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FEEDING ECOLOGY OF *Pachypterus atherinoides* (Actinopterygii; Siluriformes; Schilbeidae): A SMALL FRESHWATER FISH FROM FLOODPLAIN WETLANDS OF NORTHEAST INDIA

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ABSTRACT

The feeding ecology of *Pachypterus atherinoides* was investigated for two consecutive years (2013-2015) from floodplain wetlands in the Subansiri river basin of Assam, North East India. The analysis of its gut content revealed the presence of 62 genera of planktonic life forms along with other animal matters. The organization of the alimentary tract and maximum Relative Mean Length of Gut (0.511±0.029 mm) indicated its carnivorous food habit. The peak gastro-somatic index (GSI) in winter-spring seasons and summer-rainy seasons indicated alteration of its feeding intensity. Furthermore, higher diet breadth on resource use (Levins' and Hurlbert's) with zooplankton compared to phytoplankton and total plankton confirmed its zooplanktivore habit. The feeding strategy plots also suggested greater preference to zooplankton compared to phytoplankton. The organization of its gill rakers specified a secondary modification of gut towards either carnivory or specialized zooplanktivory. So, the fish may be a carni-omnivore with preference to zooplankton.

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INTRODUCTION

Diet composition assessment is not only important in defining nutritional requirements of fish species but also defines the ability to utilize food items by fish available in its environment (Ibrahim et al., 2003; Offem et al., 2009). Feeding habits, particularly in fish is correlated with mouth size, dentition, gill rakers, alimentary tract (Ojeda, 1986; Dasgupta, 2009) and often with changes in season, breeding and maturity of fish (Khan et al., 1988; Fatima and Khan, 1991). Moreover, morphological, anatomical and physiological adaptation of the feeding apparatus of fishes also influenced their feeding habits (Wotton, 1998). *Pachypterus atherinoides* (Bloch, 1974) is a small indigenous freshwater fish species with a maximum total length up to 8 cm (Fig. 1). It inhabits all types of freshwater bodies like rivers, streams, floodplain lakes, oxbow lake, reservoirs, ponds and in deepwater rice fields. It is distributed across Bangladesh, Pakistan, India, Myanmar and Nepal (Talwar and Jhingran, 1991). It has excellent market demand as food both in fresh as well as dried conditions (Samad et al., 2009). In spite of its wide distribution in South East Asia and demand for food, the grow-out culture of this fish has yet to be developed. Available information on *P. atherinoides* is limited to food habits and digestive enzyme profile only from river ecosystem (Sengupta and Homechaudhuri, 2011). But looking to its wider distribution across the different types of lotic and lentic water bodies, there is scope to generate new information as to how *P. atherinoides* maintains adaptability in accessing food resources, from the diverse aquatic habitats.

The pattern of feeding of a fish species is highly responsive to the availability of food items in the habitat in different seasons of the year. The understanding of diet breadth and feeding strategies through gut content analysis across seasons is essential for management of effective nutritional strategies for a fish species to be cultured. Considering that the change in feeding behaviour of *P. atherinoides* is in agreement with its breeding as well as maturity in its habitat, the information gathered would be of great importance to understand its food preferences and overlapping of food spectrum in a co-culture fisheries. It has also been observed that fish species like *P. atherinoides* often maintain endemicity to the habitat they thrive in. In such a case, the findings of the present study would be of great value to the conservation and management of *P. atherinoides*.

MATERIALS AND METHODS

Study area

All samples of fish (n=109) were collected from three wetlands viz. Hatimora deepwater rice fields or DWR (30 ha), Morikhaboli floodplain lake (10 ha) and Halmora oxbow lake (15 ha) within floodplains of Subansiri river basin located between $27^0.02$ and $27^0.15$ northern latitude and $93^0.99$ and $94^0.15$ east longitude of Assam, a northeastern State of India (Fig. 2). The floodplain area of river Subansiri is about 2,768.17 km^2 in which DWR occupies 2098.98 km^2, floodplain lake occupies 655.51 km^2 and oxbow lake covers 13.68 km^2.

Gut content sampling

Live individuals (n=10) were collected every month between May 2013 and April 2015 covering four broad seasons: Summer-rainy (SR, May to July), Rainy-autumn (RA, August to October), Autumn-winter (AW, November to January) and Winter-spring (WS, February to April). Fishes were caught in the morning hours using a cast net (pore size 64 mm^2, locally known as 15 no. Jal). Before recording morphometric measurements (total weight, total length and standard length), fish specimens were killed using MS 222 and immediately preserved in 10% formalin.

