ORIGINAL RESEARCH ARTICLE

Eco-Morphological Patterns and Diversity of Some Fishes from the Ogu River in Rivers State, Niger Delta, Nigeria

Abstract

Eco-morphological studies show that morphological traits are adaptive, which means that traits evolve and change as a result of the activities going on in the environment such as predation, competition, and other biotic associations. This study was taken to determine the eco-morphological patterns of some fishes from the Ogu River in Ogu/Bolo Local Government Area of Rivers State, Niger Delta, Nigeria. Three stations were chosen and the duration of the study was four months (January- April 2018). A total of 193 individual fishes were caught, comprising of 5 families and 11 species. Fish samples were obtained with the aid of a seine net; identified, weighed and morphometric measurements were made, to provide the eco-morphological attributes. Fishes were dissected to measure intestinal length. Statistical analysis includes Principal Component Analysis (PCA) of morphometric ratios and intestinal length - total length ratios of fish. The fish species found were *Tilapia guineensis, Tilapia zilli*, *Mugil bananensis, Mugil curema*, *Liza falcipinnis, Liza dumerili, Liza grandisquamis, Pomadasys rogerii, Pomadasys jubelini, Lutjanus endecacanthus* and *Eucinostomus melanopterus*. *Tilapia guineensis* was the most abundant species, Shannon Weiner diversity index(H) ranged from 1.83 - 1.96, Simpson's dominance index ranged from 0.79 - 0.85. The PCA analysis using different morphological attributes revealed 4 groups in feeding regime (omnivorous - Mugilids; herbivorous - Cichlids; larger carnivores - Lutjanids and smaller carnivores - Pomadasyids), and 3 groups in the fishes habitat preference in water as (1: Cichlids, 2: Mugilids and 3: Pomadasyids, Lutjanids and Gerreids). This study revealed some morphometric attributes of some fishes of the Ogu river in Rivers State Nigeria and their relation with feeding, microhabitat and environmental parameters.

Keywords: ***Eco-morphology, Niger Delta, Morphometric ratios, PCA, Ogu River, Rivers State***

INTRODUCTION

Eco-morphology has to do with the study of the relationship that exists between the role of ecology of an organism and its morphology (Wiley, 2017). Eco-morphological studies show that morphological traits are adaptive, which means that traits evolve and change as a result of the activities going on in the environment such as predation, competition, and other biotic associations (Bock, 1990). The study of eco-morphology has made it possible for morphological features to be used in predicting community or species pattern of food and habitat use (Wainwright and Richard, 1995) and this can be achievable by using eco-morphological attributes or morpho-biometric indices. In addition, diversification of the adaptive morphology or morphological features can be linked to changes in the environment, whereby individual species can change their form due to complex associations involving other living organisms or as a result of restrictions caused by the environmental change or changing environment. Considering the fact that the morphological traits of species are in a way associated with habitat use, environmental change may result in constraints in the activities of the existing species. These constraints may be linked to reproductive and or feeding patterns of the existing species, their morphological features which may influence the selection of those better suited to colonize the new environment, and because fish species may be reduced in great numbers as a result of the continued stress or constraints placed on the aquatic environment (Boris, 2006). This however does not change the fact that the cause of reduction in a number of species in an environment is as a result of habitat destruction and or alteration (Warren *et al.*, 2000).

A lot of industrial activities are going on in the aquatic habitat today and there are steady changes in the physical and chemical properties which include temperature, salinity, conductivity and pH (Metaxas and Scheibling, 1993). For these reasons, in order for the aquatic species to survive, they must devise a means to adapt to the environment in which they find themselves and one of the things they do to adapt to their environment, is by changing their morphological, behavioral and physiological features (Filho *et al.*, 2006). Breda *et al.*, (2005) used ecological and functional features as data to gain useful knowledge in the associations that exist between organisms and their environment.

Eco-morphological studies have been carried out by many. It has been used to predict habitat preferences. Santos *et al*. (2011) worked on the "morphological patterns of five fish species (four characiforms, one perciform) in relation to feeding habits in a tropical reservoir in South-Eastern Brazil", and used nine eco-morphological indices. Some eco-morphological indices used include, relative height of mouth, compression index, relative length of head, relative length of the caudal peduncle and mouth width. From their work, there were indications of divergence in the morphology of the fish used. Donald *et al.* (2001) did a research on "fish eco-morphology: predicting habitat preferences of stream fishes from their body shapes" and noticed a relationship between the morphology of the fish and habitat preference. Insectivorous bats were used to predict habitat by Saunder and Barclay (1992), and they noticed that different levels exist with which the insectivorous bats are influenced by their ecology. Eco-morphological studies have also been used to predict fish food type. Willem (2000) carried out a study on "eco-morphology as a predictor of fish diet, and used five morpho-types, which included large-mouthed flat fish, small mouthed flatfish, and soles to predict food type. Stomach content data from literature has been used to predict diet and separate different feeding guides (Willem, 2000). Luana and Monteiro-Neto (2010) studied eco-morphology to show the similarities between species diet and noticed diet similarities in the food composition of sampled species. Eco-morphology has also been used to show that morphological changes are as a result of the environmental condition. Bower and Piller (2015) observed that morphometric changes in *Centruroides gracilis* was explained by adaptation to local environmental conditions. Gaston *et al.,* (2012) revealed that the morphology of fish was associated with selection of habitat and the use of it.

