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Trophic attributes of the mudskipper, *Periophthalmus barbarus* (*Gobiidae*: *Oxudercinae*) in the mangrove swamps of Imo River Estuary, Nigeria

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Abstract: Aspects of the trophic attributes of the mudskipper, *Periophthalmus barbarus* occurring in the mangrove swamps of Imo River Estuary, Nigeria, were investigated during a 12-month period (April, 1992—March, 1993). Feeding intensity increased with size, it was higher in the dry season (November—April) than in the wet season (May—October). monthly changes in the indices of feeding intensity were significantly correlated. Major food objects comprised detritus and benthic algae; crustaceans, insects, macrophyte matter and sand grains were minor food objects while fish, molluscs, Chilopoda, nematodes and fungi were unconsciously devoured objects. Diet varied seasonally; algae and sesarmid crabs were generally more in the dry season than during the rains whereas FPOM and fish increased in the wet over dry season. The mudskipper display a high degree of euryphagy and can be considered as a generalist and an omnivore. The lower trophic status of *P. barbarus* qualifies it as a good aquaculture candidate. Food richness was higher in big-sized class (BSC) than small-sized class (SSC). Size-based and seasonal variations were not apparent in food richness. Diet breadth was higher in the BSC than the SSC. there was dry season increase in diet breadth.

Keywords: *Periophthalmus barbarus*; indices of feeding intensity; diet composition; mangrove swamp; Imo River Estuary; Nigeria

Introduction

Periophthalmus barbarus is an amphibious euryhaline gobiid fish that inhabits burrows in Nigerian coastal saline swamps. In spite of its small size, *P. barbarus* is a protein source to many of the coastal human communities. *P. barbarus* has recently been considered as an "endangered species" in view of the man-induced habitat degradation involing pollution, reclamation and the replacement of the native mangrove macrophytes (*Rhizophora mangle*, *Rhizophora harrizonii*, *Rhizohpora racemosa*, *Laguncularia racemosa* and *Avicenia africana*) by the introduced exotic nipa palm (*Nypa fruticans*; Moses, 1985; Wilcox, 1985).

P. barbarus has been considered as a potential pisciculture species in the Niger Delta, Nigeria (Fineman-Kalio, 1989) although detailed accounts of its biology have hitherto not been published to buttress thus assertion. The successful management and conservation of the wild stocks of *P. barbarus* as well as its aquaculture depend on availability of adequate knowledge of its biology. Considering the dearth of information on the tropical West African mudskipper (Clayton, 1993), the present paper focuses on the trophic attributes of *P. barbarus*. Aspects considered include feeding intensity and diet composition with respect to size, month and season.

1 Materials and methods

1.1 Study area and sampling procedure

The study was conducted in the Estuarine swamps of Imo Estuary around Ikot Abasi Local Government Area, Akwa Ibom State, Nigeria (Fig.1). Imo River basin is situated in the tropical rainforest belt with an equatorial climate regime. The climate of Ikot Abasi comprises two seasons viz: the dry (September-April) and wet (May—October) seasons. Detailed description of the Imo Estuary is provided by Enplan (Enplan, 1974).

Monthly samples of *P. barbarus* investigated in the study were collected between April, 1992 and March, 1993. The samples were collected by means of traditional non-return valved basket traps (42 – 50 cm in length; mesh sizes of 0.2 – 0.5 cm; Udolisa, 1994), set on the mudflats at low tide, baited with ground crabs and retrieved just before high tide. Each trap was fitted with two separate valves which separated the inside chamber into two compartment.

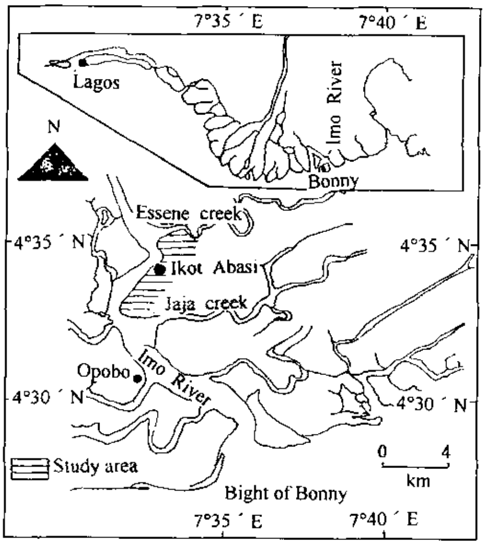

Fig.1 Map of lower reaches of Imo River Estuary, showing the sampling location. Inset: map of Nigeria, showing the location of Imo River

1.2 Gut contents analysis

The specimens collected per month were fixed immediately after capture in 10% buffered formalin for later gut analysis. The *P. barbarus* has no defined stomach, thus, the intestine was used as gut. The samples were taken to the laboratory, measured to the nearest 0.1 cm length (total (TL) and standard (SL)) and weight on a top loading electronic balance to nearest 0.001g total weight (TW). Thereafter, the guts were removed and the contents wet weight weighed. Food items were identified to the lowest taxonomic level and weighed to the nearest 0.001g.