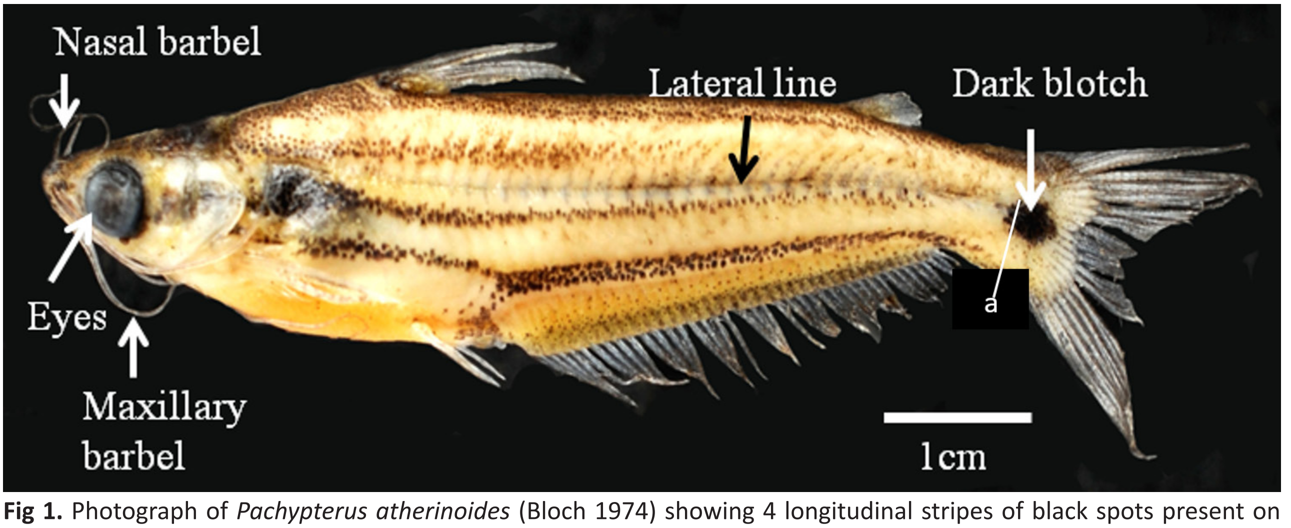

Fig 1. Photograph of *Pachypterus atherinoides* (Bloch 1974) showing 4 longitudinal stripes of black spots present on flank. A black spot is also visible on the base of caudal fin. Four pairs of barbs are prominent

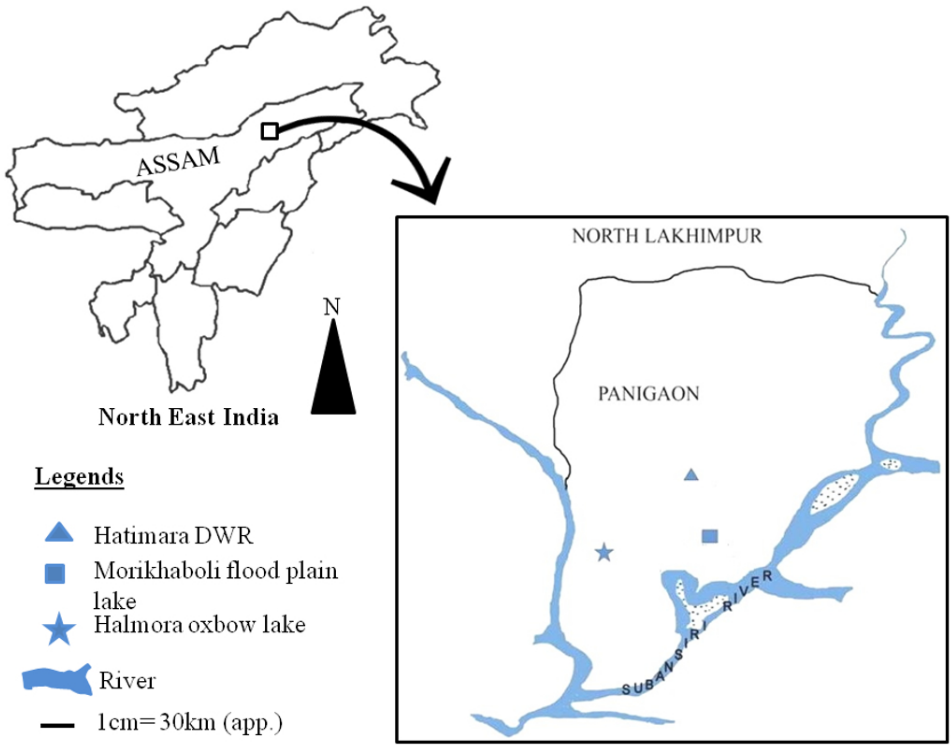

Fig 2. Location map of Subansiri floodplain wetlands where from *Pachypterus atherinoides* were sampled. The map is not to scale. The scale given represents the measure for the figure shown in the inset

The alimentary tracts were removed carefully, blotted with tissue paper and their lengths and weights were recorded. Gut contents were collected by dissecting the gut longitudinally and then immediately preserved in 4% formalin for further observation. The weight of the emptied gut was also recorded. All collected and preserved samples were carried in a container to the Fisheries and Aquatic ecology laboratory of Rajiv Gandhi University for further investigation.

Resource sampling

The plankton samples were collected with the aid of plankton net (mesh size 60 µm) on the day of fish sampling. Plankton samples were collected by filtering 100 L of subsurface water. Filtrates from collecting vial of the plankton net were transferred carefully to labelled specimen tubes and were immediately preserved in 5% formalin and allowed to settle down for further analysis.

Identification and quantification of samples

Both the gut contents and plankton samples were screened and quantified under stereoscopic binocular microscope (Nikon Eclipse E200-LED). Organisms were identified to the generic level (following Pentecost, 1984; Desikachary, 1989; Edmondson, 1992; Michael and Sharma, 1988; Shiel, 1995). Gut contents (phytoplankton, zooplankton, animal matter, detritus and unidentified organisms) and food resources were counted following modified drop count method (Lackeys, 1938).

Food composition and food selection

Food composition

Relative food composition was calculated and expressed as % composition of the food

$$\% \text{ composition of food} = Pfi / Tfi \times 100$$

[Where, Pfi = number of a particular food items in the gut, Tfi = total number of all food items combined in the gut]. The percent composition of diet present in the gut was estimated across the season. It provides accounts of seasonal changes of feeding intensity and accessibility of specific food items during each season.

