cm)	0.62 ± 0.03[a]	0.88 ± 0.06[b]	0.74 ± 0.05[ab]
Anal fin base (cm)	2.09 ± 0.07[a]	1.87 ± 0.05[a]	1.20 ± 0.11[a]

*Means with different superscripts in the same row are significantly different ($P< 0.05$).

Data analysis

Morphometric characters were expressed as mean ± standard error of the mean. Mean values of the different characters from the three water bodies were compared using a one-way analysis of variance (ANOVA) followed by Tukey's test. The significance level adopted was 95% ($P< 0.05$). Meristic counts were presented as the range (minimum-maximum). Statistical analysis was performed using the Statistical Package for the Social Sciences (Version 20). Both morphometric and meristic data were further subjected to principal component analysis (PCA) using Origin Pro 2022 to reveal patterns in measured correlated variables.

Results and discussion

Morphometric characteristics of E. fimbriata

Analysis of variance (ANOVA) indicated that the differences in morphological characters were highly significant across the water bodies with the following P-values: 0.002 (WT), 0.056 (TL), 0.084 (FL), 0.005 (SL), 0.909 (BD), 0.0001 (DFB), 0.022 (CPL), 0.0001 (CPD), 0.004 (GW), 0.738 (PrOL), 0.228 (ED), 0.0002 (PoOL), 0.017 (HL), 0.00012 (PFL), 0.001 (PCFL), 0.008 (AFL), and 0.180 (AFB). These findings indicated the heterogeneity among the fish populations. Fish from the Qua Iboe estuary and Lagos lagoon shared the most morphometric characteristics that were significantly different ($P< 0.05$) from those in the Escravos estuary. In this respect, they had the greatest WT, SL, DFB, and CPL. See Table 1. The results also showed that the values of 8 external morphometric parameters (WT, TL, FL, SL, BD, DFB, PrOL, and ED) were lower in the Escravos estuary compared with samples from the other two water bodies. The PCA for morphometric parameters of *E. fimbriata* indicated that the first two principal components (PCs) explained 74.84% of the variance (PC1: 65.54%, PC2: 9.30%). See Figure 3. According to PC 1, WT, TL, FL, SL, BD, DFB, GW, PrOL, ED, PoOL, HL, AFL, and AFB had a positive relationship with each other. PC 2 showed a positive correlation between PCFL, CPL, and CPD, and a significantly negative correlation with PFL. PC 1 suggested that WT, TL, FL, SL, BD, DFB, GW, PrOL, ED, PoOL, HL, AFL, and AFB influenced each other so that any external factor influencing the WT, TL, and SL of the fish will also influence the FL, SL, BD, DFB, GW, PrOL, ED, PoOL, HL, AFL, and AFB. Furthermore, PC 2 suggested that PCFL, CPL, and CPD had a direct positive influence on each other, but all (PCFL, CPL, and CPD) had a direct negative influence on the PFL of fish. This indicates that WT, TL, FL, SL, BD, DFB, GW, PrOL, ED, PoOL, HL, AFL, and AFB were the main morphometric traits that can be used to distinguish *E. fimbriata* from other species.

Morphometric characteristics have provided useful results for identifying fish stocks and describing their spatial distributions (Soliman *et al.,* 2018; Tizkar *et al*., 2020; Nwachi and Zelibe, 2022). In this study, morphometric characteristics demonstrated variations among the three populations of *E. fimbriata.* Variations were observed in characters associated with locomotion (pectoral fin, pelvic fin, and caudal peduncle), feeding (eyes and mouth), and other important characteristics that are vital for fish survival. However, fish from the Qua Iboe estuary and Lagos lagoon shared the most common morphometric characteristics. For instance, the weights of fish species from the Escravos estuary were significantly smaller (*P*= 0.002) from samples from the Qua Iboe estuary and Lagos lagoon. This may be attributed to environmentally–induced morphological differences. Variations in morphological characteristics may help the fish cope with environmental variability between different water bodies. The body *shape* of many fish species can respond to temperature, dissolved oxygen, radiation, water depth, food availability, current or hydrology, or correlate with their feeding mode, predation risk, and habitat use (Amoutchi *et al*., 2023). Pressure from predators can also influence the body shape of fish as a more streamlined body shape was observed in fish species in water bodies characterized by high predator presence (Scharnweber *et al*., 2013). Variations were also observed in the eye size diameter of the studied population. This may be attributed to persistent turbidity levels and feeding habits (Lisney and Collin, 2007).