1.3 Data analysis

There exist several indices for expressing the quantitative importance of different food items in the diets of fish (Hynes, 1950; Hyslop, 1980; Nataragan, 1981). Those used in the present study were: (1) Gut repletion index(GRI), i.e. number of non-empty guts divided by total number of guts multiplied by 100. (2) Food gravimetric composition(FGC), i.e. the wet weight of food in each gut divided by total weight of fish minus the weight of food and multiplied by 100. (3) Mean gut fullness (MGF), i.e. point score of each gut proportional to its degree of fullness according to an arbitrary 0, 5, 10, 15 and 20 scale. (4) Points(P) method, i.e. the total points per food item (based on the points volume of gut fullness) shared among the gut contents in unit proportional to their visual estimated bulk (see 3 above on the 0 – 20 scale). (5) The total points and frequency of occurrence of each food object were assessed by *A* and *B* system similar to the "point" and "occurrence and frequency" methods according to the formulae:

$$A = a_x 50 \cdot (A)^{-1};$$
$$B = b_x 50 \cdot (B)^{-1},$$

where, a_x is the total points per food object (x); A is the sum of all a_x; b_x is the number of times food object (x) appear; B is the sum of all b_x. A and B = 100%. The A and B system opins that food regarding individual dietary composition/importance is rather molecular but could be coded numerically in order of assumed dietary value after detailed examination and identification. It reduces the difficulty in dealing with large samples. Although it is subjectively similar to other methods in its initial criteria for award of points to food objects. It is quite easy to use. (6) The dietary status of each food object was integrated by modified food object number (MFON), a modification after indices of preponderance-methods for food grading in stomach analyses of fishes (Nataragan, 1981):

$$\mathrm{MFON} = a_x + b_x 100 \cdot (A \cup B)^{-1}.$$

The MFON moderates and adjusts numerical heaviness accruing the food objects. The MFON (range 0 – 100) functions on the premise that food object with a numerical strength greater than or equal to 10 is ranked major food object while those between 1 and 9.99 are minor and food object less than 1 is taken as unconsciously devoured object(Udo). (7) Variation in indices of feeding intensity and diet composition were determined by applying t-test, d-statistic and Spearman rank correlation (Bailey, 1959) to the recorded values. (8) Food richness (i.e. number of each individual food object in the diet) and diet breadth (i.e. *A* or *B* data based on Simpson's (Simpson, 1949) diversity index *D*) were computed.

2 Results

Of the 734 specimens of *P. barbarus* (size 3.6 – 15.6 cm TL) examined for food and feeding intensity, 621 (84.6%) contained food while 113 (15.4%) were empty guts; 529 (72.1%) had partially-filled guts while 92 (12.5%) were full guts.

2.1 Feeding intensity with size

To evaluate changes in feeding intensity of *P. barbarus*, the examined specimens were classified into two size-classes: small-sized class (SSC: range 4.0 – 9.0 cm TL) and big-sized class (BSC: 10.0 – 14.0 cm TL). The classification of the specimens into two size-groups was based on size at maturity (i.e. males = 10.5 cm TL; females = 10.2 cm TL) (Udo, 1995). From the indices of feeding intensity the BSC increased in GRI ($d = 19.259$, 618 df, $P < 0.02$) and MGF ($t = 2.172$m, 618 df, $P < 0.05$) than the SSC whereas the latter recorded higher FGC ($t = 2.475$, 618df, $P < 0.02$) than the former. From the indices, it is obvious that the BSC fed more than the SSC (Fig.2).

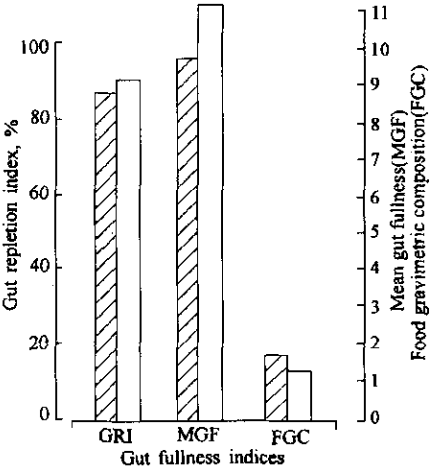

Fig.2 Size variation in indices of feeding intensity of *P. barbarus*

Table 1 Correlation matrix for indices of feeding intensity of *P. barbarus*

	GRI	MGF	FGC
GRI	1.000	0.725**	0.634*
MGF	0.725	1.000	0.865***
FGC	0.634	0.865	1.000

Note: Level of significance (*P*); * $P < 0.05$; * * $P < 0.01$; * * * $P < 0.001$; $n = 12$ in all cases

2.2 Feeding intensity with temporal regimes

Fig. 3 shows the monthly variation in the feeding intensity of *P. barbarus*. With the exception of an early drop in mean FGC in July, the monthly changes in indices of feeding intensity (GRI, MGF and FGC) followed similar pattern; the GRI peaked in July, October, December and March while peaks of MGF occurred in July, September and January and FGC occurred peaks in June, October, and March. The results suggested that high feeding intensity occurred in June—July, September—November, January and March while lowest in April. The monthly indices of feeding intensity significantly correlated with one another (Table 1).

