



Ecomorphological patterns of fish species in selected sites along Imo River, Rivers State

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Abstract

The connection between morphometry and ecology is demonstrated through studies in ecomorphology. Over the course of a year; studies on the eco-morphological patterns of various fish species at selected sites along the Imo River were conducted (April 2021 – March 2022). 13 fish species in all were harvested in Kono and Opuoko during this time. Using a measuring tape and a digital electronic scale with model number of TH-901, morphometric and body weight of fish specimens were measured to the nearest cm and gram. Ecomorphological patterns in relation to feeding in Kono indicate that *P. jubelini*, *C. hippos*, *L. dentatus*, *L. goreensis*, *M. sebae*, *P. vorax*, *S. maderensis*, *P. elongatus* were all carnivores that preyed on smaller preys with the exception of *P. quadrifilis*, which was classified as a carnivore that preyed on larger prey. *C. nigrodigitatus*, *G. nigri* and *L. falcipinnis* were classified as omnivores and *E. fimbriata* as herbivorous. On the other hand, eco-morphological patterns in relation to habitat preference show that *P. jubelini*, *L. dentatus*, *L. goreensis*, *P. quadrifilis*, *C. nigrodigitatus* and *L. falcipinnis* are Benthic/bottom dwellers, *P. elongatus* and *G. nigri* are benthopelagic while *C. hippos*, *M. sebae*, *P. vorax*, *S. maderensis* and *E. fimbriata* were classified as pelagic dwellers. Similar to this, eco-morphological ratios in relation to foraging habit in Opuoko show that *P. jubelini*, *C. hippos*, *L. dentatus*, *L. goreensis*, *S. maderensis*, *P. elongatus* were carnivores that fed on small prey while *P. quadrifilis* was a carnivore that fed on larger prey, while *C. nigrodigitatus*, *G. nigri* and *L. falcipinnis* were omnivores and *E. fimbriata* was herbivorous. Eco-morphological ratios in relation to habitat preference in Opuoko indicate that *P. jubelini*, *L. dentatus*, *L. goreensis*, *P. quadrifilis*, *C. nigrodigitatus* and *L. falcipinnis* were classified as benthic/bottom dwellers while *G. nigri* and *P. elongatus* were grouped as benthopelagic/near bottom dwellers and *C. hippos*, *S. maderensis* and *E. fimbriata* were grouped as pelagic dwellers. Overall, the relationship observed between morphology and foraging habits and habitat preference in the two sites were patterns observed in similar fish species across other waterbodies which is indicative of the role played by morphology in determining foraging tactics and resource management.

Keywords: ecomorphometry, habitat preference, foraging habit, estuary

Introduction

Eco-morphology reveals the impact of natural selection on fish assemblages by examining morphological changes (Roy *et al.*, 2020) [14]. The link between functional morphology and ecological performance is known as ecomorphology (Winemiller *et al.*, 1995) [19]. As a result of variances in their growth, development and maturation, different populations of fish produce diverse body forms (Cadrian, 2000) [2]. Individuals of the same species in various populations have morphological differences (Leveque and Paugy, 1999) [9]. A large body of evidence suggests that physical features of a species indicate adaptation to a specific habitat in a geographically and taxonomically diverse collection of fish species (Montana and Winemiller, 2013) [10]. Given that energy intake governs individual growth, survival, reproductive fitness, and death rates, food is a critical resource for living organisms. To avoid resource rivalry, fish has different food compositions and/or different space/time distributions (Stergiou and Karpouzi, 2002) [17]. In many cases, closely related species can coexist in a natural ecosystem due to a variety of factors that allow these potential competitors to coexist indefinitely (Gibran, 2007) [6]. Ecologists are interested in the strategies adopted by related group of animals to exploit resources. Many of fish's morphological qualities and behavioural pattern have

evolved in response to the need for food collection, reproduction and predator avoidance (Costa *et al.*, 2014) [3]. As a result, research into the ecomorphological patterns and diversity of fish species along the Imo River Estuary in the Niger Delta, has become necessary. In eco-morphometric studies individuals tend to concentrate in estuarine and coastal areas where they can take advantage of food resources (Russo *et al.*, 2007) [15].

Estuaries are highly productive habitats that connects the freshwater and marine environments. They host a varied collection of fish species that may likely influence resource availability (Blasina *et al.*, 2016) [11]. The majority of studies on ecomorphological patterns of fish species has been done in Europe and South-America, and it include; Ecomorphological diversification in low land freshwater fish assemblages from the biotic regions by Winemiller *et al.*, (1995) [19]. Roy *et al.* (2020) [14] researched on ecomorphological traits and assemblage pattern of small fresh water fish in smaller lentic aquatic bodies. Due to the dearth of research in Nigeria, it is imperative to carry out an investigation into the ecomorphological patterns of fish species along the Imo River, a significant river system in the Niger Delta, in order to ascertain the ecology of fish species in relation to habitat preference and foraging habits for proper fish stock management and conservation.

Materials and methods

1. Study Area

The study was carried out in Kono and Opuoko communities along the Imo river in Khana Local Government Areas respectively. The studied sites are bounded by Oyigbo in the north, Opobo in the south, Andoni and Gokhana in the west and Ikot-Abasi in the east. The Imo River passes through Khana Local Government in Rivers State, Nigeria, and is the primary stream in Kono, which has a sparse network of creeks. Kono is located in latitude 4°35'55.95" N and longitude 7°30'16.092" E. Nypa palm a kind of palm native to the Imo River region, prevail in the vegetation around Kono Creek. The creeks vegetation consists of *Avicennia germinas*, *Conocarpus erectus* and *Languncularia racemosa* and mangrove *Rhizophora mangle*, *Rhizophora. harrisonii*, *Rhizophora. racemosa*,

Avicennia (Zabbey and Tane, 2016) [20]. It is an estuary where people engage in activities including fishing, transportation, settlement and dredging. Wet and dry seasons alternate, which defines the climate. The rainy season lasts from April until October, However, there is sporadic precipitation from November to March, which is the dry season (NMA, 2008) [12]. The watercourse is subject to two different tides; mudflat sediment at high tide and low tide but the tidal ranges vary from month to month. Opuoko, on the other hand, lies at coordinates 4°41'0.096" N and 7°30'54" E. The Imo River, which empties into Gokhana runs through the settlement. The water in this River is brackish. In and near these bodies of water, human activities include; fishing, Open defecation, transportation and bathing. The site's dominant vegetation is the red mangrove (*Rhizophora mangle*).