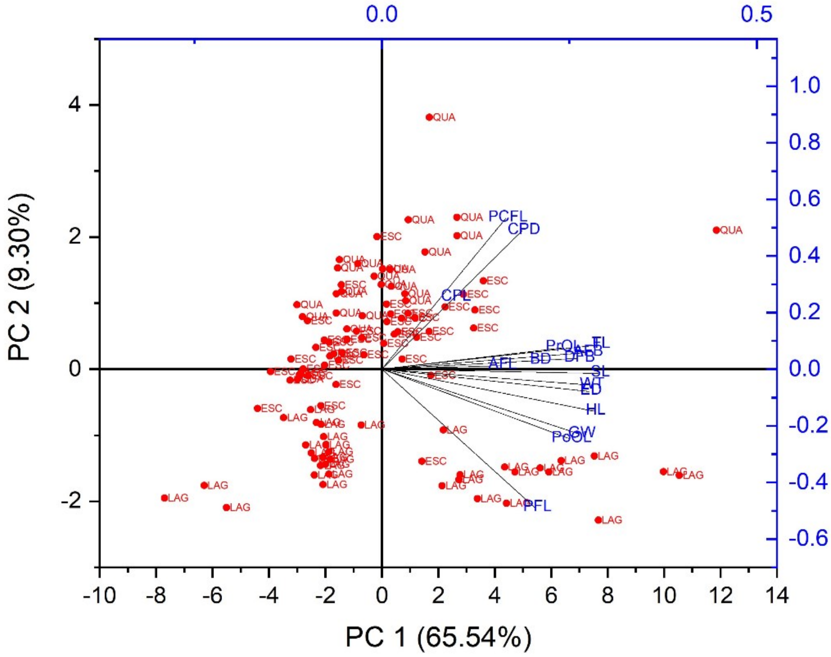

Figure 3. Principal component analysis of the morphometric parameters of *E. fimbriata*

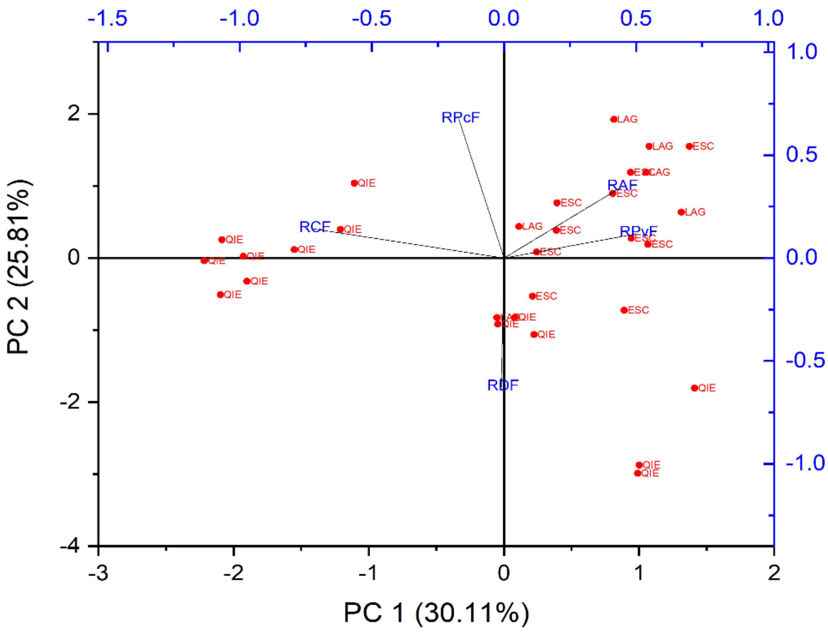

Figure 4. Principal component analysis of the meristic parameters of *E. fimbriata*

Table 2. Mean and Range values of the meristic characters of *E. fimbriata* from Qua Iboe estuary, Escravos estuary and Lagos lagoon

Counts	Qua Iboe estuary	Escravos estuary	Lagos Lagoon
Number of rays on pectoral fin	14.00 (10 -17)[a]	14.73 (13 - 16)[b]	14.83 (13 - 16)[a]
Number of rays on pelvic fin	7.13 (6 - 8)[a]	8.00 (8 - 8)[ab]	8.00 (7 - 9)[b]
Number of rays on anal fin	18.97 (17 - 21)[a]	19.63 (18 - 21)[a]	21.17 (18 - 25)[b]
Number of rays on dorsal fin	17. 33 (15 - 21)[a]	15.91 (15 - 18)[a]	16.02 (15 -17)[a]
Number of rays on caudal fin	24.60 (20 - 28)[b]	21.45 (20 - 24)[a]	23.00 (23 - 23)[ab]