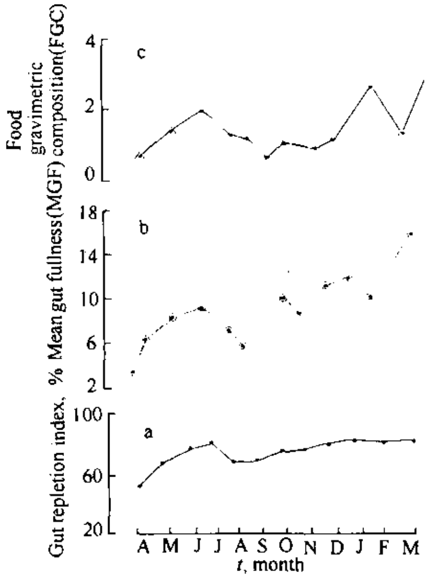

Fig.3 Monthly variations in indices of feeding intensity of *P. barbarus*

A total of 377 (51.4%) specimens were examined in the wet season and 357 (48.6%) in the dry season. The seasonal variations in indices of feeding intensity are represented in Fig. 4. There was a significant dry season increase in GRI ($d = 2.638$, $P < 0.01$), MGF ($t = 6.203$, 618 df, $P < 0.001$) and FGC ($t = 3.179$, 618 df, $P < 0.002$).

2.3 Food composition

The overall gut contents of *P. barbarus* (Table 2) revealed that 40 food items were ingested. The food items categorized into twelve major groups viz: algae, arachnids, crustaceans, detritus, fish, molluscs, Chilopoda, insects, macrophyte matter, nematodes, sand grains and fungi.

Algae comprised blue-green algae (*Oscillatoria* and *Nostoc*); diatoms (*Coscinodiscus*, *Cyclotella*, *Fragilaria*, *Gyrosigma*, *Navicula*, *Nitzschia* and *Pleurosigma*); green algae (*Closterium* and *Ulothrix*) and red algae (*Bostrychia*). Arachnids were composed of spiders. Crustaceans consisted of crabs (*Sesarma alberti* and *Pagurus* sp), shrimps (*Macrobrachium vollenhovenii* and *penaeids*) and Isopods. Detritus included coarse particulate organic matter (CPOM) and fine particulate organic matter (FPOM). Fish consisted of *Dalophis cephalopeltis*, fish remnants (bones and scales) and unidentified bivalves. Chilopoda was composed of *Geophilus* (centipede). Insects in the diet comprised Coleoptera, Hymenoptera, unidentified adult insects, insect larvae (Diptera and Lepidoptera) and pupae and remains.

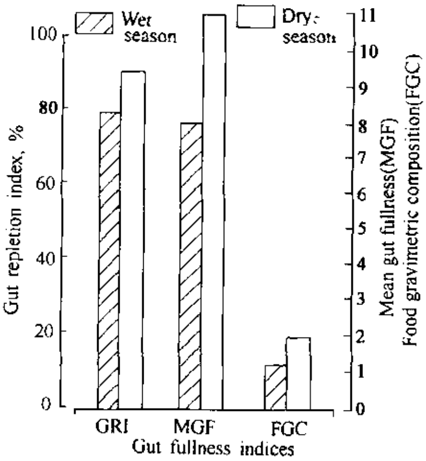

Fig.4 Seasonality variation in indices of feeding intensity of *P. barbarus*

Table 2 Overall trophic spectrum of *P. barbarus*

Food items	% modified food object number	Food items	% modified food object number
Algae		Detritus	
Blue green algae		CPOM	23.33
Oscillatoria	0.10	FPOM	27.31
Nostoc	+	Total	50.64
Diatoms		Fish	
Coscinodiscus	15.37	*Dalophis cephalopeltis*	+
Cyclotella	0.55	Unid fish	0.50
Fragilaria	0.22	Fish remnants	0.24
Gyrosigma	2.36	Total	0.74
Navicula	8.21	Molluscs	
Nitzschia	0.20	*Tympanotonus fuscatus*	0.10
Pleurosigma	4.97	*Neritina glabrata*	0.35
Green algae		*Melampus* sp.	+
Closterium	0.38	Unid bivalve	0.04
Ulothrix	0.05	Total	0.49
Red algae		Myriapods	
Bostrychia	0.07	Chilopoda	0.01
Total	32.51	Insects	
Arachnids	+	Coleoptera adults	0.01
Crustaceans		Hymenoptera adults	0.27
Decapoda (crabs)		Unid insects	2.21
Sesarma alberti	0.91	Insect eggs	+
Sesarma remains	1.39	Dipteran larvae	0.02
Pagurus sp.	0.04	Dipteram pupae	+
Decapoda (shrimps)		Lepidopteran lavae	0.03
Macrobrachim vollehovenii	+	Total	2.54
Penaeid remains	0.89	Macrophyte matter	2.71
Isopoda	0.01	Numatodes	0.44
Total	3.24	Sand grains	6.70
		Fungi (Zygomycetes)	+

Note: +, < 0.01% MFON

Modified food object number (MFON) showed that *P. barbarus* fed on major food objects of detritus (50.64%) and algae (32.48%); minor food objects included sand grains (6.70%), crustaceans (3.24%), insects (2.54%) and macrophyte matter (2.71%) while fish (0.74%), nematodes (0.44%), molluscs (0.49%), Chilopoda (0.01%) and fungi (< 0.01%) were consumed as unconsciously devoured objects. The high relative importance of detritus in diet of *P. barbarus* suggests benthic foraging while inclusion of varied food objects indicates that the fish is polyphagous.