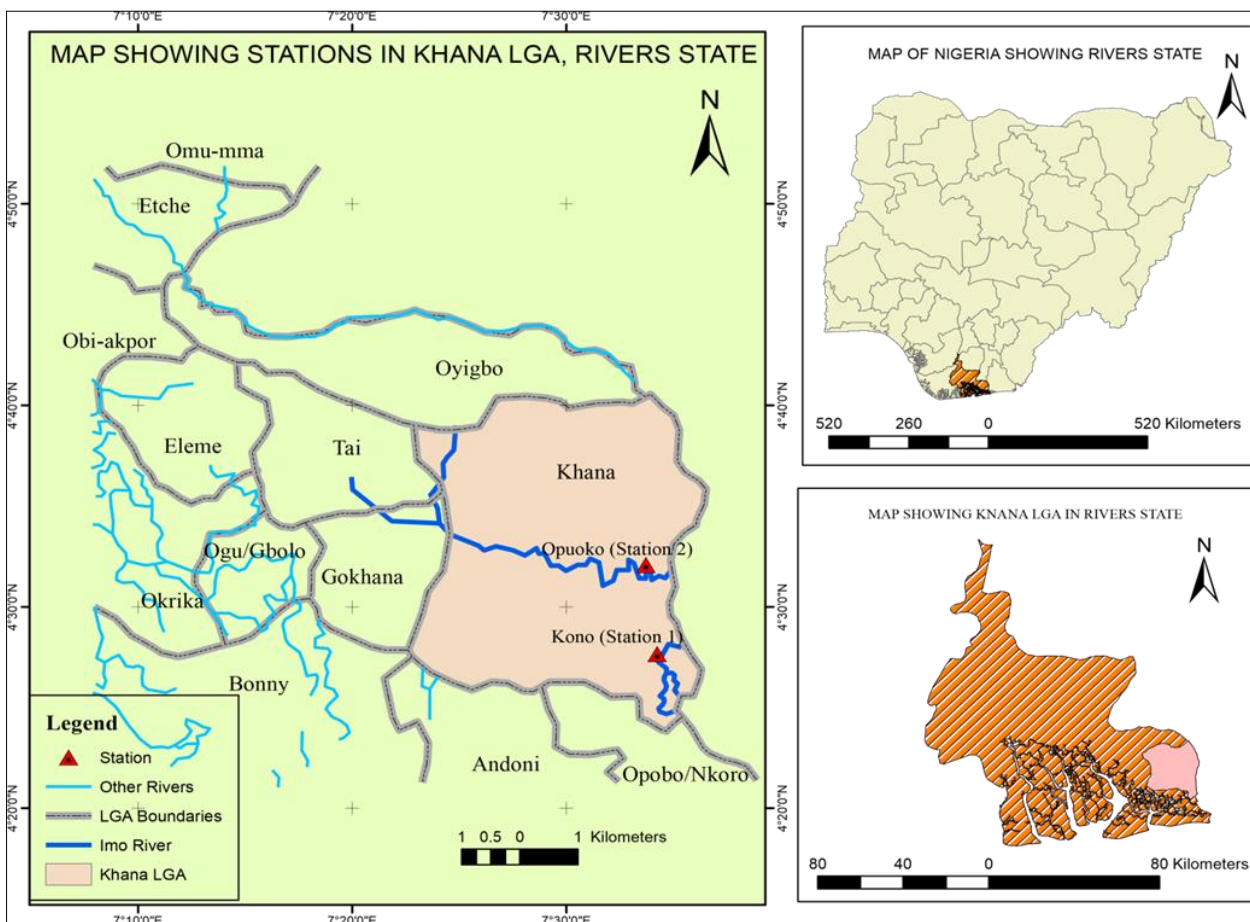


Fig 1: Map showing the sampling stations in Imo River Estuary

2. Fish Harvest and Identification

Fish samples of different species were collected over a period of 12 months (April 2021 – March 2022) from stations established in Kono and Opuoko rivers along the course of Imo River. The harvested fishes were caught with gill net, trammel net, single hook and line, long hook and line and wire basket traps. The numbers of fish harvested from each station were counted and recorded. They were placed in a properly labelled cooler filled with ice and immediately taken to the department of Animal and Environmental Biology Laboratory, Rivers State University, for identification and morphometric measurements.

On reaching the laboratory, the fish specimen from each sampled stations were identified to species level using fish

identification references like; Reed *et al.* (1967), Skelton (1993), Idodo-Umeh (2003).

3. Morphometric Measurements

Some specific parameters were measured in all the fish samples (individually) with the help of a calibrated meter rule (cm). They include; Total Length (TL), Standard Length (SL), Head length (HL), Mouth Length (ML), Mouth Gape (MG), Vertical Eye Diameter (ED), Body depth (BD) and Body width (BW) while the Body weight (wt) in grams was measured using a sensitive weighing scale (Model TH-901). The measurements were indicated in Table 1.