A comparative study of 159 species of fish revealed that a large eye size was associated with increased visual acuity and that species in complex habitats tended to have higher visual acuity than expected after accounting for eye size relative to body size (Caves *et al*., 2017). Lisney *et al*. (2020), however, did not find any evidence that fish in turbid habitats have smaller eyes. Uncommon hydrological conditions such as changes in water flow and salinity have also been reported as primary driving factors for inducing morphological changes in fish species (Dürrani *et al*., 2023). Hence, phenotypic plasticity of morphometric and meristic characters is regarded as a key strategy for populations living in changing environmental conditions. Therefore, it can be deduced that morphological variation plays a significant role in adaptive diversification (Svanbäck 2004). The mean standard length obtained in this study for the three populations was slightly lower than the value (13.46 cm) documented for *E. fimbriata* from the brackish waters of southwestern Nigeria by Soyinka *et al.* (2012).

Meristic characteristics of E. fimbriata

Analyses of the meristic characters revealed variation across the three water bodies. See Table 2. The number of rays on the anal fin from the Lagos lagoon population was significantly higher (P= 0.009) than the range obtained for Qua Iboe and Escravos estuarine populations. All samples from the Escravos estuary had a constant number (8) of pelvic fin rays. Similarly, the number of rays on the caudal fin remained constant (23) in the Lagos lagoon population. The number of rays on the dorsal fin was not statistically significant (P= 0.052) across the three populations. Although a wider range was observed in fish from the Qua Iboe estuary. Qua Iboe estuarine population had the least number of rays on the pectoral fin compared with Escravos and Lagos lagoon. The PCA for meristic parameters of *E. fimbriata* indicated that the first two principal components (PCs) explained 55.92% of the variance (PC1: 30.11%, PC2: 25.81%). See Figure 4. According to PC 1, RAF related positively with RPvF and was negatively related to RCF. PC 2 showed that RPcF related negatively with RDF. PC 1 suggested that RAF and RPvF influenced each other so that any external factor that is positively influencing any also affects the other positively. More so, any external influence on RAF and RPvF will influence the RCF negatively. PC 2 suggested that RPcF had a direct negative influence on RDF. PCA showed that RCF (check the magnitude of the arrow for PC 1) was the main meristic trait that can be used to distinguish *E. fimbriata* from other species.

The numbers of dorsal rays observed in all the populations of this study were slightly different from the range documented by Whitehead (1985) who reported a range of 16-19 in *E. fimbriata*. Although, fish from the Escravos estuary were closer to the range. Similarly, the numbers of anal rays were similar to the range (19-25) provided by Whitehead (1985). However, a narrower range was observed in the anal rays of fish from the Escravos population. Despite the variations in all the meristic counts, the principal component analysis revealed that meristic parameters were not useful in distinguishing populations of *E. fimbriata* across the three water bodies. This was in agreement with Idowu *et al*. (2012), who reported that meristic characters although varying in number were laid down during embryonic development and environmental modification did not change the structural characteristics of morphometric characters. It is therefore possible to conclude that *E. fimbriata* from the three water bodies cannot be separated based on environmental factors.

Length - Weight relationship

The results revealed that the fit index or modeling efficiency was high (with the coefficient of determination ranging from 0.85 to 0.97) for fish from the three water bodies. See Table 3. The length-weight relationship (LWRs) reflects the condition and growth pattern of the fish. This relationship is a very important fishery management tool as it provides information on the relative well-being of the fish population and determines whether somatic growth is isometric or allometric (Ekelemu and Zelibe, 2014; Uneke, 2015).

Table 3. Length-Weight relationship and Condition Factor (*K*) of *E. fimbriata* from Qua Iboe estuary, Escravos estuary, and Lagos lagoon

Water Body	Equation (R^2)	*K* ± S.E	Range of *K*
Qua Iboe estuary	$W = 0.163TL^{2.7078}$ (0.968)	0.93 ± 0.01^b	0.78 – 1.07
Escravos estuary	$W = 0.1915TL^{1.4322}$ (0.854)	0.79 ± 0.02^a	0.44 – 1.13
Lagos Lagoon	$W = 0.2039TL^{1.4394}$ (0.956)	1.01 ± 0.02^c	0.73 – 1.13

*Means with different superscripts in the same column are significantly different ($P< 0.05$).