Fish in the wild, exhibits various changes in their morphology (Matthews, 1998; Pflieger, 2004) and this reflects the direct or indirect association with the changing environment (Ross, 1986). Streamlined fish have their caudal peduncles elongated, as this enhances the ability of sustained swimming for a longer time and reduces loss of energy as a result of recoiling (Brinsmead and Fox, 2002). To survive in a swift flowing river, a cylindrical body shape with a small surface area to the volume of the body with stiff and short fins are required, while fish in rivers that flow slowly require a deep body that is compressed laterally and possess fins big enough to hasten their ability in rapid angular acceleration and turning (Webb, 1984; Webb and Weihs, 1986). To exploit certain habitat types, fish have evolved various behavioural and morphological adaptations (Gorman and Karr, 1978; Wood and Bain, 1995).

Usually, in eco-morphological studies on fish, two recent aspects are used. These are interest in the foraging behaviour of fish species, using their morphological features that are directly associated with foraging habits (example, total length of the fish against the length of the fish intestine) given that the intake of the fish will be associated to these features (Wainwright and Richard, 1995). The second aspect is related to the morphological positioning of the fish by identifying features such as, the horizontal and vertical eye diameters which are approaches of habitat structures such as prey size and partitioning of the use of habitat (Willis *et al.*, 2005). According to the principle of eco-morphology, behaviour, feeding and habitat preference can be explained from the morphometrics used to measure eco-morphological characteristics. These characteristics can be explained in terms of lifestyles and habitat use and can also give information on the feeding pattern of the fish (Barrela, 1989, Costa and Souza-Conceicao, 2009). Proper understanding of fish species that occupy the system is the basis for fishery stocks conservation. The aim of this study is to determine the eco-morphological attributes of fishes caught using beach seine in Ogu River, Rivers State, Nigeria.

MATERIALS AND METHODS

Study Area

The study area was the Ogu River located in Ogu/Bolo Local Government Area of Rivers State, which is the Niger Delta of Nigeria. Three stations were sampled (Fig 1). The first station was at the point where the river enters the village; this station is closer to Ikpokiri village which is also in Ogu/Bolo Local Government Area. The second station was at the point between Ogu town and Ikpokiri village. The third station was closer to the landing site in Ogu town. The Ogu River is tidal and estuarine. Salt water flows into it from the Bonny river and meets with the freshwater coming from the streams in Ogu town. Anthropogenic activities other than fishing include fuel wood extracting from the mangroves, snail gathering and the collection of other non-timber products such as bamboo and rattans. The river is surrounded by vegetation such as *Nypa fruticans*.