Table 1: Indices of Eco-morphology and ecological implications

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 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 captured larger prey
4.	Relative length of digestive tract (RLDT)	GL/TL	Feeding	Higher values are associated with omnivorous or herbivorous diets
5.	Relative area of eye	$\pi^*(HED/2)^2/TL$	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 values indicate species associated with the environment near the bottom
8.	Streamline index (SI)	BW/BD	Position	High values indicate benthic or bottom dwellers
9.	Fish depth index (FDI)	BD/TL	Position	Low values indicate long slimmer fish

Source: Ugbomeh *et al.* (2020)

TL - Total Length; HL - Head Length; VED - Vertical Eye Diameter; HED - Horizontal Eye Diameter; MG - Mouth Gap; ML - Mouth Length; BD - Body Depth

4. Morphometric ratio

These ratios became the variable for Principal component analysis (PCA). Principal component analysis (PCA) was used to separate eco-morphological characteristics such that the differences and the similarities among species can be seen at a glance. Morphometric ratios of the parts to be measured were calculated for each fish species as thus: Head length/Total length (HL/TL), mouth length/total length (ML/TL), mouth gape/total length (MG/ML), vertical eye diameter/head length (VED/HL) and gut length/total length (GL/TL).

5. Data analysis

Data collected from morphometric traits were arranged and analysed using Microsoft Excel version 2016 while Principal Component Analysis (PCA) showing similarities of eco-morphological patterns between species in terms of feeding and habit preference was performed using PAST 3.0 Ecological software.

Results

Table 2 and 3 shows the mean values of 4 Eco morphological attributes for the 13 fish species in Kono landing site, the matrix of which was applied to a PCA that originated the first four components with eigenvalues greater in PC 1 (3.09604). The first four components were used in the interpretation of feeding preference of the species encountered in Kono landing site. PC 1 accounted for 77.40% of the variance explained in the model. Although, PC 2 (12.76%) PC 3 (6.75%) and PC 4 (3.09%) also formed part of the explained variability, they did not reveal additional information about the Eco morphological patterns of the fishes in regards to feeding pattern. From PC 1 the attributes that contributed negatively to the formation of this axis was relative length of digestive tract (RLDT) while relative length of head (RLH), relative height of mouth (RHM) and protrusion index (PI) all contributed positively. The positive scores for the first axis (PC 1) were observed for *P. jubelini*, *C. hippos*, *L. dentatus*, *L. goreensis*, *M. sebae*, *P. vorax*, *S. maderensis*, *P. elongatus* and *P. quadrifilis*. However, for the species *C. nigrodigitatus*, *G. nigri*, *L. falcipinnis* and *E. fimbriata*, the scores were negative. Thus, the PC 1 grouped fishes with positive scores as carnivores feeding on small preys except for *P. quadrifilis* that was categorized as carnivorous

feeding on larger prey. Whilst the negative contributors were grouped as omnivores except *E. fimbriata* that was grouped as herbivorous (Fig. 1).

The first four components (PC 1, PC 2, PC 3 and PC 4) were used for interpretation of ecological attributes of the species in relation to habitat preference. The first and second component (PC 1 and PC 2) accounted for 96.09% the variance explained by the model. From PC1 it was noted that Compression Index (CI), fish depth index (FDI), position of eye (PE) and relative height of mouth (RHM) all contributed positively to the formation of this axis whilst in PC 2 position of eye (PE) contributed negatively whilst compression index (CI), fish depth index (FDI) and relative height of mouth (RHM) contributed positively to the formation of the axis. The positive scores for the first axis (PC 1) was recorded for *P. jubelini*, *L. dentatus*, *L. goreensis*, *P. elongatus*, *P. quadrifilis*, *C. nigrodigitatus*, *G. nigri*, and *L. falcipinnis* whilst *C. hippos*, *M. sebae*, *P. vorax*, *S. maderensis* and *E. fimbriata* were the negative contributors. The PCA thus grouped *P. jubelini*, *L. dentatus*, *L. goreensis*, *P. quadrifilis*, *C. nigrodigitatus* and *L. falcipinnis* as Benthic/bottom dwellers and *P. elongatus* and *G. nigri* as benthic-pelagic whilst the negative contributors (*C. hippos*, *M. sebae*, *P. vorax*, *S. maderensis* and *E. fimbriata*) were categorized as pelagic dwellers (Fig. 2). In PC 2 the positive contributors were *M. sebae*, *P. elongatus*, *G. nigri* and *E. fimbriata* whilst the negative contributors were *P. jubelini*, *C. hippos*, *L. dentatus*, *L. goreensis*, *P. vorax*, *S. maderensis*, *P. quadrifilis*, *C. nigrodigitatus* and *Liza falcipinnis*.

In Opuoko, PC 1 explained 72.67% of the variance indicated by the model. Although PC 2 (22.58%), PC 3 (4.157%) and PC 4 (0.59%) contributed to the variance but their contributions were not significant (Table 4). From PC 1 it was observed that protrusion index (PI), and relative height of mouth (RHM) contributed the most positively to the formation of the axis whilst relative length of digestive tract contributed negatively to the formation of the axis (Table 4). The positive scores for PC 1 was recorded for *P. jubelini*, *C. hippos*, *L. dentatus*, *L. goreensis*, *S. maderensis*, *P. elongatus* and *P. quadrifilis* whilst the negative coefficients were recorded for *C. nigrodigitatus*, *G. nigri*, *L. falcipinnis* and *E. fimbriata*. Thus, *P. jubelini*, *C. hippos*, *L. dentatus*, *L. goreensis*, *S. maderensis*, *P. elongatus* were grouped as carnivorous feeding on smaller prey and *P.*

quadrifilis as carnivorous feeding on larger prey while the negative contributors like *C. nigrodigitatus*, *G. nigri*, *L. falcipinnis* were grouped as omnivores and *E. fimbriata* as herbivorous (Fig. 3).