The value of regression coefficient b revealed that all three populations of *E. fimbriata* experienced a negative allometric growth pattern The negative allometric growth deduced for nearly all analyzed fish (b< 3) suggested that *E. fimbriata* have a relatively slow growth rate and tend to be thinner which may be related to its specific phenotype or the environmental conditions of its habitat (Jisr *et al*., 2018). Only samples from Lagos lagoon were found within the normal expected range of 2 and 4 for teleosts (Bagenal and Tesch, 1978). All values were however in agreement with the report by Soyinka and Kusemiju (2007) and Soyinka *et al.* (2012), that noted a negative allometric growth pattern in *E. fimbriata* from the Lagos lagoon. The relationship between length and weight differs within the same species according to the condition (robustness) of individual fish. LWRs are therefore not constant over the year (Mehanna and Farouk, 2021). The LWRs of fishes are affected by intrinsic and extrinsic factors including the length range of sampled specimens, number, habitat, seasonality, sex, feeding, stomach fullness, etc. (Abbasi *et al*., 2019; Mehmood *et al*., 2021). Other factors such as sex, number of specimens examined, temperature, trophic level, and food availability in the community were also important (Li *et al*., 2023).

Condition factor

The fish species from the Lagos lagoon had the highest Fulton's condition while fish from the Escravos estuary had the lowest condition. See Table 3. The result revealed that *E. fimbriata* from the Escravos estuary were less fit compared with the other water bodies. Condition factor (k) compares the well-being of fish with the hypothesis that heavier fish of a given length are in better physiological condition than the less robust in relation to their welfare (Bagenal and Tesch, 1978). Population dynamics studies have shown that high condition factor values indicated favourable environmental conditions and that of low values less favourable environmental conditions (Blackwell *et al*., 2000).

The computed condition factor for *E. fimbriata* in the Escravos estuary was in agreement with preliminary reports on the same fish species by Eriegha and Eyo, (2023). These values were however lower than the value (2.55) obtained off the coast of Lagos (Soyinka *et al*., 2012). The condition factor of fish can also vary due to nutrition (Abobi and Ekau, 2013) and the condition of life in the aquatic environment (Ndiaye *et al*., 2015). The poor condition of the fish in the Escravos estuary compared with the other water bodies may be attributed to occasional crude oil spillage in the area (Eriegha and Sam, 2020; Binyotubo *et al*., 2022; Eriegha and Eyo, 2023) and frequent water disturbance by boat and ships (Nwaogbe *et al*., 2023). Life cycle, sex, frequency of spawning and sampling season, and overexploitation may also influence the condition factor of fish species (Chigeru and Amachree, 2019; Amoutchi *et al*., 2021).

Conclusion

The study revealed a significant morphological variation among the three populations of *E. fimbriata.* Specifically, fish from the Escravos estuary were significantly smaller compared with samples from the Qua Iboe estuary and Lagos lagoon. Findings from this study also showed that only morphometric parameters can be used to differentiate the *E. fimbriata* from the three stocks as meristic features could not separate them. Fish from all three populations of *E. fimbriata* experienced a negative allometric growth pattern suggesting a relatively slow growth rate. Only samples from Lagos lagoon were found within the normal expected range for teleosts. Similarly, *E. fimbriata* from the Lagos lagoon had the highest condition factor. The lowest condition was observed in samples collected from the Escravos estuary, implying that the stock at the Escravos estuary was overexploited. Therefore, appropriate management strategies, including observance of closed-season fishing (when fishermen are prohibited from fishing during the breeding season), reduction of fishing efforts, and monitoring of fishing gear, should be adopted for sustainable exploitation of this resource. The frequent spillage of crude oil that is endemic to the area should also be checked by the various regulating agencies as well as the immediate cleanup of contaminated sites to mitigate the impacts of such spills.

Acknowledgments

We are deeply grateful to Dr. Victor Oscar Eyo and Dr. Amarachi Onyena for their kind assistance in the field at the Qua Iboe estuary and Lagos Lagoon, respectively. Special thanks to Dr. Joseph Akaninyene for reviewing the manuscript and guidance on statistical analysis.

References

Abbasi, K., Mouludi-Saleh, A., Eagderi, S. & Sarpanah A. 2019. Length-weight relationship and condition factor of eight species of the genera Capoeta, Garra, Chondrostoma, Schizothorax and Paraschistura from Iranian inland waters. *Iran. J. Ichthyol*., 6(4): 264-270. https://doi.org/ 10.220 34/iji.v6i4.432

Abdul, W., Bajela, M., Quadri, A. & Adekoya, E. 2023. Length-weight relationship and condition factor of some commercial fish species in Lekki lagoon, southwest Nigeria. *Ife J. Agric.*, 35(2): 78-87.