2.4 Food composition with size

Table 3 illustrates the changes in the trophic spectra of different sizes of *P. barbarus*. There were slight differences in diets of the size-classes; *Macrobrachium vollenhovenii* and fungi were not ingested by the SSC whereas arachnids and dipteran larvae were not eaten by the BSC. Similar trends occurred in the rank-order of the MFON of the food objects (Spearman rank correlation: $r_s = 0.746$, $P < 0.002$), evenso, significant differences occurred in the proportions of some of the food objects.

Table 3 Trophic spectra of the small-sized class (SSC) and big-sized class (BSC) of *P. barbarus*

Food items	% modified food object number			Food items	% modified food object number		
	SSC	BSC	P^*		SSC	BSC	P^*
Algae				Detritus			
Blue green				CPOM	23.97	20.74	*
Oscillatoria	0.09	0.13	*	FPOM	25.79	28.51	*
Nostoc	+	0.1	ns	Total	49.76	49.25	*
Diatoms				Fish			
Coscinodiscus	16.2	12.97	*	*Dalophis cephalopeltis*	+	0.01	ns
Cyclotella	0.55	0.53	ns	Unid fish	0.10	0.81	*
Fragilaria	0.24	0.17	*	Fish remnants	0.07	1.98	*
Gyrosigma	2.42	2.10	*	Total	0.17	1.80	*
Navicula	10.37	4.31	*	Molluscs			
Nitzschia	0.13	0.37	*	*Tympanotomus fuscatus*	0.14	0.03	*
Pleurosigma	4.84	4.93	ns	*Neritina glabrata*	0.50	0.12	*
Green algae				*Melampus* sp.	+	+	ns
Closterium	0.61	0.09	*	Unid bivalve	0.01	0.14	*
Ulothrix	0.10	+	ns	Total	0.65	0.19	*
Red algae				Myriapods	0.01	0.01	ns
Bostrychia	0.05	0.12	*	Chilopoda	0.01	0.01	ns
Total	35.60	25.73	*	Insects			
Arachnids				Coleoptera adults	0.30	0.21	*
Crustaceans				Hymenoptera adults	0.01	0.05	*
Decapoda (crabs)				Unid insects	+	+	ns
Sesarma alberti	0.42	2.28	*	Insect eggs	0.01	0.08	*
Sesarma remains	0.41	4.56	*	Dipteran larvae	+	–	ns
Pagurus sp.	0.03	0.05	*	Dipteran pupae	2.31	1.21	*
Decapoda (shrimps)				Lepidopteran lavae	0.25	0.29	*
Macrobrachim vollehovenii	–	0.03	ns	Total	2.88	1.84	*
Penaeid remains	0.19	3.48	*	Macrophyte matter	2.15	3.77	*
Isopoda	+	0.04	ns	Nematodes	0.27	0.82	*
Total	1.05	10.44	*	Sand grains	7.44	5.02	*
				Fungi(Zygomycetes)	–	0.01	ns
				Food richness	39	39	
				Diet breadth	0.93	0.94	

Notes: +, 0.01% MFON; P^*: significance level; *, significant at $P < 0.001$; ns: not significant

The SSC was higher in the ingestion of algae, detritus, molluscs, insects and sand grains. In contrast, the BSC increased significantly in the consumption of larger food objects of crustaceans, fish, macrophyte matter, nematodes and fungi. No significant size-based differences was apparent in food richness. Diet breadth was higher in the BSC than SSC, revealing an increase food generalization with fish growth.

2.5 Diet composition with temporal regimes

Monthly MFON (Table 4) shows that detritus predominated in all the months as major food object except in June, February and March. Peaks were recorded in April, July, September, December, February. With exception of September and November, algae were major food objects in all other months.