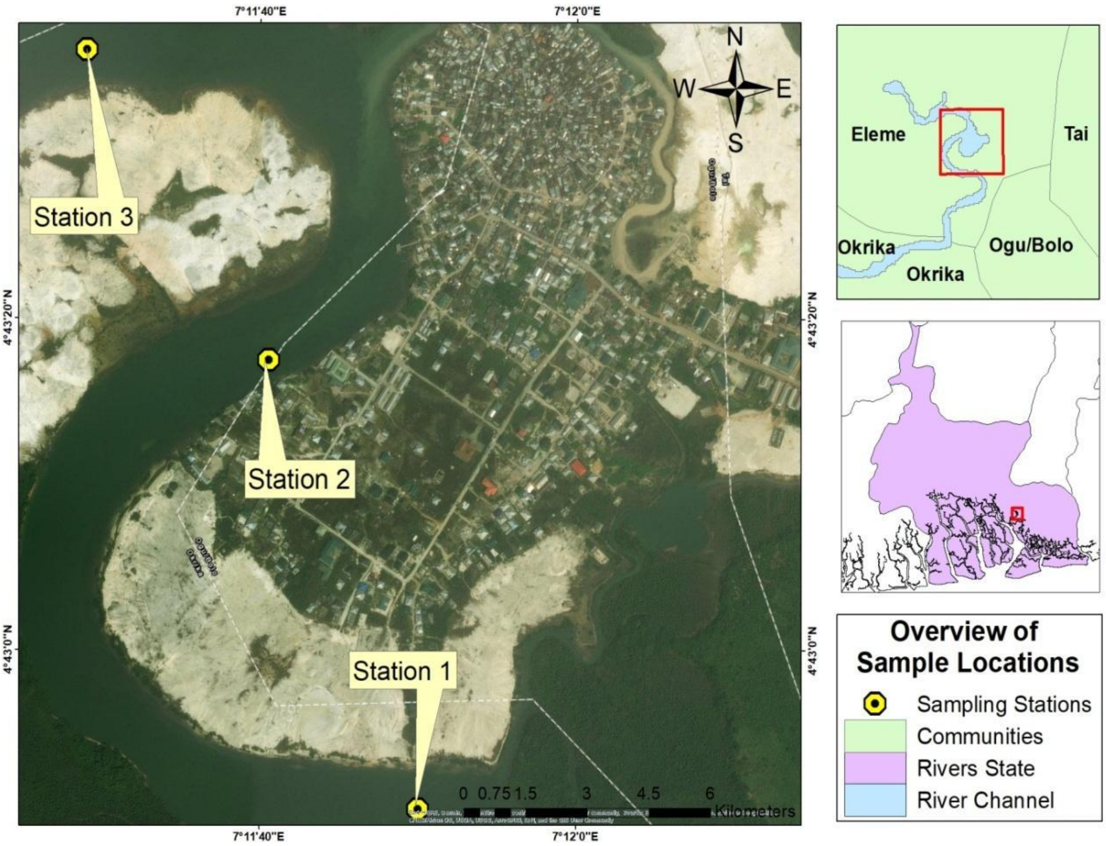

Fig 1: Map of the Study Area Showing the Three Stations in Ogu River

Collection of Fish Samples

Fish samples were collected in triplicate hauls from each of the stations with a beach seine, pre-served in ice cool box and taken to the laboratory. The total number of individual fish species that were caught from the three stations during the period of the sampling was sorted out into similar species. With the help of the various identification keys, the fishes were identified to species level (Idodo-Umeh, 2003; Leveque *et al.*, 1991; Reed *et al.*, 1967; Gourene and Tuegels, 1991).

Morphometric Measurements

In all fish samples, the following parameters were measured in centimeters (cm) using a calibrated meter rule to the nearest mm: total length of the fish, standard length, head length, mouth length, mouth gap, eye diameter (horizontal), eye diameter (vertical), body depth, body width, length of the stomach, length of intestine (Fig 2).

Fig. 2: Measured Morphometric Traits *(TL: Total Length, BD: Body Depth, ML: Mouth Length, MG: Mouth Gape, HED: Horizontal Eye Diameter,VED: Vertical Eye Diameter, BW: Body Width, HL: Head Length and SL: Standard Length)*

Morphometric Ratios

Principal Component Analysis (PCA) was used to analyze eco-morphological characteristics that explained the differences and similarities among species. Morphometric ratios of the measured parts were calculated for each fish species: head length/total length (HL/TL), month length/ total length (ML/TL), mouth gape/mouth length (MG/ML), vertical eye diameter / head length (VED/HL), and gut length/ total length (GL/TL), body width/body depth (BW/BD), body depth/ total length (BD/TL) and relative area of eye calculated as $\pi*(HED/2)^{2/}TL^{2}$ and used as eco-morphological attributes (Table 1).

Table 1: Indices of eco-morphology and ecological implications (Soares *et al.*,2012)

S/No	**Eco-morphology Indices**	**Formulae**	**Association**	**Eco-morphological Implications**

1.	**Relative Length of Head**	RLH=HL/TL	Feeding	High values indicate fish that captures larger prey and are expected in piscivorous species
2.	**Relative Height of the Mouth**	RHM=ML/TL	Feeding	High values may indicate fishes that feed on larger prey.
3.	**Protrusion Index**	PI=MG/ML	Feeding	Higher values are found in fishes that capture larger prey.
4.	**Relative Length of the Digestive Tract**	RLDT = GL/TL	Feeding	Higher values are associated with omnivorous or herbivorous diets.
5.	**Relative Area of Eye**	$\pi*(HED/2)^{2/}TL^{2}$	Feeding	Index related to the detection of food items and the use of vision during predatory behavior.
6.	**Position of the Eye**	PE=VED/HL	Position	High values indicate dorsally positioned eyes, which are found in benthic fishes.
7.	**Compression Index**	CI = BD/HL	Position	High value indicates species associated with the environment near the bottom.
8.	**Streamline Index**	BW/BD	Position	High values indicate benthic or bottom dwellers.
9.	**Fish Depth Index**	BD/TL	Position	Low values indicate long slimmer fish.