Abobi, S.M. & Ekau, W. 2013. Length-weight relationships and condition factors of *Alestes baremoze, Brycinus nurse* and *Schilbe intermedius* from the lower reaches of White Volta River (Yapei), Ghana. *Int. J. Fish. Aquac.*, 5(6): 152-165. https://doi.org/10.5897/IJFA2 012.0001

Abowei, J.F.N. 2009. The morphology, abundance, condition factor and length weight relationship of *Ethmalosa fimbriata* from Nkoro River, Niger Delta Nigeria. *Adv. J. Food Sci. Technol.,* 1(1): 51-56.

Ajah, P.O. & Asuquo, P.E. 2017. Sex Ratio, Length-Weight Relationship and Condition Factor of Ethmalosa fimbriata in The Cross River Estuary, Nigeria. *IOSR J. Biotechnol. Biochem.,* 3(2): 46-55. https://doi.org/10.9790/264X-03024655

Ama-Abasi, D., Holzloehner, S. & Enin, U. 2004. The dynamics of the exploited population of *Ethmalosa fimbriata* (Bowdich, 1825, Clupeidae) in the Cross River Estuary and adjacent Gulf of Guinea. *Fish. Res.*, 68(1-3): 225-235. https://doi.org/10.1016/j.fishres.20 03.12.002

Ama-Abasi, D.E. 2004. Length weight parameters and condition factor of bonga, *Ethmalosa fimbriata* in the crossriver estuary. *Nigeria Global J. Pure and Applied Sci.,* 10(3): 379-383.

Amoutchi, A.I., Mehner, T., Ugbor, O.N., Kargbo, A. & Kouamelan, E.P. 2021. Fishermen's perceptions and experiences toward the impact of climate change and anthropogenic activities on freshwater fish biodiversity in Côte d'Ivoire. *Discov. Sustain.,* 2(1): 56. https://doi.org/ 10. 1007/s43621-021-00062-7

Amoutchi, A.I., Ugbor, O.N., Kouamelan, E.P. & Mehner, T. 2023. Morphological variation of African snakehead (*Parachanna obscura*) populations along climate and habitat gradients in Côte d'Ivoire, West Africa. *Environ. Biol. Fish.*, 106(6): 1233-1246. https://doi.org/10. 1007/s10641-023-01409-x

Atique, U. & An, K.G. 2022. Potential risky exotic fish species, their ecological impacts and potential reasons for invasion in Korean aquatic ecosystems. *J. Ecol. Environ.*, 46(05): 1–13. https://doi.org/10.5141/jee.22.008

Bagenal, T.B. & Tesch, A.T. 1978. Conditions and Growth Patterns in Fresh Water Habitats. Blackwell Scientific Publications, Oxford.

Baldé, B.S., Brehmer, P., Sow, F.N., Ekau, W., Kantoussan, J., Fall, M. & Diouf, M. 2018. Population dynamics and stock assessment of *Ethmalosa fimbriata* in Senegal call for fishing regulation measures. *Reg. Stud. Mar. Sci.*, 24: 165-173. https://doi.org/10.1016/j.rsma.20 18.08.003

Baldé, B.S., Döring, J., Ekau, W., Diouf, M. & Brehmer, P. 2019. Bonga shad (*Ethmalosa fimbriata*) spawning tactics in an upwelling environment. *Fish. Oceanogr.*, 28(6): 686-697. https://doi.org/ 10.1111/fog.12451

Binyotubo, T.E., Eyo, V., Eriegha, O.J. & Eze, F. 2022. Status and Constraints of Artisanal Fishers in Escravos Estuary around Okerenkoko and Kurutie Axis, Niger Delta, Nigeria. *Adv. Multidiscip. Scientif. Res.,* 8: 51-62.

Blackwell, B.G., Brown, M.L. & Willis, D.W. 2000. Relative weight (Wr) status and current use in fisheries assessment and management. *Rev. Fish. Sci.,* 8: 1- 44.

Bolarinwa, J.B., Fasakin, E.A. & Fagbenro, A.O. 2015. Species composition and diversity of the coastal waters of Ondo State, Nigeria. *Int. J. Res. Agricultur. For.*, 2(3): 51 – 58.