Four components (PC 1, PC 2, PC 3, and PC 4) were used to explain the Eco morphological attributes of species in Opuoko in regards to habitat preference. However, PC 1 (51.26%) and PC 2 (42.91%) contributed the most significantly to the variance explained by the model (Table 4). The attributes that contributed positively to the formation of PC 1 were position of eye (PE), Relative length of head (RLH) and streamline index (SI), whilst the negative contributor was Relative length of digestive tract (RLDT) (Table 4). In PC 2 compression index (CI) and fish depth index (FDI) were the positive contributors to the formation of the axis whilst streamline index was the negative contributor for PC 2 (Table 5). The positive scores for PC 1 was recorded for *P. jubelini*, *L. dentatus*, *L. goreensis*, *P. elongatus*, *P. quadrifilis*, *C. nigrodigitatus*, *G. nigri*, *L.*

falcipinnis whilst the negative scores were recorded for *C. hippos*, *S. maderensis* and *E. fimbriata*. The positive contributors for PC 2 were *P. elongatus*, *S. maderensis* and *G. nigri* whilst the negative contributors were *P. jubelini*, *L. dentatus*, *L. goreensis*, *P. quadrifilis*, *C. nigrodigitatus*, *G. nigri* and *E. fimbriata*. Thus, *P. jubelini*, *L. dentatus*, *L. goreensis*, *P. quadrifilis*, *C. nigrodigitatus* and *L. falcipinnis* (Table 5), were grouped as benthic/bottom dwellers whilst *P. elongatus* (0.2139) and *G. nigri* (0.3845) with positive scores in PC I were grouped as benthopelagic/near bottom dwellers (Fig. 3).

Observing the negative contributors for PC 1, it was noted that *C. hippos*, *S. maderensis* and *E. fimbriata* were grouped as pelagic dwellers (Fig 4). Observations from positive contributors in PC 2 indicated that *P. elongatus* and *G. nigri* were grouped as benthopelagic dwellers (Fig 4). Observations from the negative contributors in PC 2 indicated that *P. jubelini*, *L. dentatus*, *L. goreensis* were grouped as benthic/bottom dwellers (Fig. 4)

Table 2: Main Morphological principal component axis, Eigenvalues and variance on feeding pattern and habitat preference in Kono landing site

	PC 1	PC 2	PC 3	PC 4
Feeding				
GL/TL (RLDT)	-0.52157	0.41833	0.026026	0.74317
HL/TL (RLT)	0.44277	0.86586	-0.158	-0.17112
MG/ML (PI)	0.5147	-0.0501	0.77546	0.36227
ML/TL (RHM)	0.51673	-0.26978	-0.61076	0.5359
Eigenvalue	3.09604	0.51045	0.26989	0.123617
% variance	77.401	12.761	6.7472	3.0904
Habitat				
VED/HL (PE)	0.46499	-0.56482	0.007638	0.68169
BD/HL (CI)	0.4764	0.53247	0.69119	0.10848
BW/BD (SI)	0.54178	-0.42472	0.067118	-0.72221
BD/TL (FDI)	0.51313	0.4659	-0.71951	0.044078
Eigenvalue	2.45071	1.39273	0.101017	0.055538
% variance	61.268	34.818	2.5254	1.3885

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; CI - Compression Index; SI - Streamline Index; PI - Protrusion Index.

Table 3: Principal component axis and the loadings in terms of feeding habit and habitat preference in Kono landing site

	PC 1	PC 2	PC 3	PC 4
Feeding				
<i>Pomadasys jubelini</i>	0.75845	0.68419	0.07496	-0.54827
<i>Caranx hippos</i>	1.1452	-0.54259	-1.0979	0.33305
<i>Lutjanus dentatus</i>	0.88783	-0.19077	0.44571	0.02206
<i>Lutjanus goreensis</i>	1.245	-0.42651	-0.15123	0.30464
<i>Monodactylus sebae</i>	0.76646	-0.42976	0.69039	-0.05887
<i>Pellonula vorax</i>	1.6099	0.1748	-0.79387	-0.12038
<i>Sardinella maderensis</i>	0.53127	-0.64181	0.45305	0.14716
<i>Pseudotolithus elongatus</i>	0.2718	-0.43942	-0.00973	-0.7412
<i>Polydactylus quadrifilis</i>	2.4233	1.091	0.54951	0.37456
<i>Chrysichthys nigrodigitatus</i>	-2.5701	1.2278	-0.01023	0.34227
<i>Gerres nigri</i>	-1.9857	0.75463	-0.39499	-0.18489
<i>Liza falcipinnis</i>	-2.3826	-0.2693	0.06789	-0.14667
<i>Ethmalosa fimbriata</i>	-2.7008	-0.99225	0.17648	0.27653
Habitat				
<i>Pomadasys jubelini</i>	1.0785	-0.84911	-0.22994	-0.26716
<i>Caranx hippos</i>	-2.604	-0.248	-0.03832	-0.42965
<i>Lutjanus dentatus</i>	1.1844	-0.55256	-0.13941	-0.09469
<i>Lutjanus goreensis</i>	1.8406	-0.66905	-0.09794	0.29732
<i>Monodactylus sebae</i>	-1.5248	0.31717	0.003884	0.094619

<i>Pellonula vorax</i>	-1.7515	-0.17699	-0.27908	0.27525
<i>Sardinella maderensis</i>	-1.7881	-0.45168	0.084658	0.35677
<i>Pseudotolithus elongatus</i>	0.87145	2.5111	-0.07502	-0.22558
<i>Polydactylus quadrifilis</i>	0.72439	-1.3215	-0.4002	-0.05492
<i>Chrysichthys nigrodigitatus</i>	1.0687	-0.70606	0.055185	-0.0731
<i>Gerres nigri</i>	1.2761	2.3096	-0.07865	0.19612
<i>Liza falcipinnis</i>	1.219	-0.7682	0.87575	-0.02019
<i>Ethmalosa fimbriata</i>	-1.5947	0.60533	0.31909	-0.0548