Table 4 Monthly variations in the % modified food object number (MFON) of *P. barbarus*

Food items	April	May	June	July	August	September	October	November	December	January	February	March
Algae												
Oscillatoria	-	-	-	-	0.04	1.43	1.36	0.18	-	-	-	0.64
Nostoc	-	0.02	-	-	-	-	0.16	0.05	0.01	-	-	-
Coscinodiscus	33.59	23.08	37.80	7.34	21.46	0.26	13.66	1.25	12.94	12.44	4.86	11.37
Cyclotella	1.25	0.35	0.01	0.38	0.40	-	1.06	-	0.01	2.63	0.52	2.16
Fragilaria	-	-	0.03	0.05	-	-	0.11	-	0.78	0.62	1.51	0.38
Gyrosigma	0.04	1.02	0.01	0.12	0.76	0.02	0.12	0.25	3.01	7.84	12.18	8.29
Navicula	1.16	12.94	10.01	4.64	7.17	0.64	1.18	0.02	11.30	9.64	8.60	14.59
Nitzschia	0.15	0.60	0.01	0.03	0.21	-	-	0.02	-	0.09	0.30	2.41
Pleurosigma	0.61	1.55	6.81	0.42	1.74	-	0.03	0.71	5.01	10.94	18.47	14.78
Closterium	0.04	0.23	-	0.02	0.08	1.02	0.08	-	2.87	0.07	0.09	0.53
Ulothrix	-	-	-	-	-	-	-	-	0.36	0.73	0.17	-
Bostrychia	-	-	-	-	-	-	-	2.86	-	-	0.77	0.54
(Total)	(36.87)	(39.79)	(54.68)	(13.00)	(31.86)	(3.37)	(17.76)	(5.34)	(36.29)	(45.00)	(47.47)	(55.60)
Arachnids	-	-	0.05	0.03	-	0.02	-	-	-	-	-	-
Crustaceans												
Sesarma alberti	-	0.39	1.65	0.05	0.24	0.27	1.61	4.69	0.14	0.12	2.13	2.78
Sesarma remains	-	0.02	0.22	0.18	0.66	15.50	0.87	42.30	0.17	0.52	0.22	0.36
Pagridae (Hermitcrab)	-	-	-	-	0.02	-	0.41	0.18	0.39	0.02	-	-
M. vollehovenii	-	-	-	0.10	0.01	-	-	-	-	0.06	-	-
Penaeid remains	-	0.39	0.13	2.56	2.04	2.03	0.61	0.04	0.25	0.31	0.22	2.52
Isopoda	-	-	-	0.39	0.14	-	0.06	-	-	-	-	-
(Total)		(0.80)	(2.00)	(3.28)	(3.11)	(17.8)	(3.56)	(47.21)	(0.95)	(1.03)	(2.57)	(5.66)
Detritus												
CPOM	25.73	25.98	6.03	14.85	21.30	18.54	31.38	10.12	29.06	21.6	20.22	16.49
FPOM	30.31	23.28	31.40	45.85	29.22	41.89	22.82	8.36	16.75	14.79	18.17	16.73
(Total)	(56.04)	(49.26)	(37.43)	(60.70)	(50.52)	(60.43)	(54.20)	(18.48)	(45.81)	(36.39)	(44.39)	(33.22)
Fish												
Dalophis cephalopeltis	-	-	-	0.15	-	-	-	-	-	-	0.02	0.01
Fish scales	0.04	0.08	0.03	0.14	0.04	1.07	0.01	2.42	0.17	-	0.03	0.02
Fish bones	-	-	0.02	0.52	0.28	0.03	0.47	0.25	-	0.03	-	0.29
Unid fish	-	0.82	-	0.03	0.03	1.99	2.03	2.05	0.37	0.52	0.63	0.14
(Total)	(0.04)	(0.90)	(0.05)	(0.84)	(0.35)	(3.09)	(2.51)	(4.72)	(0.54)	(0.55)	(0.68)	(0.46)

Table 4(continued)

Food items	April	May	June	July	August	September	October	November	December	January	February	March
Gastropoda												
Tympanotonus fuscatus	–	0.03	–	–	0.34	1.20	–	7.30	–	–	–	–
Neritina glabrata	–	–	0.42	–	0.11	0.03	1.78	8.52	0.81	0.07	0.02	0.05
Melampus sp.	–	–	–	0.01	–	–	–	–	–	0.03	–	–
Unid bivalve	–	–	–	–	–	0.03	–	0.58	0.02	0.01	0.16	0.21
(Total)	–	(0.03)	(0.42)	(0.01)	(0.45)	(1.23)	(1.78)	(16.40)	(0.83)	(0.11)	(0.18)	(0.27)
Ceophilid												
Insects												
Coleoptera	–	–	0.05	0.04	–	0.43	0.13	–	0.01	–	–	–
Hymenoptera	–	0.19	0.02	1.72	0.29	0.64	0.34	0.05	0.14	0.59	0.40	–
Dipteran larvae	–	–	–	–	–	–	–	–	0.68	–	–	–
Dipteran pupae	–	–	0.02	0.50	–	–	–	–	–	–	–	–
Lepidopteran lavae	–	–	0.02	0.01	0.228	0.23	0.63	–	–	–	–	–
Insect egg	0.22	–	–	–	–	–	–	–	–	–	–	–
Insect remains	1.25	0.29	0.44	2.89	1.78	1.84	1.22	1.55	4.40	8.88	0.31	–
Unid insects	0.07	0.05	0.06	0.04	0.24	0.39	0.47	2.01	0.91	0.36	–	–
(Total)	(1.54)	(0.53)	(0.61)	(5.20)	(2.55)	(3.53)	(2.79)	(3.61)	(6.14)	(9.83)	(0.71)	–
Macrophyte matter	0.35	2.19	0.25	2.40	0.99	3.10	4.14	3.51	1.93	4.02	6.52	2.47
Nematodes	5.03	0.19	0.91	0.60	0.12	1.53	4.74	–	0.19	0.01	0.11	0.13
Sand grains	–	6.26	3.58	14.65	9.99	5.82	8.74	0.72	7.32	3.18	3.37	2.20
Zygometes	–	–	0.02	–	–	0.03	–	–	–	–	–	–
Food richness	15	23	26	31	29	27	29	25	27	28	25	23
Diet breadth	0.73	0.80	0.74	0.74	0.85	0.76	0.82	0.79	0.85	0.88	0.86	0.89