Brraich, O.S. & Akhter, S. 2015. Morphometric characters and meristic counts of a fish, *Crossocheilus latius* (Hamilton-Buchanan) from Ranjit Sagar Wetland, India. *Int. J. Fish. Aquat. Stud.*, 2(5): 260-265.

Chigeru, K. & Amachree, D. 2019. Composition, length-weight relationship and condition factor of Schilbeidae (siluiriformes) from Agbura landing site, Bayelsa state, Nigeria. *Glob. Sci. J.*, 7(2): 210–218.

Döring, J., Tiedemann, M., Stäbler, M., Sloterdijk, H. & Ekau, W. 2017. *Ethmalosa fimbriata* (Bowdich 1825), a clupeid fish that exhibits elevated batch fecundity in hypersaline waters. *Fishes*, 2(3): p.13. https://doi.org/10.3390/fishes2030013

Dürrani, Ö., Ateşşahin, T., Eroğlu, M. & Düşükcan, M. 2023. Morphological variations of an invasive cyprinid fish (*Carassius gibelio*) in lentic and lotic environments inferred from the body, otolith, and scale shapes. *Acta Zool.,* 104(3): 458–472. https://doi.org/10.1111/azo.12431

Ekelemu, J.K. & Zelibe, A.A. 2014. Growth patterns and condition of four dominant fish species in Lake Ona, Southern Nigeria. *J. Agric. Food Environ.,* 1(2): 148–155.

Ekpo, I.E., & Essien-Ibok, M.A. 2013. Development, prospects and challenges of artisanal fisheries in Akwa Ibom State, Nigeria. *Int. J. Environ. Sci. Manag. Eng. Res.*, 2(3): 69-86.

Eriegha, O.J. & Sam, K. 2020. Characterization of crude oil impacts and loss of livelihood in the Niger Delta, Nigeria: A fisheries perspective. *Int. J. Mar. Interdiscip. Res.*, 1: 255-273.

Eriegha, O.J. & Eyo, V.O. 2023. Length-Weight Relationship and Condition Factor of *Ethmalosa fimbriata* (Bowdich, 1825) from the Escravos Estuary, Delta State, Nigeria. *J. Aquac. Fish.,* 7(5): 1–4. https://doi.org/10.24966/AAF-5523/1000 51

Fischer, J. 2014. Fish identification tools for biodiversity and fisheries assessments: review and guidance for decision-makers. Rome: FAO Fisheries and Aquaculture Technical Paper.

George, A.D.I., Akinrotimi, O.A. & Nwokoma, U.K. 2021. Productivity and Constraints of Artisanal Fisher folks in Some Local Government of Rivers State, Nigeria. *J. Res. Anim. Sci. Agric.*, 8(2): 32-38.

Idodo-Umeh, G. 2003. Freshwater fishes of Nigeria (taxonomy, ecological notes, diet and utilization*)*. Idodo-Umeh Publishers Limited. 232p.

Idowu, A.A., Odulate, D.O., Olaoye, O.J., Ikenweiwe, N.B., Obasa, S.O. & Abdul, W.O. 2012. Morphometric and meristic study of *Ethmalosa fimbriata* (Bowdich) from brackish water and marine environment. *J. Agric. Sci. Environ.*, 12(1): 60-66. https://doi.org/10.51406/jagse.v12i1.1 360

James, N.C., Cowley, P.D., Whitfield, A.K. & Lamberth, S.J. 2007. Fish communities in temporarily open/closed estuaries from the warm-and cool-temperate regions of South Africa: a review. *Rev. Fish Biol. Fish.*, 17: 565-580. https://doi.org/10.1007/s11160-007-9057-7

Jisr, N., Younes, G., Sukhn, C. & El-Dakdouki, M.H. 2018. Length-weight relationships and relative condition factor of fish inhabiting the marine area of the Eastern Mediterranean city, Tripoli-Lebanon. *The Egypt. J. Aquat. Res.*, 44(4): 299-305. https://doi.org/10.1016/j.ejar.2018.11.004

Kaur, V., Ana, Y. & Heer, B.K. 2019. Morphometric analysis of fish, Labeo rohita (Hamilton) from pond near Kalayat, Kaithal, Haryana India. *J. Fish. Aquat. Stud.*, 7: 299-306.