Diversity of Fish Species

The distribution and abundance of species were analyzed using Shannon-Weiner and Simpson dominance Index.

Shannon-Wiener (H)

$$H = [\sum pi \text{ in } pi]$$

(Shannon and Weaver, 1949)

Where

H - Diversity index
Pi = the proportion of individual found in species i, (Hutchinson, 1970)

Simpson's Index

$$D = 1 - (\sum n\,(n-1)/N\,(N-1)$$

n = the total number of individuals of a particular species

N = the total number of individual of all species

(as in Clarke and Warwick, 2001)

RESULTS

Species and abundance

Species caught from all the stations were, *Lutjanus endecacanthus, Eucinostomus melanopterus, Tilapia guineensis. Tilapia zilli, Pomadasys jubelini, Pomadasys rogerii, Liza gandisquamis, Liza falcipinnis, Liza dumerili, Mugil curema, Mugil bananensis.*

Fig. 3 showed that, *T. guineensis* was the most abundant species (27.46%), followed by *L. grandisquamis* (22.28%), *E. melanopterus* (14.51%), *L. falcipinnis* 10.88%, *T. zilli* and *M. curema* 5.18% each, *M. bananensis* 4.66%, *P. jubelini* 4.15%, *P. rogerii* 3.11% , *L. dumerili* 1.55% and *L. endecacanthus* the least abundant species (1.04%).

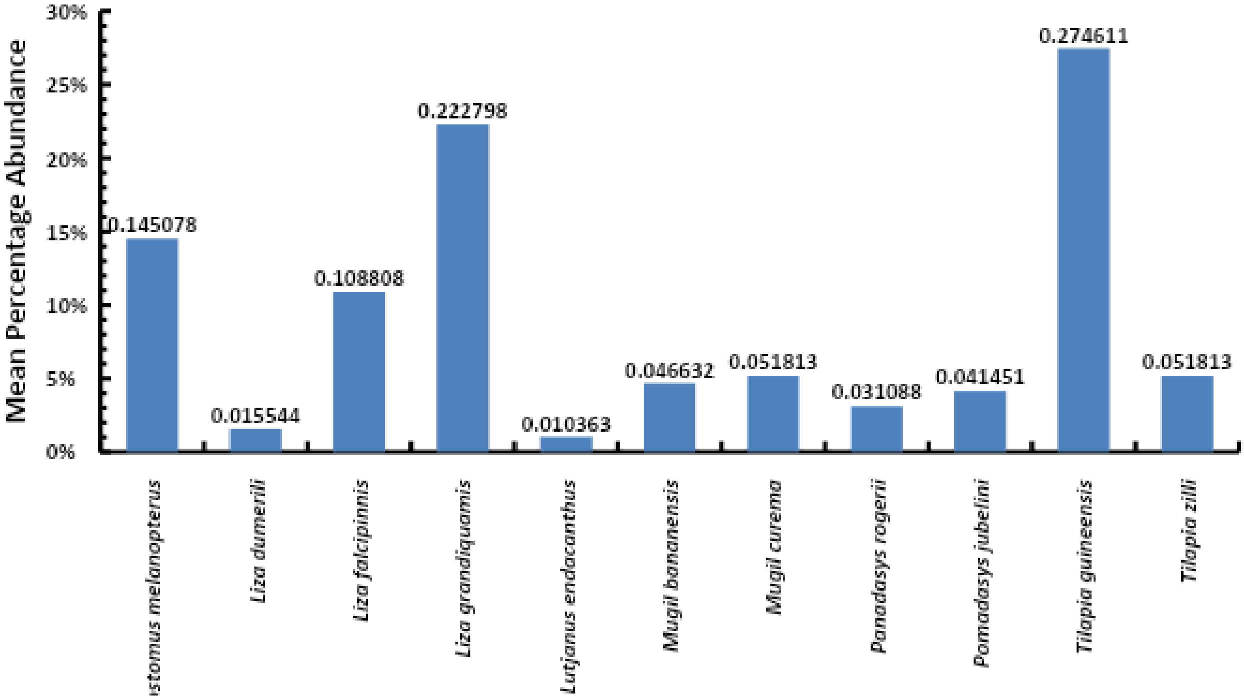

Fig 3: Mean Percentage Abundance of Species across Stations

The eco-morphological ratios of the species, their formulae and ecological implication are indicated in Table 2