Crustaceans were not eaten in April but were ingested as major objects in November as minor dietary in June—August, October and January—March; there were unconsciously devoured food objects in the rest of the months. Sand grains occurred as major food objects only in July and as minor objects in all other months except November when they were unconsciously devoured. Molluscs occurred as major objects in September—November and as minor objects in November whereas they were unconsciously devoured objects in all other months except in April when they were not eaten. Macrophyte matter were of minor importance in May, July and September—March while in April, June and August they were unconsciously devoured objects. Insects occurred as minor objects in April, July—January and as unconsciously devoured food objects in May and February but were not encountered in March. The fish and nematodes components of the diet were ingested as minor food objects in September—November although nematodes were absent in November; both items were unconsciously devoured in all other months. Chilopoda was unconsciously devoured in May, June—October and January. Fungi occurred as unconsciously devoured objects in June and September. The high proportions of detritus, benthic algae and inclusion of sand grains portrayed *P*.

barbarus as a bottom feeder. Monthly food richness ranged between 15 in April and 31 in July. Diet breadth apparently increased during the study with minimum and maximum values obtained at beginning (April) and end of the study (March) respectively. There was no relationship between the months in food richness and diet breath.

The seasonality in the food composition of *P*. *barbarus* showed differences in both seasons (Table 5). Although there was similarity in the rank-order of the MFON of the food objects ($r_s = 0.892$, $P < 0.002$), the proportion of some of them were different. *Ulothrix*, *Bostrychia* and insect eggs were excluded from the diet during the wet season while the diet during the dry season was devoid of arachnids, Isopoda, Coleopterans, insect pupae and fungi. There was a marked wet season increase in the MFON of *Coscinodiscus*, FPOM, unidentified fish, nematodes and sand grains and a dry season increase in that of *Fragilaria*, *Gyrosigma*, *Navicula*, *Pleurosigma* and *Sesarma* remains. No seasonality occurred in the MFON of the food objects (Table 5). There was marked dry season increase in diet breadth over the rains.

Table 5　Seasonal variation in the food composition of *P*. *barbarus*

Food items	% modified food object number (MFON)			Food items	% modified food obfect number (MFON)		
	Wet season	Dry season	*d*-statistic		Wet season	Dry season	*d*-statistic
Algae				Detritus			
Blue green	0.15	0.06	0.503^{ns}	CPOM	19.89	23.83	1.789^{ns}
Oscillatoria	0.01	+	0.152^{ns}	FPOM	35.22	18.77	6.945***
Nostoc				Total	55.12	42.61	3.224***
Diatoms				Fish			
Coscinodiscus	17.81	11.89	3.116***	*Dalophis cephalopeltis*	0.01	+	0.061^{ns}
Cyclotella	0.28	0.78	1.316^{ns}	Unid fish	0.29	0.19	5.333***
Fragilaria	0.02	0.55	2.038*	Fish remnants	0.45	4.77	1.227^{ns}
Gyrosigma	0.25	5.45	6.155***	Molluscs			
Navicula	6.04	9.33	2.350*	*Tympanotonus fuscatus*	0.10	0.08	0.125^{ns}
Nitzschia	0.07	0.35	1.130^{ns}	*Neritina glabrata*	0.19	0.48	0.967^{ns}
Pleurosigma	1.33	9.13	5.860***	*Melampus* sp.	+	+	1.103^{ns}
Green algae				Unid bivalve	+	0.11	0.865^{ns}
Closterium	0.13	0.65	1.625^{ns}	Total	0.29	0.67	0.946^{ns}
Ulothrix	–	0.15	–	Myriapods			
Red algae				Chilopoda	0.04	+	0.563^{ns}
Bostrychia	–	0.24	–	Insects			
Total	26.09	38.58	5.081***	Coleoptera adults	0.05	+	0.597^{ns}
Arachnids	0.01	–	–	Hymenoptera adults	0.44	0.14	1.034^{ns}
Crustaceans				Unid insects	1.62	2.45	1.135^{ns}
Decapoda (crabs)				Insect eggs	–	+	–
Sesarma alberti	0.59	1.12	1.250^{ns}	Dipteran larvae	–	0.06	–
Sesarma remains	1.22	1.38	2.667**	Dipteran pupae	0.01	–	–
Pagurus sp.	0.02	0.06	0.364^{ns}	Lepidopteran lavae	0.13	–	–
Decapoda (shrimps)				Total	2.25	2.65	0.506^{ns}
Macrobrachim				Macrophyte matter	1.94	3.15	1.458^{ns}
vollehovenii	0.01	+	0.125^{ns}	Nematodes	0.99	0.12	2.122*
Penaeid remains	1.21	0.54	1.196^{ns}	Sand grains	9.41	4.16	2.987***
Isopoda	0.06	–	–	Fungi (Zygomycetes)	+	–	–
Total	3.11	3.10	0.055^{ns}	Food richness	35	35	
				Diet breadth	0.79	0.87	