Diet breadth estimation

Two indices of diet breadth viz. Levins' and Hurlbert's diet breadths were estimated to draw a clear understanding of the resource utilization and mode of resource selection by the fish under study. Two resources (total plankton and zooplankton) of the fish gut were considered for the estimation of Levins' diet breadth. However, in the case of Hurlbert's diet breadth, three resources (total plankton, zooplankton and phytoplankton) were considered for analysis. The Levins' diet breadth measure was based on the food items present in the gut. Since Levins' diet breadth relies on gut content only, the individual group of phytoplankton from the gut were too scanty (<10%) to count and hence ignored for the estimation of Levins' diet breadth.

i) Levins' diet breadth (Levins, 1968) accounts gut resources and was calculated as:

$$B_A = \frac{(1/\Sigma p_j^2) - 1}{n - 1}$$

[Where, B_A = Levins' normalized diet breadth, p_j= proportions of food items in the diet and n = total number of resource items]

ii) Hurlbert's diet breadth (Hurlbert, 1978) accounts resource of both environment and diet. It was calculated as:

$$B_A' = \frac{[1/\Sigma(p_j^2/a_j)] - a_{\min}}{1 - a_{\min}}$$

[Where, B_A'= Hurlbert standardized diet breadth, p_j= proportion of items in the diet, a_j= proportion of available resources in environment]

Both diet breadths maintain range from 0-1, indicating variations from complete avoidance (0) to the highest preferences (1) for a particular resource.

Feeding strategy

Ivlev's electivity index (Ivlev, 1961) was measured to identify the selection of available food items from the environment by the fish. It was calculated as:

$$E_i = S_{t_i} - P_i / S_{t_i} + P_i$$

[Where, E_i= Ivelv's electivity index for species i, S_{t_i} = Relative proportion of species i in the diet, P_i = Relativeproportion of species i in the environment]

E value varies from -1 to +1. E value around 0 indicates random ingestion, +1.0 or around +1.0 indicates strong ingestion and -1.0 or around -1.0 indicates weak to strong avoidance. Feeding strategy was analysed by plotting E values against a relative proportion of resource available in the environment as Ivlev's electivity (E) values are sensitive to the relative densities of the food types (Jacobs, 1974). Selective feeding strategy was estimated based on prey-specific abundance as proposed by Amundsen et al. (1996).

Relative gut length (RLG) and Gastrosomatic Index (GSI)

RLG and GSI were computed after Al-Hussaini (1949) and Desai (1970):

$$\mathrm{RLG} = \frac{Total\ length\ of\ A\lim entary\ canal}{Total\ length\ of\ Fish}$$

$$\mathrm{GSI} = \frac{Weight\ of\ stomach\ content}{Weight\ of\ the\ fish} \times 100$$

RLG is a measure to identify the types of feeding habits of a fish species as there is a considerable increase in its value from carnivore to herbivore. To validate such feeding nature of *P. atherinoides*, RLG has been investigated. The GSI estimation indicates feeding intensity of fish species which may be linked to the seasonal availability of diet, maturity and breeding of a fish species. The variation of RLG and GSI within the season for the studied year was verified using a one-way ANOVA.

Gill rakers count

Gills were collected from fresh fish by removing operculum, then cut was made through the angle of mouth and jaw to expose bucco-pharyngeal cavity. The first left branchial arch was cut off from the rest of the gill and washed, immediately preserved in 10% formalin, following Abuzinadah (1995). Gills were put in alizarin red S stain for 5 days. The stained gills were observed under a microscope (Nikon-CDS) and the number of gill rakers was counted following Roberts (1992). Images were taken by using a digital Sony camera (DSC-H50).

RESULTS

Diet composition

A total of 62 food items (59 genera, 3 detritus matters) of planktonic organisms were recorded from the gut content which can be broadly grouped as –zooplankton, phytoplankton, other animal matters and detritus (Table 1). The gut content shared 69.11% zooplankton, 16.86% phytoplankton, 2.74% other animal matter and 11.29% unidentified/detritus (Fig. 3a). Zooplankton was recorded as most prevailing food item in the gut, with Protozoa attributing to 7.46% (3 genera), Rotifera 25.96% (10 genera), Copepoda 27.31% (6 genera), Cladocera 6.03% (8 genera) and Ostracoda 2.34% (2 genera) (Table 1 and Fig. 3b). The common zooplankton genera recorded throughout all seasons were *Arcella, Difflugia, Centripyxis, Testudinella, Brachionus, Keratella, Monostyla, Chydorus, Daphnia, Macrothrix, Cyclops, Mesocyclops, Diaptomus*, and *Cypris*. The abundance of zooplankton was more in RA and less in WS (Table 1).

Phytoplankton was represented by Bacillariophyceae, Chlorophyceae and Cyanophyceae. Bacillariophyceae shared 7.98% of the total diet with 12 genera. Chlorophycea 7.90% with 15 genera and Cyanophyceae 0.99% with 2 genera (Fig. 3b). Among phytoplankton, *Pinnularia, Gomphonema, Chlorella, Spahaerocystis, Oedogonium, Closteriopsis* and *Oscillatoria* were most prevailing genera in food items throughout all seasons. The abundance of phytoplankton was comparatively greater during WS and lower during RA season (Table 1). The percent composition of both phytoplankton and zooplankton food items present in the gut exhibit seasonal variability with a higher presence of zooplankton food items in comparison to phytoplankton food items (Fig 4-a, b).

Alimentary tract and gill rakers

The alimentary tract of *P. atherinoides* is a short coiled tube with a distinct stomach. Oesophagus, stomach, intestine and rectum are noticeably distinguishable (Fig. 5a). The average gut length of *P. atherinoides* is 25.42± 3.58 mm.