Table 2 Eco-morphological Ratios of the different species

S/No.	Formulae	*TZ*	*TG*	*EM*	*LF*	*LD*	*LG*	*MB*	*MC*	*PJ*	*PR*	*LE*	**Ecological implications**
1.	RLH= HL/TL	0.25	0.26	0.24	0.19	0.17	0.18	0.21	0.21	0.27	0.28	0.38	High values indicated fish that captured larger prey and were piscivorous species.
2.	RHM = ML/TL	0.11	0.11	0.09	0.09	0.11	0.10	0.08	0.11	0.08	0.10	0.17	High values indicated fishes that fed on larger prey.
3.	RLDT= GL/TL	3.34	5.19	0.82	1.28	1.27	1.36	1.88	1.93	0.41	0.40	0.40	Higher values were associated with omnivorous or herbivous diets.
4.	FDI= BD/TL	0.34	0.33	0.28	0.21	0.20	0.21	0.21	0.21	0.29	0.28	0.21	Low values indicated long slimmer fish.
5.	PE= VED/LH	0.24	0.25	0.37	0.34	0.30	0.29	0.25	0.24	0.29	0.30	0.30	High values indicated dorsally positioned eye, found in benthic fishes.
6.	RAE= π*(HED/2)^2/TL^2	0.10	0.09	0.04	0.16	0.14	0.10	0.13	0.09	0.07	0.07	0.07	Index related to the detection of food items and the use of vision during predatory behavior.
7.	CI= BD/HL	0.88	0.89	1.11	1.13	1.15	1.93	1.97	1.00	1.09	1.00	0.74	High values indicated species associated with environment near the bottom.
8.	SI= BW/BD	0.08	0.13	0.13	0.33	0.28	0.29	0.25	0.27	0.12	0.13	0.12	High values indicated benthic or bottom dwellers.
9.	PI= MG/ML	0.78	0.74	0.65	0.62	0.45	0.61	0.66	0.60	0.73	0.72	0.84	Higher values were found in fishes that captured larger preys.

TZ (*T.zilli*), TG (*T.guinensis*), EM (*E. melanopterus), LF (L. falcipinnis), LD (*L.*dumerili), LG (L. grandisquamis), MB (M. bananensis), MC (M. curema), PJ (P. jubelini), PR (P. rogerii), and LE (L. endecacanthus). TL: Total Length; HL: Head Length;VED: Vertical Eye Diameter; HED: Horizontal Eye Diameter; MG: Mouth Gap; ML: Mouth Length; BD: Body Depth; RLH: Relative Length of Head; RHM: Relative Height of Mouth; RLDT: Relative Length of Digestive Tract; FDI: Fish Depth Index; PE: Position of Eye; RAE: Relative Area of Eye; CI: Compression Index; SI: Streamline Index; PI: Protrusion Index.*

Species feeding preference

Fig. 4 shows the PCA related to the fish feeding pattern. PCA divided fish species into four groups, Cichlids were in a group, the Mugilids and *E.melanopterus* were in another group, and the Pomadasyidae were yet in a group while *L. endecacanthus* appeared to be all alone in a group.