Notes: +. < 0.01% MFON; *d*-statistics: * $P < 0.05$; * * $0.02 < P < 0.01$; * * * $0.002 < P < 0.001$; ns: not significant at $P = 0.05$

3 Discussion

Periophthalmus barbarus from Imo River Estuary, Nigeria, fed principally on detritus and benthic algae; crustaceans, insects, macrophyte matter and sand grains were minor food objects while fish, molluscs, Chilopoda, nematodes and fungi unconsciously devoured. These results contradict with those reports of Irvine (Irvine, 1947) that the species in Ghana fed largely on Sesarmid crabs and small breathing roots of the white mangrove (*Avicenia africana*). FAO (FAO, 1981) noted that the food comprised crabs and insects. Fineman-Kalio and Alfred-Ockiya (Fineman-Kalio, 1989) also reported that this fish in the Niger Delta, Nigeria, fed mainly on detritus and algae while other foods, occurred as minor and unconsciously devoured objects. Tytler and Vaughan (Tytler, 1983) described mudskipper Beleophthalmus dussumerie in Kuwat Bay as a feeder on fiddler crabs.

The above reports are broadly similar to the present findings except that the order of relative importance and range of the food objects ingested by *P. barbarus* in Imo River Estuary, Nigeria, are appreciably higher than those documented by Irvine (Irvine, 1947), FAO (FAO, 1981), Fineman-Kalio and Alfred-Ockiya (Fineman-Kalio, 1989) and Tytler and Vaughan (Tytler, 1983). The gut contents of *P. barbarus* in the present study depicted predominantly benthic foraging. This was at variance with planktophagy displayed by some related species (Sarket, 1980; Tytler, 1983). The possibilities for this contrast could be differences in the habitats of the different geographical regions and differences in the food between the species.

The wide food spectrum of *P. barbarus* under current study portrayed high trophic flexibility. It enables the fish to switch easily from one food category to another in response to fluctuation in their abundance. Another possibility is the ability of the species to utilize many different foods effectively. This was accentuated by the high proportion of non-empty guts.

The study revealed that the relative importance of large-sized food objects such as crustaceans, fish, and macrophyte matter and nematodes increased with fish size while that of small-sized objects such as algae and detritus decreased. The inherent increase in mouth gape with body growth of the fish probably permits the prey-size related feeding pattern by *P. barbarus*. Diversification in diet of a fish with growth reduces intraspecific competition while offering a vast spectrum of food objects or exploitation. The monthly and seasonal dynamics in the relative importance of the food objects eaten by *P. barbarus* from the swamps of Imo River Estuary are probably due to the temporal patterns in the availability and abundance of the food objects. The reliance of *P. barbarus* on detritus (CPOM and FPOM) as a major dietary components throughout the year is probably facilitated by the vast mangrove swamp (Enplan, 1974) which ensures a constant allochthonous input of this food object through decaying shed leaves of *Rhizophora*.

The proportion of non-empty guts of *P. barbarus* is considered as high. This is attributed to frequent feeding. This study revealed that the feeding intensity of *P. barbarus* increased with fish size. Similarly, based on the percentage of empty stomach, juveniles of *B. dussumierei* in the Bombay Coast, apparently have lower feeding intensity than the adults (Mutsaddi, 1969). The increase in feeding with size is not consistent with the idea of negative correlation between feeding and fish size relative to metabolic rates (Lagler, 1977; Sarker, 1980; Blay, 1982). It is postulated here that the increase in feeding intensity with size is not only influenced by increase mouth gape and body growth but also by the ability of the fish to become less vulnerable to predation while feeding which is also a function of body size.

The seasonality in indices of gut fullness of *P. barbarus* in this study indicated a higher feeding intensity in the dry season than during the rains; the result contradicts a trend generally observed in tropical fishes (Lowe-McConnell, 1987). The precise reason is uncertain but could reflect an adaptation linked to reproduction (Udo, 1995), ensuring that progeny hatch into more favourable feeding condition of improved food resources at on set of the rainy season.

The higher dry season in diet breadth vis-à-vis the wet season in the present study conforms to the theory of optimal foraging (Schoener, 1971; Angermeier, 1982). The theory assumes that an inverse relationship should exist between diet breadth and food richness; it theorizes also that the diet breadth should become enlarged during periods of shortage supply and abundance and vice-versa. The higher feeding intensity in the dry season, though in line with the optimal foraging theory, is at variance with those works including, Lowe-McConnell (Lowe-McConnell, 1987) on tropical fish and fisheries which reported high wet season abundance of food resources over the dry season.