Table 1. Resource utilization (% composition of food) by *Pachypterus atherinoides* in Subansiri floodplain wetland sampled during May 2013-April 2015

Resource Category	Summer-Rainy			Rainy-Autumn			Autumn-Winter			Winter-Spring		
(Genera)	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Protozoa												
Arcella	3.853	4.992	6.250	4.982	1.898	3.794	3.773	1.193	5.208	3.476	6.789	4.205
Difflugia	2.096	4.459	1.026	3.844	1.367	1.968	0.700	0.503	0.979	0.746	1.212	2.144
Centropyxis	2.252	2.753	2.910	1.406	0.315		1.335	1.817	0.870	0.597	1.574	2.278
Rotifera												
Testudinella	3.808	2.879	2.186	4.422	8.913	5.664	11.490	3.070	2.822	2.934	5.054	3.433
Brachionus	5.915	4.005	3.479	2.896	5.234	4.007	2.271	1.573	3.199	4.766	6.925	3.609
Keratella	1.790	1.524	4.399	4.141	2.636	1.762	2.464	6.364	5.413	5.858	2.958	2.334
Monostyla	3.781	1.672	1.980	1.626	6.002	4.127	2.679	3.296	3.436	3.778	4.887	1.028
Lecane	4.433	2.848	2.707	2.474	5.214	1.273	4.953	5.071		2.090		2.914
Asplanchia	1.576	4.589	3.097	1.254	3.253	2.590	1.335	0.950	3.488	2.087		1.562
Platyias	5.334	1.137	2.967	2.842	2.781	1.926	2.165	0.976	1.037	2.036	2.124	2.160
Eosphora		1.098	1.115	0.995	1.139	0.813		1.193		1.045	1.466	0.771
Acomorpha	1.223	0.569	0.638	0.736	0.315			1.229	1.894	0.595	0.960	0.522
Mytilina	1.253	1.109	1.223	2.492	0.684	3.178	1.578	2.573	1.971	1.938	0.683	2.785
Cladocera												
Chydorus	2.008	1.444	0.937	1.648	1.717	3.464	2.781	0.550	0.582	1.342	0.947	1.321
Alona	0.520	0.649	0.491	0.750	0.594	0.873	1.352	0.335		0.497	0.434	0.597
Kurzia		0.142	0.213	0.184	0.420	0.527	0.247			0.149	0.354	
Macrothrix	0.805	0.183	0.801	0.303	1.859	1.812	1.987		0.154	0.348	0.706	0.462
Daphnia	2.055	1.043		0.216	0.130	0.924	0.397	0.271	1.228	0.795	1.723	2.009
Ceriodaphnia	0.594	0.606	0.357	0.130	0.195	0.461	0.728		0.473	0.497	0.889	1.202
Bosmina	1.613	0.704	0.614	0.389	0.260	1.195	0.932	1.824	1.024	1.191	1.117	1.246

Resource Category	Summer-Rainy			Rainy-Autumn			Autumn-Winter			Winter-Spring		
(Genera)	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Bosminopsis	0.853	0.984	0.988			0.484	0.212	0.822	0.800	0.546		0.190
Copepoda												
Cyclops	8.952	7.993	10.222	7.149	10.424	12.383	10.289	12.646	10.929	9.786	10.038	11.628
Mesocyclops	4.049	4.874	6.063	3.830	5.587	5.068	7.092	8.634	8.152	7.204	5.689	5.525
Diaptomus	4.607	4.072	4.116	5.046	5.535	9.764	5.076	6.594	6.085	3.676	5.896	6.854
Neodiaptomus	1.559	2.516	1.338	1.298	1.367		2.458	2.820		2.736	2.172	2.467
Bryocamptus	1.325	0.995	0.745	1.104	1.993	1.975	1.524	0.503		1.240	1.566	
Calonida	0.866	2.544	2.383	0.952	4.133	3.494	3.054	2.736	4.621	3.331	1.900	2.515
Ostracoda												
Cypris	2.348	3.518	1.886	1.976	1.643	1.783	1.747	0.651	0.518	1.390	0.597	1.646
Eucypris	0.843	0.595	0.944	0.999	0.901	1.273	0.815	0.380		0.446	0.380	0.779
Bacillariophyceae												
Navicula	1.019	2.012	2.481		1.231	1.309	2.230			3.379	3.326	2.982
Cymbella	0.751	0.332		0.819	0.508	0.439	0.371	1.270	1.619	0.942		
Pinnularia	1.905	1.381	3.652	0.664	1.400	1.247	1.123		1.498	1.838	0.326	0.771
Gomphonema	0.357	0.791	1.093	0.869	0.385		0.932	1.860	1.171	1.390	1.910	2.171
Amphora		0.853	0.745	0.491			0.371	0.447	0.614			
Rhopalodia	0.404	0.229		3.330	0.505	0.615	0.676	0.391	1.267		0.455	0.930
Nitzchia	0.346		0.535	0.433	0.553		0.789		2.650	0.448	0.326	0.257
Acanthes	0.714	0.474	0.585			0.407	1.001	0.813	0.749	1.888	1.140	
Netrium		0.190		0.491			0.206	0.391		0.546	0.354	1.253
Tabellaria	0.346	0.412	0.401	0.216	0.781			0.271				
Surrelia		0.758	0.585	0.552	0.315	0.219	0.288	0.447	0.614		0.505	0.237
Diatoma	0.255	0.284	0.479	0.307	0.420		0.329			0.446	0.253	0.380