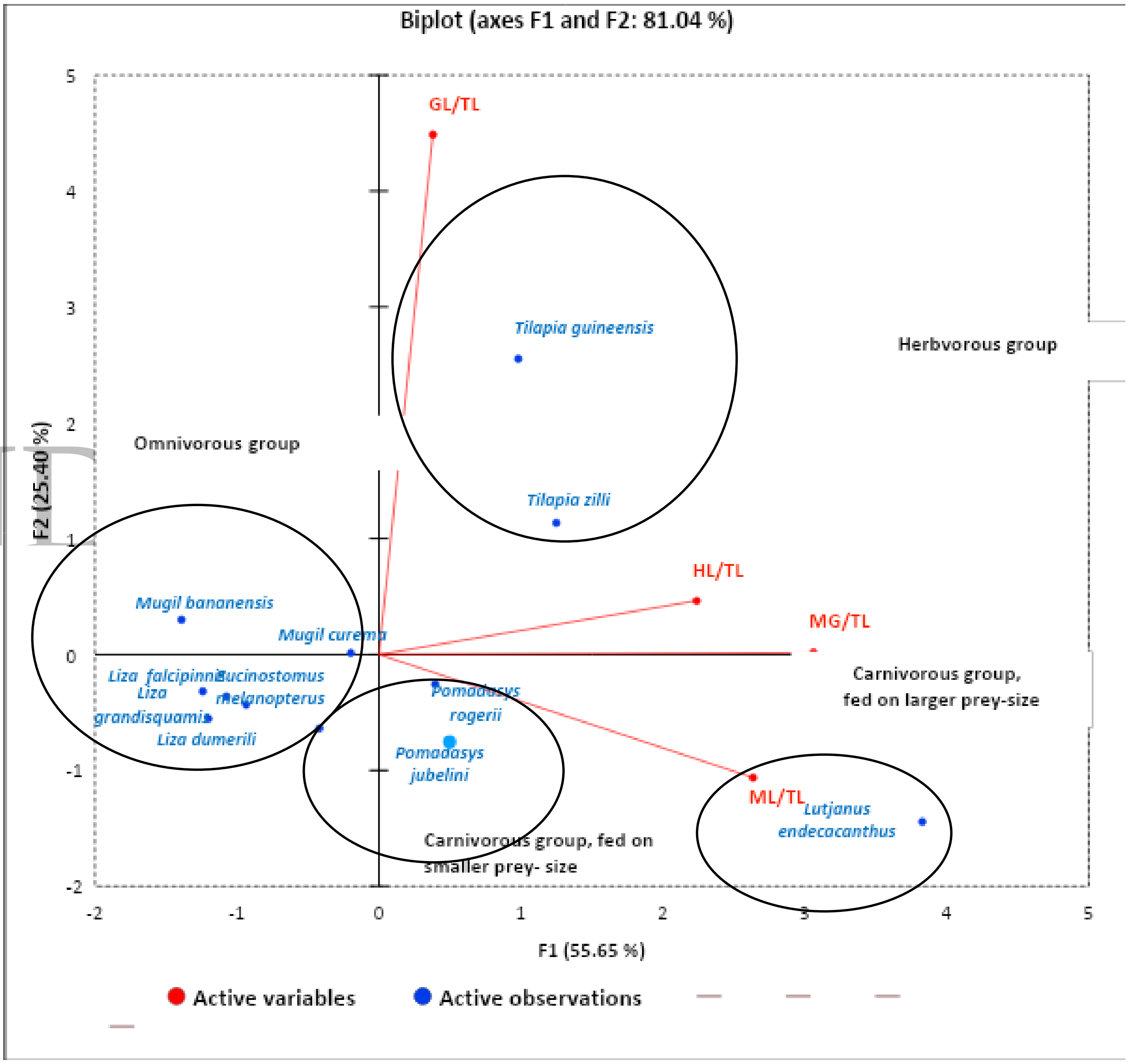

Fig 4: PCA related to the feeding pattern of species morphology.

Species habitat preference

Fig. 5, PCA divided the fish species into 3 groups, cichlids were in a group, mugilidae (*M. curema*, *M. bananensis*, *L. grandisquamis*, *L. dumerili* and *L. falcipinnis*) were in another group, while Pomadasyidae (*P. rogerii* and *P. jubelini*), Gerreidae (*E. melanopterus*) and Lutjanidae (*L. endecacanthus*) were in one group. Following characterization in Table 1 and 2, the groups are bottom dwellers, slimmer and more pelagic fishes, more rounded and benthopelagic.