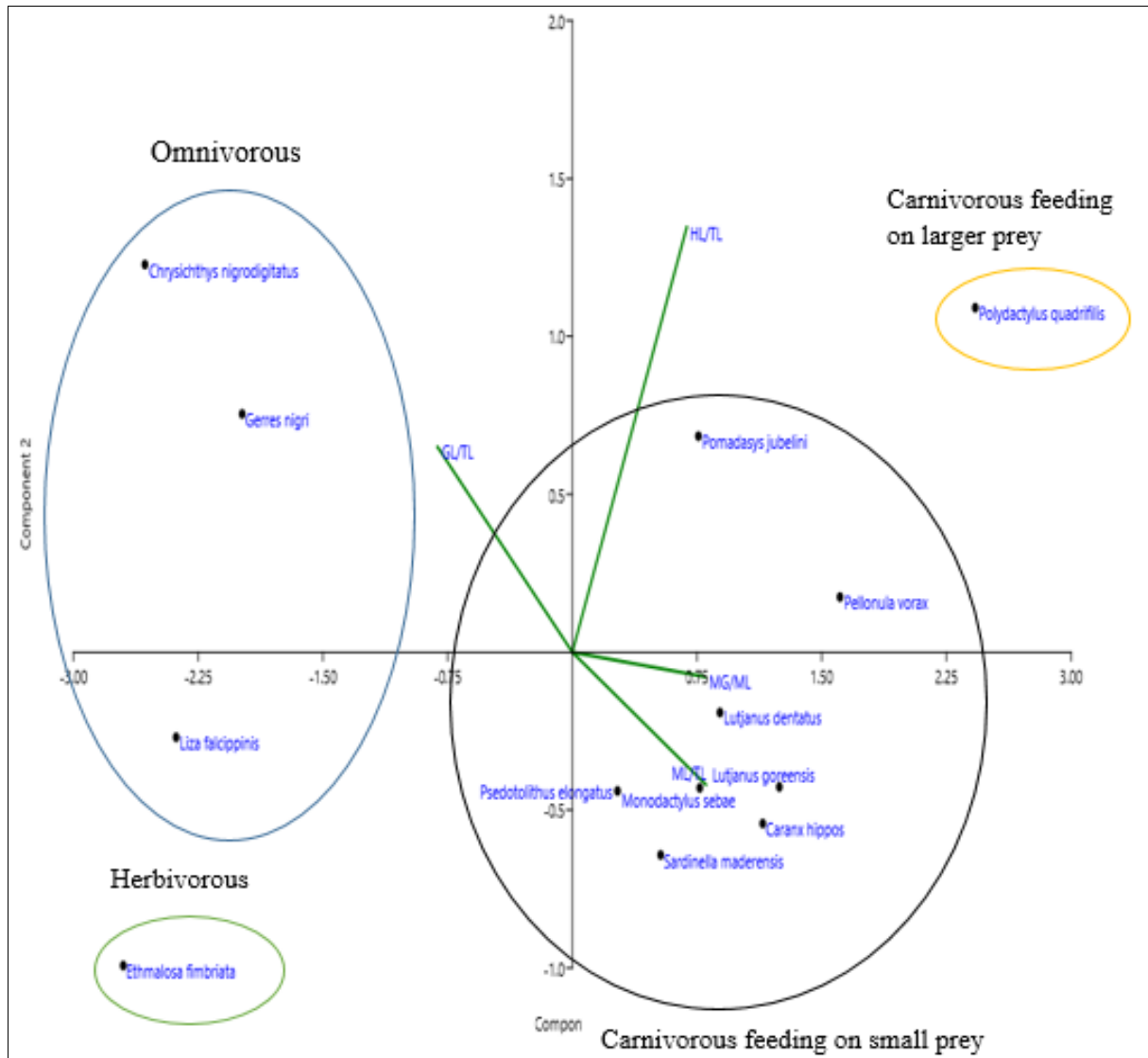


Fig 2: PCA related to the feeding pattern of species morphology in Kono landing site