Resource Category	Summer-Rainy			Rainy-Autumn			Autumn-Winter			Winter-Spring		
(Genera)	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Chlorophyceae												
Chlorella	1.212	3.090		1.781	1.776	0.702	0.941	2.320	1.228	0.794	0.707	0.760
Staurastrum		0.664	0.638	0.859	0.350	0.439		0.279	0.205	0.248		
Sphareocystis	1.172	0.869		1.990	0.524	2.054	1.229	1.448	2.176	0.893	1.832	1.593
Closterium	0.346	0.701	0.755	1.133	0.350		0.273	0.882	0.710	0.348		
Closteriopsis	0.462	1.448	2.332	2.204	0.945	1.097	0.288	1.975	1.676	1.341	1.343	1.519
Cosmarium	0.812	0.467	0.213	0.245	0.245	0.351	0.247	0.279	0.461	0.844	0.675	0.427
Schoroderia		0.474	0.319		0.315	0.922		0.503	0.563			
Scenedesmus	0.982							1.155	0.646	0.546	0.354	0.190
Oedogonium	0.231	0.753	0.906	3.047	0.815	0.804	0.520	0.503	1.638	1.093	0.217	0.206
Spirogyra	0.204	0.284		0.613	0.175	0.395		0.335				
Pandorina	0.153	0.190		0.307			0.371		0.358	0.347		
Desmococcus	0.255	0.237	0.266	0.429	0.245		0.535			0.248	0.606	0.475
Ankistodesmus	0.462		0.223	0.346	0.163					0.299	0.380	
Ulothrix	0.102	0.284	0.479	0.491	0.315	0.483	0.165	0.168	0.358	0.347	0.101	
Euastrum		0.190	0.851		0.210	0.219	0.247	0.335	0.102	0.248	0.101	0.237
Cyanophyceae												
Microcystis			0.585	0.491						0.248		
Oscilatoria	0.897	0.605	1.110	0.930	0.575	0.852		1.053	0.614	1.491	0.556	1.847
Others												
Water mites	0.153	0.427			0.105					0.149	0.253	0.095
Hymanella		0.095										
Crustacean/ Insect Parts	7.018	6.994	5.094	6.749	4.466	4.412	4.669	4.396	4.230	4.026	6.699	6.410
Unidentified/ Detritus	9.131	8.018	9.599	10.128	5.821	6.453	6.765	9.904	9.969	8.494	8.543	9.076

(n = 10 fish individuals/each month; all samples were pooled)

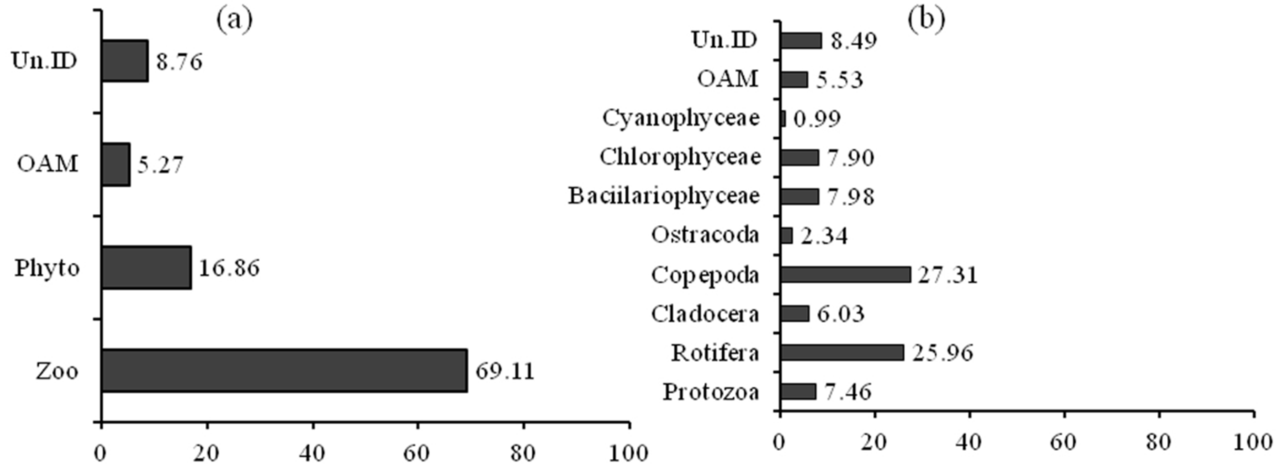

Fig 3. Abundance of food items in the gut of *Pachypterus atherinoides*. Percent composition of (a) phytoplankton, zooplankton, other animal matter and detritus (b) different planktonic groups. Un.ID, Unidentified Detritus; OAM, Other Animal Matters; Zoo, Zooplankton; Phyto, Phytoplankton

The gill rakers of *P. atherinoides* are long, needle-like and adjacently placed. The number of gill rakers ranges from 33-35 (Fig. 5b). Structure and number of gill rakers suggested a secondary modification for plankton filter to its carnivory nature.

RLG and GSI

Its total length (TL) varied from 46 mm to 65 mm, standard length (SL) varied between 39 mm to 54 mm and the total weight (TW) varied between 0.80 gm to 1.7 gm. Morphometric data are presented in Table 2. The RLG was estimated as 0.486±0.046 mm for the fish having an average total length of 45.2 to 65.5 mm. Lowest RLG was 0.440±0.058 mm and the highest RLG was 0.511±0.029 mm (Fig. 6a). The GSI was recorded as 2.683±0.495 gm for the fish having an average total weight of 0.7 to 1.7 gm. Maximum GSI (2.832±0.754 gm) was recorded during WS and minimum GSI (2.525±0.363 gm) was found during SR (Fig. 6b). The variation of RLG and GSI within the seasons for the studied years were not statistically significant ($p>0.05$, one-way ANOVA).