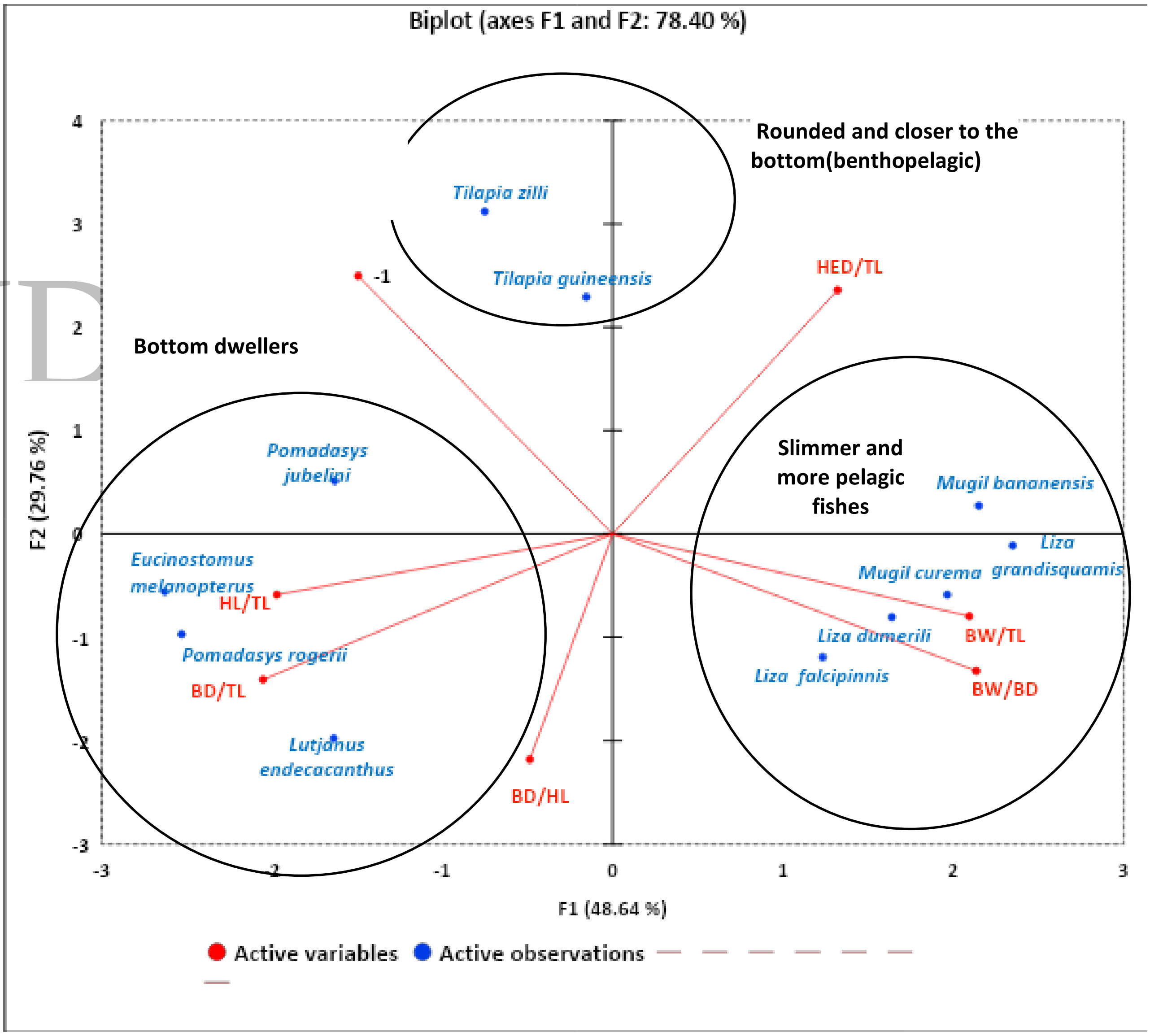

Fig 5: PCA related to species habitat preference

DISCUSSION

Some of the fishes that were found in Ogu river were also observed by Oguntade *et al.* (2014), in Brass and Nun, both in the Niger Delta region of Nigeria These include *T. guineensis, L. grandisquamis* and *M. curema.* Davies (2009), in her report, found *T. guineensis* in the lower reaches of Okpoka creek also in the Niger Delta region. Deinye *et al.,* (2018) also observed *T. guineensis, T.zilli, L. grandisquamis, L. falcipinnis and P. jubelini* in the New Calabar river in the Niger Delta region. Shannon-Weiner diversity index across stations ranged from 1.83 – 1.96. The results confirmed the report of Bibi and Ali (2013) that "the values of Shannon-Weiner diversity index is usually between 1.5 and 3.5 and seldomly surpasses 4.5, however values close to 4.6 depicts that the number of individuals were evenly distributed". The result in the present study showed that the number of individuals were not evenly distributed, and the Simpson's dominance index (D) ranged from 0.79 – 0.85 which showed that some of the species were dominant. According to Ogbeibu (2005)

L. falcipinnis

; Edoghotu *et al.*,(2016), "a higher Simpson's dominance index (D) reflects a higher diversity". *T. guineensis* which was the most abundant species could be as a result of their ability to adapt to their environment. This result confirmed that of Dienyi *et al.*, (2018), who reported *T. guineensis* as the most abundant fish species in their study.

The morphometric ratios have shown that some of the species had similar features, such as the HL/TL ratios of *P.jubelini, P. rogerii, L. endecacanthus* and *E. melanopterus.* PCA was to separate species into different feeding and ecomorphological groups and it revealed that the cichlids (*T. guineensis* and *T. zilli)*, Pomadasyidae, Lutjanidae, the Mugilidae and Gerreidae formed four groups. This was because morphometric ratios on relative length of head (HL/TL), length of digestive tract (GL/TL) protrusion index (MG/ML)and the relative height of mouth(ML/TL) of the two species of the cichlids (*T. guineensis* and *T. zillli*) were similar. Their GL/TL ratios revealed that they were herbivorous fishes as their gut length - total length ratio was above 3. Therefore, in relation to their feeding features, the cichlids which are herbivores belonged to one group. *E. melanopterus* (Gerreidae) are carnivorous fishes and their GT/TL ratio was < 1. From morphometric ratios, they were close to the mugilids that are omnivorous. This similar grouping was as a result of certain similar morphometric ratios that they shared in common. Their HL/TL, MG/ML and ML/TL ratios were similar and revealed small sized prey or food type. The GL/TL ratios of the mugilids on the other hand, showed that they are omnivorous fishes. Therefore, based on the feeding characteristics, the mugilids were omnivorous fishes that fed on small sized food or prey, while the *E. melanopterus* were carnivorous fishes that fed on small sized food or prey. This report is in agreement with the reports of Asadiy *et al.* (2001), Zismann and Kimor (1975) and Lopez *et al.,* (2011) who reported that *E. melanopterus* and the mugilids were carnivorous and omnivorous fishes that fed on crustaceans and plant materials with diatoms respectively.