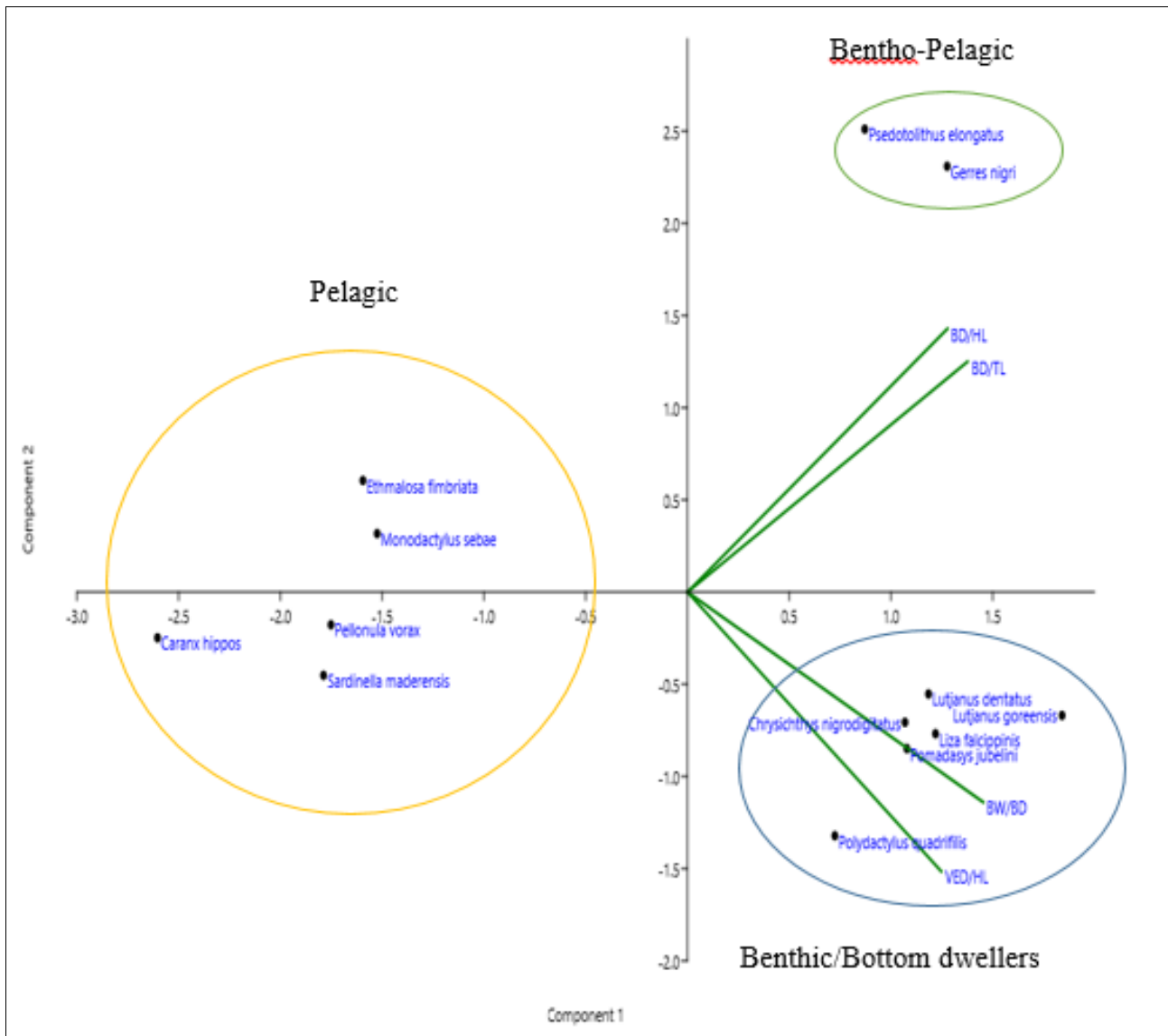


Fig 3: PCA related to the habitat preference of species morphology in Kono landing site

Table 4: Main Morphological Principal component axis, Eigenvalues and variance on feeding pattern and habitat preference in Opuoko landing site

	PC 1	PC 2	PC 3	PC 4
Feeding				
GL/TL (RLDT)	-0.49211	0.48297	0.71537	0.11322
HL/TL (RLH)	0.31688	0.87073	-0.37478	0.030894
MG/ML (PI)	0.57488	-0.08957	0.33892	0.73934
ML/TL (RHM)	0.57178	0.023173	0.48263	-0.66302
Eigenvalue	2.90678	0.903156	0.166269	0.023795
% variance	72.669	22.579	4.1567	0.59488
Habitat				
VED/HL (PE)	0.65405	-0.23963	-0.24301	-0.67509
BD/HL (CI)	0.20295	0.69597	0.63048	-0.27737
BW/BD (SI)	0.55956	-0.4171	0.50411	0.50871
BD/TL (FDI)	0.46682	0.53313	-0.53788	0.45665
Eigenvalue	2.05021	1.71625	0.206754	0.026785
% variance	51.255	42.906	5.1688	0.66961

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; CI - Compression Index; SI - Streamline Index; PI - Protrusion Index

Table 5: Principal component axis and the loadings in terms of feeding habit and habitat preference in Opuoko landing site

	PC 1	PC 2	PC 3	PC 4
Feeding				
<i>Pomadasys jubelini</i>	1.572	0.1585	-0.65065	0.12921
<i>Caranx hippos</i>	0.63228	-0.72125	0.67599	-0.10898
<i>Lutjanus dentatus</i>	0.97802	0.029154	0.19901	-0.1318
<i>Lutjanus goreensis</i>	0.79511	0.11274	0.25931	0.11999
<i>Sardinella maderensis</i>	0.89463	-1.4676	0.006923	-0.03314
<i>Pseudotolithus elongatus</i>	0.92674	-0.94293	-0.41223	0.070495
<i>Polydactylus quadrifilis</i>	2.3899	1.6013	0.028661	-0.07141
<i>Chrysichthys nigrodigitatus</i>	-1.5967	1.5778	-0.03721	0.06899
<i>Gerres nigri</i>	-2.0464	-0.23391	0.4149	0.30967
<i>Liza falcipinnis</i>	-1.9823	0.33981	0.084565	-0.21822
<i>Ethmalosa fimbriata</i>	-2.5633	-0.45361	-0.56927	-0.13479
Habitat				
<i>Pomadasys jubelini</i>	1.2109	-0.29688	-0.95401	0.14534
<i>Caranx hippos</i>	-2.3046	-0.6882	0.0406	0.15908
<i>Lutjanus dentatus</i>	1.0196	-0.70269	0.16853	-0.1418
<i>Lutjanus goreensis</i>	1.0656	-0.6318	0.36838	-0.03616
<i>Sardinella maderensis</i>	-2.0565	0.12156	-0.22268	-0.37338
<i>Pseudotolithus elongatus</i>	0.2139	3.0555	-0.30342	-0.02983
<i>Polydactylus quadrifilis</i>	0.74661	-0.84663	-0.40405	-0.0436
<i>Chrysichthys nigrodigitatus</i>	0.98644	-0.692	0.056732	0.073461
<i>Gerres nigri</i>	0.3846	2.0415	0.61761	0.11119
<i>Liza falcipinnis</i>	0.91502	-0.865	0.54218	-0.05633
<i>Ethmalosa fimbriata</i>	-2.1815	-0.49536	0.090118	0.19201