Diet breadth

For both resources (total plankton and zooplankton), the BA exhibited higher value during SR and WS, indicating more accessibility to resources, while the low value in RA and AW indicated resource partitioning. The fish showed comparatively higher B_A on zooplankton compared to total plankton (Table 3). The $B^/_A$ of zooplankton was high compared to total plankton and phytoplankton resources. It reached a maximum during SR and WS of 2013-14, and during SR and RA of 2014-15 (Table 4).

Feeding strategy

Most of the selection of *P. atherinoides* falls under generalization (Ei within -0.4 and +0.4) and no strong avoidance of any particular food item was observed (Fig. 7-10). Rarely, mild avoidance was observed of a few dominant food items. Strong positive selection of a few moderately available food items was also recorded.

Selection of zooplankton

In spite of their moderate availability in the environment, food items such as *Macrothrix, Bosmina, Arcella* were strongly selected by the fish in 2013-14. Except *Testudinella* which received moderate to highly rejection, few other zooplankton like *Cyclops, Mesocyclops, Neodiaptomus, Brachionus* were only mildly rejected, although they were abundant in the environment. Among zooplankton, the highly selected genera were *Macrothrix, Daphnia, Ceriodaphnia, Bosmina, Chydrorus* and *Platyias*, and those moderately avoided were *Cyclops, Mesocyclops* and *Testudinella* during SR (Fig. 7a). During RA, *Macrothrix, Arcella, Chydorus* were highly selected whereas *Brachionus, Mesocyclops* were mildly rejected (Fig. 7b). During AW, *Macrothrix, Bosmina, Arcella* were highly selected and *Neodiaptomus, Mesocyclops* and *Diaptomus* were mildly avoided (Fig. 7c). During WS, *Bosmina, Daphnia* were highly selected, while *Neodiaptomus, Mesocyclops, Testudinella* were mildly rejected (Fig. 7d).

In 2014-15, although mild variability was observed in the selection of food items in different seasons, the selection of zooplankton was more or less similar to the previous year. During SR, *Alona, Chydorus* were highly selected while *Diaptomus, Brachionus, Cyclops* were mildly rejected (Fig. 8a).

Similarly, during RA, *Arcella, Macrothrix, Alona* were highly selected, *Mesocyclops, Keratella, Diaptomus* and *Cyclops* were mildly rejected (Fig. 8b). *Bosmina, Bosminopsis* and *Chydorus* were highly selected during AW and those that received mild rejection during this season were *Mesocyclops, Cyclops* (Fig. 8c). During WS season, *Ceriodaphnia, Bosmina, Daphnia, Chydorus* were highly selected, and *Mesocyclops, Diaptomus, Arcella, Brachionus, Cyclops* were mildly rejected (Fig. 8d).

Table 2. Morphometric measurement of *P. atherinoides* from floodplain habitat for May 2013- April 2015 (n=109)

Parameters	2013-14			
	Summer-rainy (Mean ± SD)	Rainy-autumn (Mean ± SD)	Autumn-winter (Mean ± SD)	Winter-spring (Mean ± SD)
Total length (mm)	53.761±5.512	53.858±4.184	53.333±4.904	53.254±6.158
Standard length (mm)	46.101±5.390	45.773±3.708	45.632±4.642	45.470±5.523
Gut length (mm)	24.777±4.440	23.684±4.075	24.987±3.351	25.070±3.503
Total weight (gm)	1.106±0.226	1.011±0.182	1.047±0.204	1.058±0.202
Gut weight (gm)	0.028±0.008	0.026±0.007	0.027±0.007	0.028±0.006
	2014-15			
	Summer-rainy (Mean ± SD)	Rainy-autumn (Mean ± SD)	Autumn-winter (Mean ± SD)	Winter-spring (Mean ± SD)
Total length (mm)	52.971±5.947	53.683±5.642	53.438±4.563	53.160±6.656
Standard length (mm)	45.510±5.492	45.227±4.850	45.397±4.251	44.780±6.190
Gut length (mm)	24.447±3.751	24.963±3.691	25.975±3.434	27.175±3.444
Total weight (gm)	1.043±0.223	1.047±0.296	1.041±0.176	1.054±0.209
Gut weight (gm)	0.026±0.007	0.027±0.038	0.028±0.059	0.030±0.009

During both years, cladoceran were highly selected and rotiferan and copepods were mildly or totally rejected as food by the fish.

Selection of phytoplankton

In 2013-14, a large numbers of genera of phytoplankton fell under generalization with few cases showing high selectivity and avoidance. During SR, *Oedogonium, Cymbella, Navicula* were highly selected while *Pinnularia* was strongly avoided (Fig. 9a). *Cymbella, Navicula, Ankistodesmus* were highly selected, while *Chlorella* was mildly rejected in RA (Fig. 9b). During AW, *Oscillatoria* and *Navicula* were highly selected (Fig 9c). *Closterium, Ankistodesmus, Rhopalodia* were highly selected during WS season (Fig. 9d).

In 2014-15, most of the phytoplankton fell under generalization and there was no absolute avoidance of any food item. *Cymbella, Spirogyra, Chlorella* were highly selected, *Acanthes* and *Chlorella* received moderate rejection during SR (Fig. 10a). *Desmococcus, Cosmarium, Navicula* were highly selected, whereas *Pinnularia, Sphaerocystis, Closteriopsis* and *Chlorella* were mildly rejected during RA (Fig. 10b). During AW, *Navicula, Pinnularia, Spirogyra* were highly selected and *Gomphonema* and *Cymbella* were rejected moderately (Fig. 10c). *Pinnularia, Ulothrix* were highly selected while *Closteriopsis, Chlorella* and *Gomphonema* were mildly rejected during WS (Fig. 10d).