Kürzel, K., Kaiser, S., Lörz, A.N., Rossel, S., Paulus, E., Peters, J., Schwentner, M., Martinez Arbizu, P., Coleman, C.O., Svavarsson, J. & Brix, S. 2022. Correct species identification and its implications for conservation using Haploniscidae (Crustacea, Isopoda) in Icelandic Waters as a Proxy. *Front. Mar. Sci.*, 8: p.795196. https://doi.org/10.3389/fmars.2021.795196

Li, Y., Feng, M., Huang, L., Zhang, P., Wang, H., Zhang, J., Tian, Y. & Xu, J. 2023. Weight–Length Relationship Analysis Revealing the Impacts of Multiple Factors on Body Shape of Fish in China. *Fishes*, 8(5): 269. https://doi.org/10.3390/fish es8050269

Lisney, T.J. & Collin, S.P. 2007. Relative eye size in elasmobranchs. *Brain. Behav. Evol.*, 69(4): 266-279. https://doi.org/10.1159/000100036

Lisney, T.J., Collin, S.P. & Kelley, J.L. 2020. The effect of ecological factors on eye morphology in the western rainbowfish, *Melanotaenia australis*. *J. Exp. Biol.*, 223(10): 1-11. https://doi.org/10.12 42/jeb.223644

Mahmoud, U.M., Mehanna, S.F. & Mohammad, A.S. 2016. Sexual Dimorphism of Morphometrics and Meristics of *Carangoides Bajad* (Forsskål, 1775) and *Caranx Melampygus* (Cuvier, 1833) from the Southern Red Sea, Egypt. *Int. J. Sci. Res.,* 5(1): 448-456. https://doi.org/10.21275/v5i1.NOV15 2695

Masood, Z., Yasmeen, R., Rehaman, F., Haider, M.S., Zehra, L., Hossain, M.Y., Rehman, H., Asim, U., Ahmed, W. & Shah, Q.U. 2015. Comparative studies on some Morphometric and Meristic Characteristics of the Scales in four *Mugilid* species of the family *Mugilidae* for identifying their Significance in Taxonomy. *Biol. Forum Int. J.*, 7(1): 176-184.

Mehanna, S.F. & Farouk, A.E. 2021. Length-weight relationship of 60 fish species from the Eastern Mediterranean Sea, Egypt (GFCM-GSA 26). *Front. Mar. Sci.*, 8: 1–7. https://doi.org/ 10.3389/ fmars.2021.625422

Mehmood, S., Ahmed, I. & Ali, M.N. 2021. Length-weight relationship, morphometric and meristic controlling elements of three freshwater fish species inhabiting North Western Himalaya. *Egyptian J. Aquat. Biol. Fish.*, 25(6): 243–257. https://doi.org/ 10.21608/ejabf.2021.211325

Naser, M.A., Ahmmed, S., Parvin, S., Mondal, D.K., Islam, M.L. & Mahmud, Y. 2023. Morphometric and Meristic Characteristics of Paradise Threadfin (*Polynemus paradiseus* Linnaeus 1758) in Sundarbans Estuary of Bangladesh. *South Asian J. Exp. Biol.*, 13(1): 12-19. https://doi.org/10.38150/sajeb.13(1).p12-19

Ndiaye, W., Diouf, K., Samba, O., Ndiaye, P., Panfili, J., Marbec, U.M.R., Montpellier, U.D. & Bataillon, P.E. 2015. The length-weight relationship and condition factor of white grouper (*Epinephelus aeneus*, Geoffroy Saint Hilaire, 1817) at the south-west coast of Senegal, West Africa. *Int. J. Adv. Res.*, 3(3): 145-153.

Ndibukke, M.E., Ndibukke, E.E.O. & Akpan, M. 2020. Fish Species Diversity and Abundance from Cross River Estuary, Ibaka Beach, Mbo, Akwa Ibom State, Nigeria. *Akwapoly J. Comm. Sci. Res.*, 5(1): 113-121.

Nwachi, O.F. & Egbuchunam, R. 2021. Morphology of strains produced at partial diallel cross of Gift Tilapia and UPM Red Tilapia. *J. Agric. Agric. Technol.,* 7(1): 64-71.

Nwachi, O.F. & Zelibe, S.A.A. 2022. Morphometric Characterization of Hybrid Progenies of Nile Tilapia and Ecotype Cichlid, 'Wesafu'. *J. Agric. Food Environ.,* 9(2): 10-18.

Nwaogbe, O.R., Eyo, V.O., Olisameka, A. & Nwaogbe, G.O. 2023. Emperical solutions to fish logistics and supply value chain to Warri markets from Escravos route fishing camps, Delta State, Nigeria. *Proccedings of the 37/38 Annual Conference, Association for Aquatic Science*. River State University, Port Harcourt. 26th – 29th June, 2023.