The fact that both Pomadasyds were grouped together showed that they shared similar features. The morphometrics revealed that their HL/TL, MG/ML and ML/TL ratios were similar, and indicated smaller sized prey or food, their GL/TL ratios appeared to be shorter than those of other species and were < 1, an indication that they were carnivorous fishes. Therefore, based on their feeding characteristics, these fishes were carnivorous fishes that fed on smaller sized prey. These findings were in agreement with the findings of Adebiyi (2011), who reported that *P. rogerii and P. jubelini* are carnivorous fishes. *L. endecacanthus* (Lutjanidae) had similar morphometric ratios with the Pomadasyidae and Gerreidae (GL/TL ratios) which revealed that they were carnivorous fishes yet they were separate. This was because their protrusion index (MG/ML), head length (HL/TL) and length of mouth (ML/TL) ratios were the largest and indicated that they fed on large sized prey or food. Therefore based on the feeding characteristics of *L. endecacanthus,* they were carnivorous fishes that fed on larger prey or food. Udoh and Ekpo (2017) reported *L.endecacanthus* as a carnivorous fish that fed on large prey confirming the categorization.

PCA related to the habitat preference grouped fish species into 3 groups. The Cichlids (more rounded and benthopelagic), Mugilidae (slimmer pelagic fish), while Pomadasyidae, Gerreidae and Lutjanidae (bottom dwellers). *T. guineensis* and *T. zilli* had relative eye ratios similar to the mugilids, but the eyes may not be needed for feeding or predation. Their BD/TL, VED/HL, BD/HL and BW/BD ratios were different. Their BD/TL ratios were higher than those of other species and revealed fishes that were rounded and indicated fishes that were closer to the bottom of the river. This is in agreement with the report of Costa-Pierce (2003), that *Tilapia* are bottom dwellers. For the Mugilids, their body depth index (BD/TL), compression index (BD/HL) and position of eye (VED/HL) ratios were similar which indicated that they were pelagic and had dorsally positioned eyes so they grub from the bottom. The report of (Ugbomeh, 1989) confirms this, while their BW/BD ratios revealed that they are slim and long fishes. Also, their relative eye diameter indicate that they made use of their eyes for predation or feeding. Therefore, the mugilids in this study were pelagic, bottom grubbers, slim and long fishes that made use of their eyes for feeding. *E. melanopterus* (Gerreidae), *P. jubelini* and *P. rogerii* (Pomadasyidae) and *L. endecacanthus* (Lutjanidae) were in one group. They shared similarities in morphometric ratios relating to position in water such as their VED/HL, BW/BD and BD/TL. However, their BW/BD and VED/HL ratios revealed that these fishes were more rounded than slim fishes with dorsally positioned eyes. Their compression index (BD/HL) also showed that they were more benthopelagic (except for the Gerreidae that showed higher ratio which indicated that they may be closer to the bottom). Therefore, Pomadasyidae, Gerreidae and Lutjanidae were classified as more benthpelagic, slimmer than the tilapias, with dorsally positioned eyes. These findings are in agreement with Courtenay, (1961), Rocha and Rossa (1999) and Woodland (1984), that *L. endecacanthus* and *Pomadasys spp* were bottom dwellers.

CONCLUSIONS

A total of 193 individual fish samples were caught, belonging to 5 families and 11 species from three stations in the Ogu river using a beach seine. The fish species were *Tilapia guineensis* and *Tilapia zilli* (Cichlidae), *Mugil bananensis, Mugil curema, Liza falcipinnis, Liza dumerili* and *Liza grandisquamis* (Mugilidae), *Pomadasys rogeri* and *Pomadasys jubelini* (Pomadasyidae), *Lutjanus endecacanthus* (Lutjanidae) *and Eucinostomus melanopterus* (Gerreidae). The Shannon-Weiner diversity index ranged from 1.83 - 1.96, and Simpson's dominance index (D) from 0.79 - 0.8, showing dominance of some species and indicating low fish diversity in study area. Ecomorphological attributes revealed four groups - herbivores, carnivores that fed on larger prey, carnivores that fed on smaller prey and omnivorous group. Ecomorphological ratios revealed three groups in relation to habitat preference as more rounded and closer to the bottom, bottom dwellers, slimmer and more pelagic fishes. This study showed that eco-morphological traits were determined using the morphometric ratios of fishes used in this study.

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