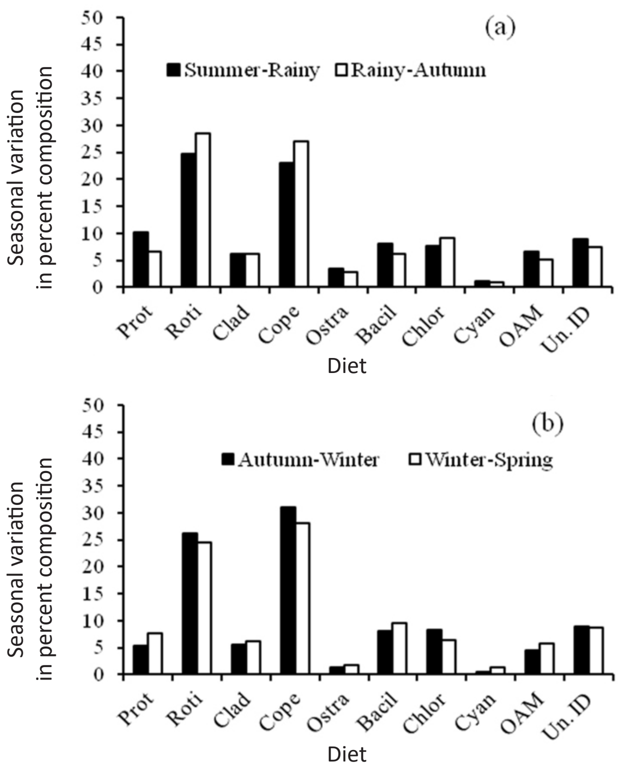

Fig 4. Seasonal variation in percent composition of diet of *Pachypterus atherinoides*: (a) Summer-rainy and Rainy-autumn (b) Autumn-winter and Winter-spring. Prot, Protozoa; Roti, Rotifera; Clad, Cladocera; Cope, Copepoda; Ostra, Ostracoda; Bacil, Bacillariophyceae; Chlor, Chlorophyceae; Cyan, Cyanophyceae; OAM, Other Animal Matters; Un. ID, Unidentified Detritus

Table 3. Levins' diet breadth (B_A) of *P. atherinoides* for total plankton and zooplankton resources throughout four seasons (SR, RA, AW, WS) in Subansiri floodplain wetland of North East India

Resources	2013-14				2014-15			
	SR	RA	AW	WS	SR	RA	AW	WS
Total plankton	0.553	0.499	0.490	0.526	0.447	0.389	0.343	0.389
Zooplankton	0.686	0.595	0.574	0.589	0.556	0.499	0.415	0.456

(SR, Summer-rainy; RA, Rainy-autumn; AW, Autumn-winter; WS, Winter-spring)

Table 4. Hurlbert's diet breadth (B'_A) of *Pachypterus atherinoides* for total-plankton, zooplankton and phytoplankton throughout four seasons (SR, RA, AW, WS) in Subansiri floodplain wetland of North East India

Resources	2013-14				2014-15			
	SR	RA	AW	WS	SR	RA	AW	WS
Total plankton	0.564	0.517	0.469	0.640	0.666	0.539	0.417	0.493
Zooplankton	**0.635**	**0.576**	**0.524**	**0.708**	**0.723**	**0.658**	**0.468**	**0.569**
Phytoplankton	0.434	0.358	0.332	0.429	0.469	0.421	0.335	0.391

(SR, Summer-rainy; RA, Rainy-autumn; AW, Autumn-winter; WS, Winter-spring)

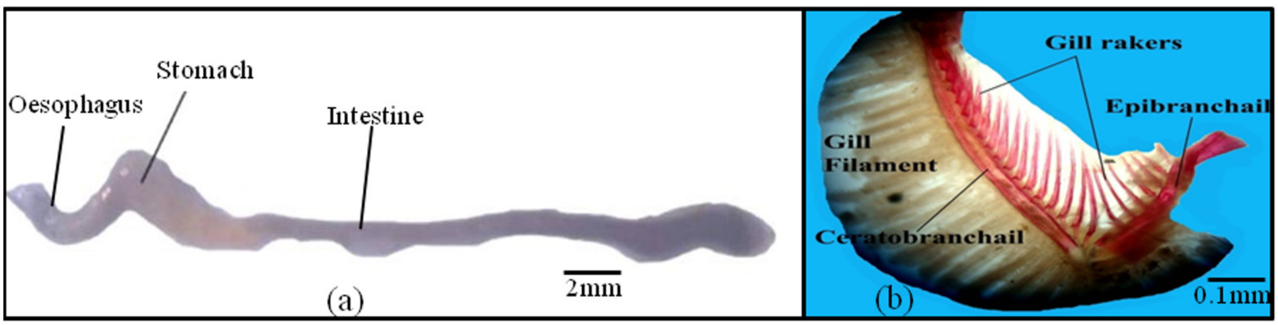

Fig 5. (a) Alimentary tract and (b) Gill rakers (from 1st branchial arch) of *Pachypterus atherinoides*