Olaoye, O.J. & Ojebiyi, W.G. 2018. Marine fisheries in Nigeria: A review. *Marine ecology—biotic and abiotic interactions*, 1: p.13. http://doi.org/ 10.5772/intechopen.75032

Olopade, O.A., Taiwo, I.O. & Dienye, H.E. 2017. Management of overfishing in the inland capture fisheries in Nigeria. *J. Limnol. Freshw. Fisheries Res.*, 3(3): 189-194. https://doi.org/ 10.17216/limnofish.335549

Olopade, O.A., Dienye, H.E. & Eyekpegha, A. 2018. Length frequency distribution, length-weight relationship and condition factor of cichlid fishes (Teleostei: Cichlidae) from the New Calabar River, Nigeria. *Iran. J. Ichthyol.*, 5(1): 74-80. https://doi.org/10.22034/iji.v5i1.251

Omoniyi, I.T., Oyewumi, J.O. & Ezeri, G.N.O. 2010. Morphometric structuring of Nile tilapia *Oreochromis niloticus* from three man-made lakes in South West, Nigeria. *Niger. J. Fish.,* 7(1): 39-48.

Onuche, U. & Ogbe, F.G. 2021. Comparative analysis of Nigeria's aquaculture and capture fisheries development across different policy regimes from 1960 to 2016: A case for an inclusive and sustainable fisheries development. University-Led Knowledge and Innovation for Sustainable Development, p.143.

Pauly, D. 1984. Fish population dynamics in tropical waters: A manual for use with programmable calculators. International Center for Living Aquatic Resources Management Manila, 8: 325.

Ricker, W.E. 1973. Two mechanisms that make it impossible to maintain peak-period yields from stocks of Pacific salmon and other fishes. *J. Fish. Board Can.*, 30(9): 1275-1286. https://doi.org/10.1139/f73-207

Samba, O., Diouf, K., Ndiaye, W., Mbengue, M., Diop, K., Ndiaye, P. & Panfili, J. 2016. Evolution of catches and variability in the life history traits of the bonga shad, *Ethmalosa fimbriata* (Bowdich, 1825), a highly targeted small pelagic fish in West African coastal waters. *Int. J. Fish. Aquat. Stud.,* 4(5): 98-108.

Scharnweber, K., Watanabe, K., Syväranta, J., Wanke, T., Monaghan, M.T. & Mehner, T. 2013. Effects of predation pressure and resource use on morphological divergence in omnivorous prey fish. *BMC Evol. Biol.,* 13: 1-12. https://doi.org/10.1186/1471-2148-13-132

Shuai, F., Yu, S., Lek, S. & Li, X. 2018. Habitat effects on intra-species variation in functional morphology: Evidence from freshwater fish. *Ecol. Evol.*, 8(22): 10902-10913.http://doi.org/ 10.10 02/ece3.4555

Soliman, F.M., Mehanna, S.F., Soliman, H.A. & Baker, T.S. 2018. Meristic and morphometric characteristics of Five-Lined Snapper, *Lutjanus quinquelineatus* (Bloch, 1790) from the Red Sea, Egypt. *Egypt. J. Aquat. Biol. Fish.*, 22(1): 41-48. https://doi.org/10.21608/ejabf.2018. 7723

Soyinka, O.O. & Kusemiju, K. 2007. The growth pattern, food and feeding habits of young bonga, *Ethmalosa fimbriata* (Bowdich) from the Lagos and Lekki Lagoons, Nigeria. N*iger. J. Fish.,* 4(1): 1–8.

Soyinka, O.O., Ayo-Olalusi, C.I., Mokah, S. & Edah, B. 2012. Population, growth pattern and biometric characteristics of the bonga, *Ethmalosa fimbriata* (Bowdich) from marine, brackish and freshwaters of South-Western Nigeria. *Zool.*, 10: 6-12.

Soyinka, O.O. 2013. Observation on the sex ratio, fecundity, egg size and gonadosomatic index of grey mullet (*Mugil cephalus*) from high brackish tropical lagoon. Fison, p.241–246.

Uneke, B.I. 2015. Length-weight relationship and condition factor of *Chrysichthys nigrodigitatus* (Lacepede: 1803) of Ebonyi River, South Eastern Nigeria. *Am. J. Agric. Sci.,* 2(2): 70- 74.

Whitehead, P.J.P. 1985. Clupeoid fishes of the world (suborder Clupeoidei). An annotated and illustrated catalogue of the herrings, sardines, pilchards, sprats, shads, anchovies and wolf-herrings. FAO Fish.