In conclusion, *P*. *barbarus* in the Imo River Estuary, Nigeria, is an omnivore, exhibiting a high degree of euryphagy. The high ingestion of detritus and benthic algae depicts a lower trophic association. The presence of sand grains in the array of food objects of the mudskipper is probably to augment its mineral-deficient diet as practiced by Marsupial order of mammal (Koala), confined only to eastern states of Australia. The wide range and trophic flexibility of *P*. *barbarus*, account invariably for its success and predominance in the estuary. Culturing techniques for rearing of mudskipper have improved in recent years and the developmental stages of the Chinese and Japanese are now known. Considering the successes in artificial propagation of larval mudskipper, the potential for commercial rearing of the fish is also on the increase. Nevertheless, successful aquaculture relies solely now on understanding the reproductive as well as trophic cycles of the mudskipper.

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References:

Angermeier P L, 1982. Resource seasonality and fish diets in an Illinois stream[J]. Env Biol Fish, 7(3): 251 – 264.

Bailey N T J, 1959. Statistical method in biology[M]. The English Language Book Society. English University Press. 200.

Blay J Jr, Eyeson K N, 1982. Feeding activity and food habits of the shad, *Ethmalosa fimbriata* (Bowdich) in the coastal waters of Cape Coast, Ghana[J]. J Fish Biol, 21: 403 – 410.

Clayton D A, 1993. Mudskipper In: Oceanography marine biology annual review, 31 (A. D. Ansell, R. N. Gibson, Margaret Barnes eds.) [M]. UCL Press. 507 – 577.

Enplan Group, 1974. Imo River Basin pre-feasibility[R]. Federal Ministry of Agriculture. Lagos. Nigeria. 1 – 74.

FAO, 1981. Species identification sheets for fisheries purposes[C]. East Central Atlantic Fishing Area 34 and part of 47. Dept of Fish and Oceans. Canada Vol. II: 1 – 8.

Fineman-Kalio A S, Alfred-Okeiya J F, 1989. Towards large scale farming of the mudskipper in the brackish environment[C]. In: Proceeding of 4th annual conference of the Nigerian Association for Aquatic Sciences at the Dept. of Wildlife and Fisheries Management, University of Ibadan, Nigeria. 7.

Hynes H B N, 1950. The food of freshwater sticklebacks (*Gasterosterus aculetus* and *Pygosteus pungitus*) with a review of methods used in studies of the food of fishes[J]. J Anim Ecol, 19: 36 – 58.

Hyslop E J, 1980. Stomach content analysis. A review of methods and their application [J]. J Fish Biol, 17: 411 – 429.

Irvine F R, 1947. Fish and fisheries of gold coast[Z]. Crown Agents. 45 – 60.

Lagler K F, Bardach J E, Miller R R *et al*., 1977. Ichthyology[M]. New York: John Wiley and Inc. 506.

Lowe-McConnell R H, 1987. Ecological studies in tropical fish communities[M]. London: Cambridge University Press. 382.

Moses B S, 1985. Distribution, ecology and fisheries potential of Nigeria. Wetlands. In: Nigeria Wetlands (Akpata T. V. I., D. U. O. Okali eds.)[M]. Ibadan. Nigeria: Printed by Offset Lithography. 165.

Mutsaddi K B, Bal D V, 1969. Food and feeding of *Beleophthalmus dussumeirei* (Cuv. and Val.)[J]. Journal of University of Bombay, 39: 42 – 55.

Nataragan A V, Jhingram A G, 1981. Index of preponderance. A method of grading the food elements in the stomach analysis of fishes[J]. Indian J Fish, 8: 54 – 59.

Sarker A L, A l-daham N K, Bhatti M N, 1980. Food habits of the mudskipper, *Pseudocryptes dentatus* (Val.)[J]. J Fish Biol, 17: 636 – 639.

Schoener T W, 1971. Theory of feeding strategies[J]. Ann Rev Ecol Syst, 2: 269 – 404.

Simpson E H, 1949. Measurement of diversity[J]. Nature, 163: 688

Tytler P, Vaugham T, 1983. Thermal ecology of the mudskipper, *Periophthalmus koelreuteri* (Pallas) and *Beleophthalmus boddarti* (Pallas) of Kuwait Bay[J]. J Fish Biol, 23: 327 – 337.

Udo M T, 1995. Some aspects of the biology of the mudskipper, *Periophthalmus barbarus* (Linne, 1766) (Teleostei, Gobiidae) in the estuarine swamp of Imo River[D]. M.Sc. Thesis, University of Uyo, Nigeria. 145.

Udolisa R E K, Solarin B B, Lebo P E *et al*., 1994. A catalogue of small scale fishing gear in Nigeria[R]. RAFR Publication, RAFR/O14/FI/94/02. 142.

Wilcox B H R, 1985. Angiosperm flora of the Niger Delta[M]. In: The mangrove ecosystem of the Niger Delta (Wilcox B. H. R., Powell C. B. eds.). Publications Committee, University of Port Harcourt, Nigeria. 357.

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