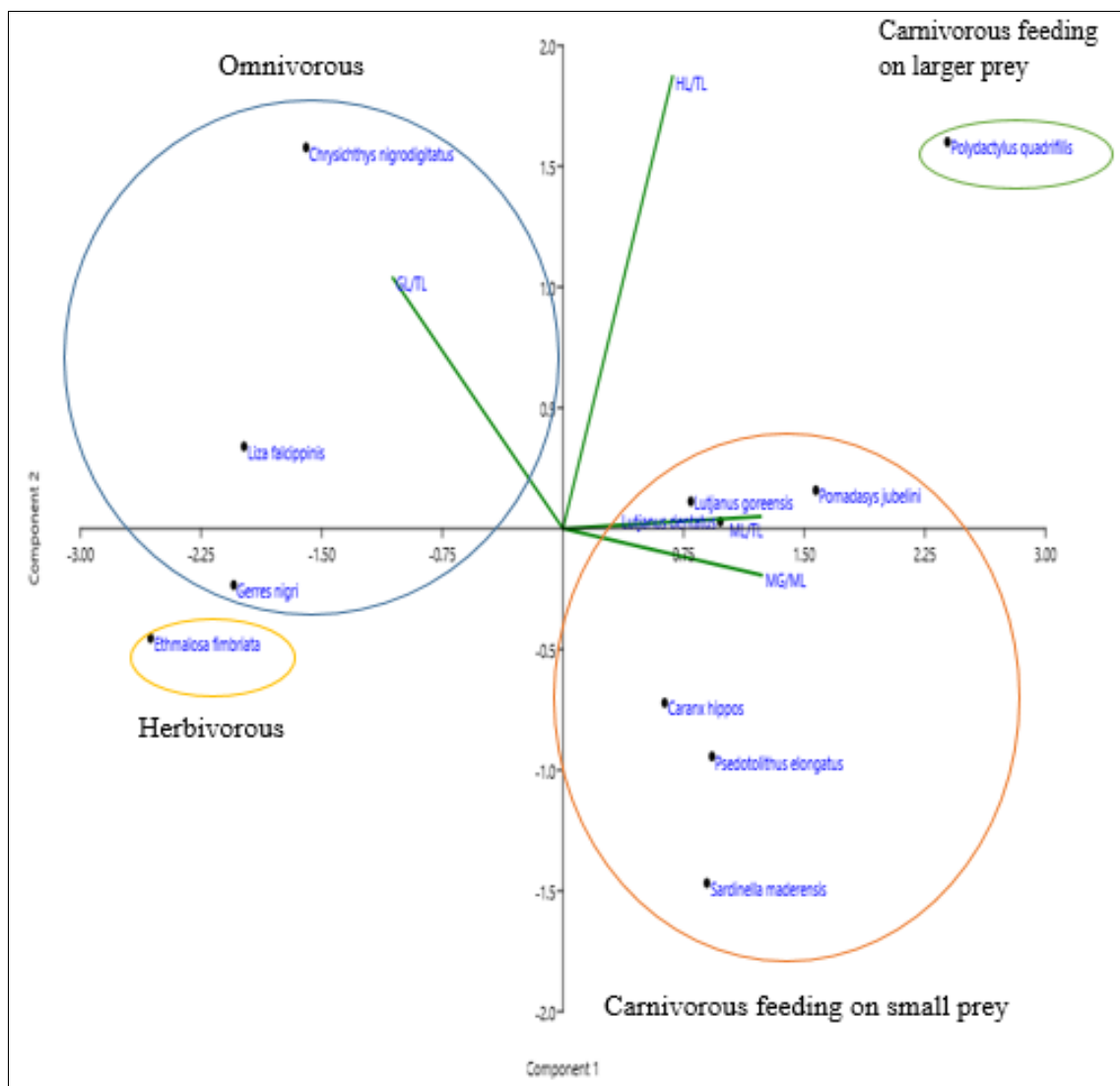


Fig 4: PCA related to the feeding pattern of species morphology in Opuoko landing site

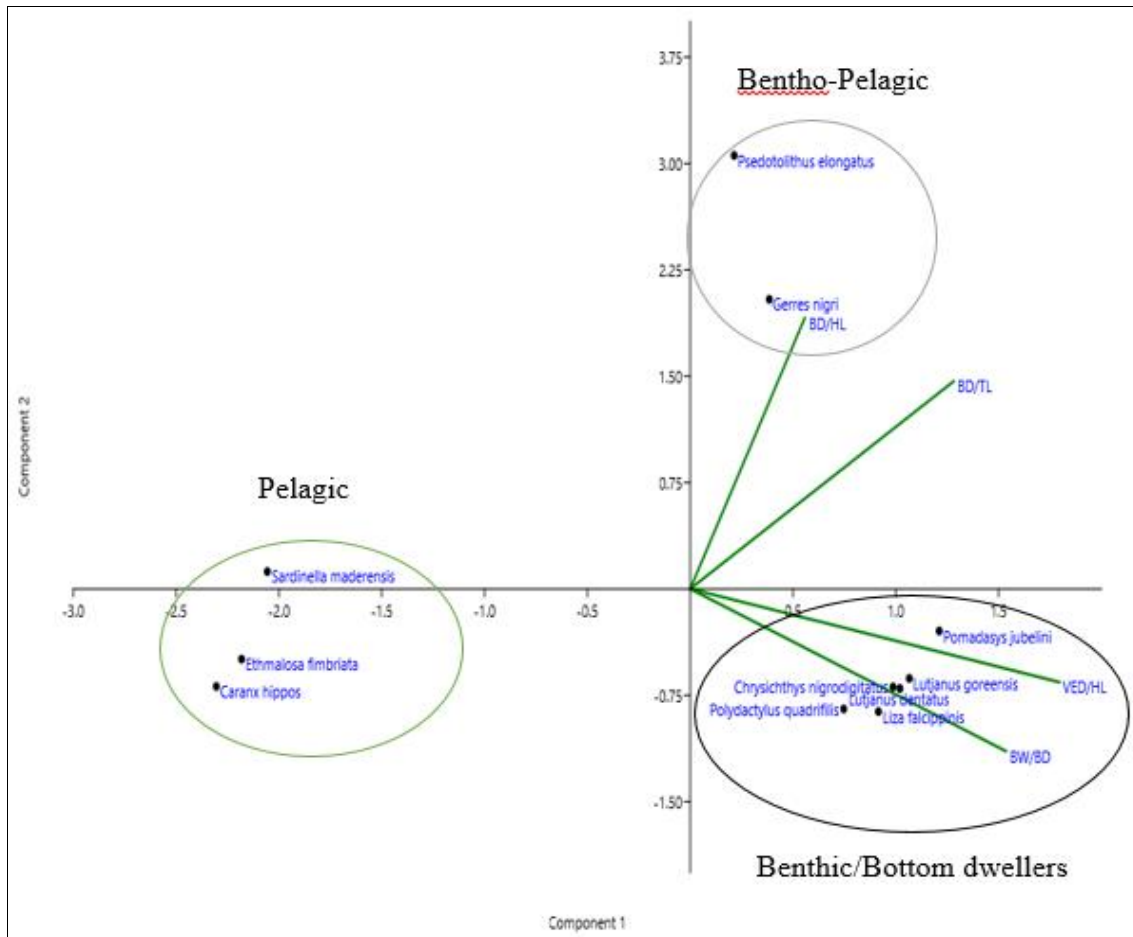


Fig 5: PCA related to the habitat preference of species morphology in Opuoko landing site

Discussion

Observing the positive coefficients of the first axis (PC 1), in Kono in terms of feeding preference. It can be noted that these species (*P. jubelini*, *C. hippos*, *L. dentatus*, *L. goreensis*, *M. sebae*, *P. vorax*, *S. maderensis*, *P. elongatus*) share in common longer relative digestive tract, longer lengths of head and mouth and a higher protrusion index with *P. quadrifilis* recording the highest value for all the ecological attributes mentioned above. However, the second negative group (negative values of PC 1 - *C. nigrodigitatus*, *G. nigri*, *L. falcipinnis* and *E. fimbriata*) is characterized by distinct morphological attributes from the first group, which are fishes with relatively shorter digestive tract, smaller mouths and a reduced protrusion index compared to fishes with positive coefficients. The PC 1 grouped fishes with positive scores as carnivores feeding on small preys except for *P. quadrifilis* with relatively longer digestive tracts, length of head and mouth and a larger protrusion index as characteristic of carnivores feeding on larger prey. On the other hand, fishes with negative scores recorded ecological attributes likened to herbivores and omnivores thus the PC 1 separated the species (*E. fimbriata*) with the highest negative coefficient (-2.708) as herbivorous. Whilst *C. nigrodigitatus*, *G. nigri* and *L. falcipinnis* were grouped as omnivores. In the same vein, observing the positive scores from PC 1 in terms of habitat preference in Kono it was observed that all the species had larger compression index and fish depth index. The PCA thus grouped *P. jubelini*, *L. dentatus*, *L. goreensis*, *P. quadrifilis*, *C. nigrodigitatus* and *L. falcipinnis* as Benthic/bottom dwellers and *P. elongatus*

and *G. nigri* as benthic-pelagic whilst the negative contributors (*C. hippos*, *M. sebae*, *P. vorax*, *S. maderensis* and *E. fimbriata*) with relatively longer height of mouth and a smaller compression index and body depth index in PC 1 were grouped as pelagic dwellers. Similarly, In Opuoko landing site, observing the species with positive scores in terms of habitat preference it was noted that they had relatively larger protrusion index and larger mouths which are attributes of carnivores, thus *P. jubelini*, *C. hippos*, *L. dentatus*, *L. goreensis*, *S. maderensis*, *P. elongatus* were grouped as carnivorous feeding on smaller prey and *P. quadrifilis* (2.3899) with relatively larger mouths and compression index compared to other fishes with positive coefficients as carnivorous feeding on larger prey. On the other hand, fishes with negative coefficients were observed to have similar longer digestive tract compared to fishes with positive scores except for *E. fimbriata* (-2.5633) with a relatively shorter digestive tract compared to fishes with negative scores. Thus *C. nigrodigitatus*, *G. nigri*, *L. falcipinnis* were grouped as omnivores and *E. fimbriata* as herbivorous. In the same vein, observing the positive scores for PC 1, in Opuoko in regards to habitat preference, it was noted that they have larger streamline index and compression index compared to other species. Thus, *P. jubelini*, *L. dentatus*, *L. goreensis*, *P. quadrifilis*, *C. nigrodigitatus* and *L. falcipinnis* with a higher streamline index were grouped as benthic/bottom dwellers whilst *P. elongatus* (0.2139) and *G. nigri* (0.3845) with a relatively larger compressive index compared to other fishes with positive scores in PC I were grouped as benthic-pelagic/near

bottom dwellers. Observing the negative contributors for PC 1, it was noted that *C. hippos*, *S. maderensis* and *E. fimbriata* had lower Position of Eye (PE) values indicating ventrally positioned eye found in pelagic fish species thus, it was grouped as pelagic dwellers. Observations from positive contributors in PC 2 indicated that *P. elongatus* and *G. nigri* were short and stouter fishes and near bottom fishes owing to their high fish depth index and compression index values thus, were grouped as benthopelagic dwellers. Observations from the negative contributors in PCA in PC 2 indicated that *P. jubelini*, *L. dentatus*, *L. goreensis*, *P. quadrifilis*, *C. nigrodigitatus*, had similar fish depth index and compression index thus grouped as benthic/bottom dwellers. The categorization of fish species in Kono and Opuoko corresponds to reports by Ekpo *et al.* (2014)^[4] that listed *P. jubelini*, *L. goreensis*, *P. elongatus* and *P. quadrifilis* as carnivorous fishes in the Niger Delta. It also agrees with the report by Oribhabor and Ogbeibu (2012)^[13] that named *L. goreensis*, *P. jubelini* and *P. quadrifilis* as carnivorous in a Niger Delta Creek. In the Cross River estuary, *E. fimbriata* was found to be primarily herbivorous according to Idung *et al.* (2013)^[8], whereas *C. nigrodigitatus* was found to be omnivorous with a strong preference for algae according to Ndome and Udo (2018)^[11]. Additionally, *P. jubelini* is classified as demersal fish species that lives in sandy, muddy bottoms of coastal waters and is found at depths lower than 100m (benthopelagic) according to findings from Fatimat (2011)^[5]. The report listed above matches the categorization in this study in regards to habitat preference.

Conclusions

The Imo River fish assemblage's feeding behaviour and habitat preferences, as well as the cohabitation of many fish species, provided proof that the hypothesis regarding the relationship between morphology and ecology is correct. The morphological characteristics of fish species reflects the ecology of the ecosystem in a wide community of tropical ecosystem like the Imo River. Therefore, the findings of this study provides data on the habitat preference and feeding patterns of fish populations in the Kono and Opuoko segments of the Imo River, which can aid in making better decisions about fishing practices and management.

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