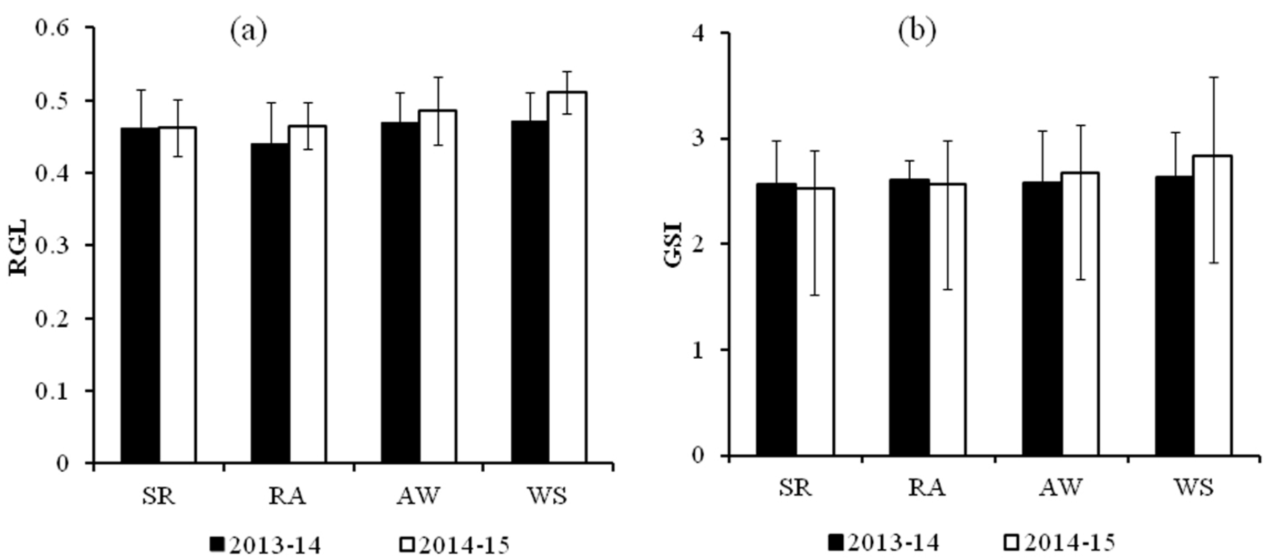

Fig 6. (a) Relative Gut Length (RGL) and (b) Gastrosomatic Index (GSI) of *Pachypterus atherinoides* during SR: Summer-rainy, RA: Rainy-autumn, AW: Autumn-winter and WS: Winter-spring season

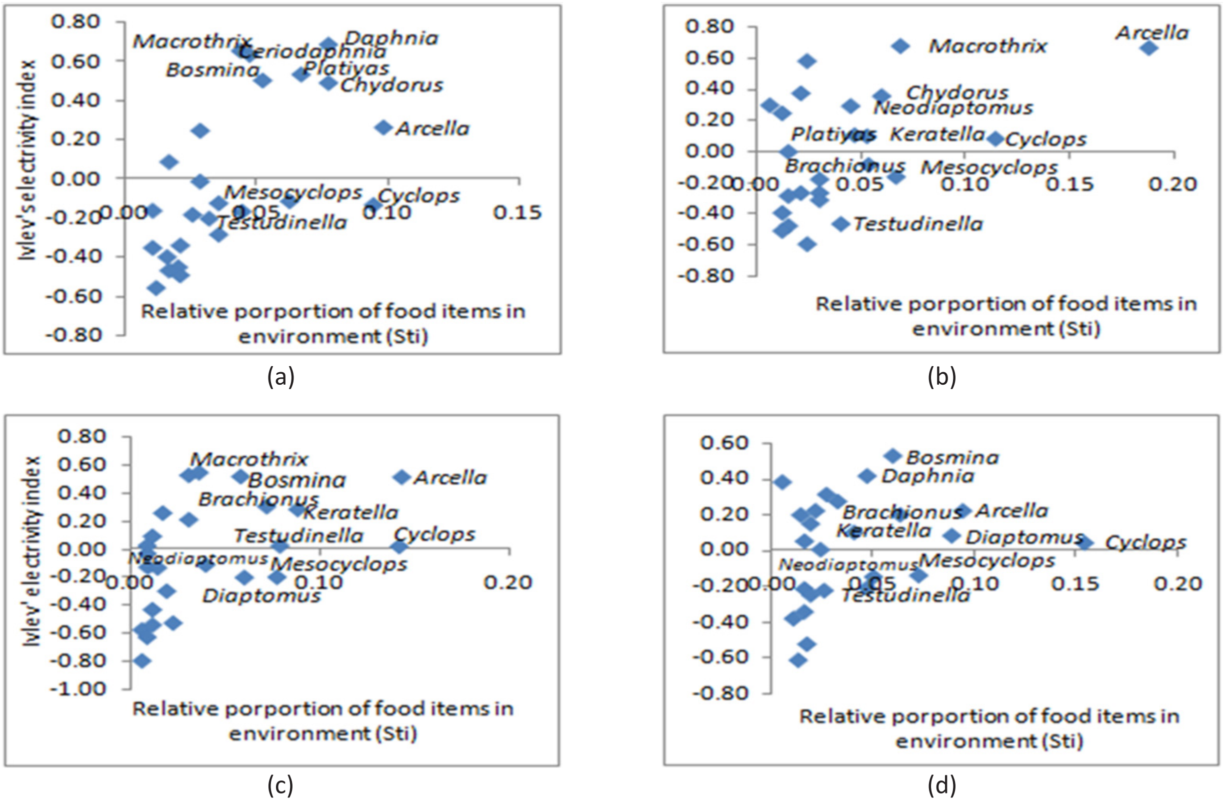

Fig 7. Feeding selectivity (E_i) of *Pachypterus atherinoides* on zooplankton resources during (a) Summer-rainy (b) Rainy-autumn (c) Autumn-winter and (d) Winter-spring in 2013-2014 (Y axis, Ei, Ivlev's electivity index; X axis, relative occurrence of zooplankton in the environment)

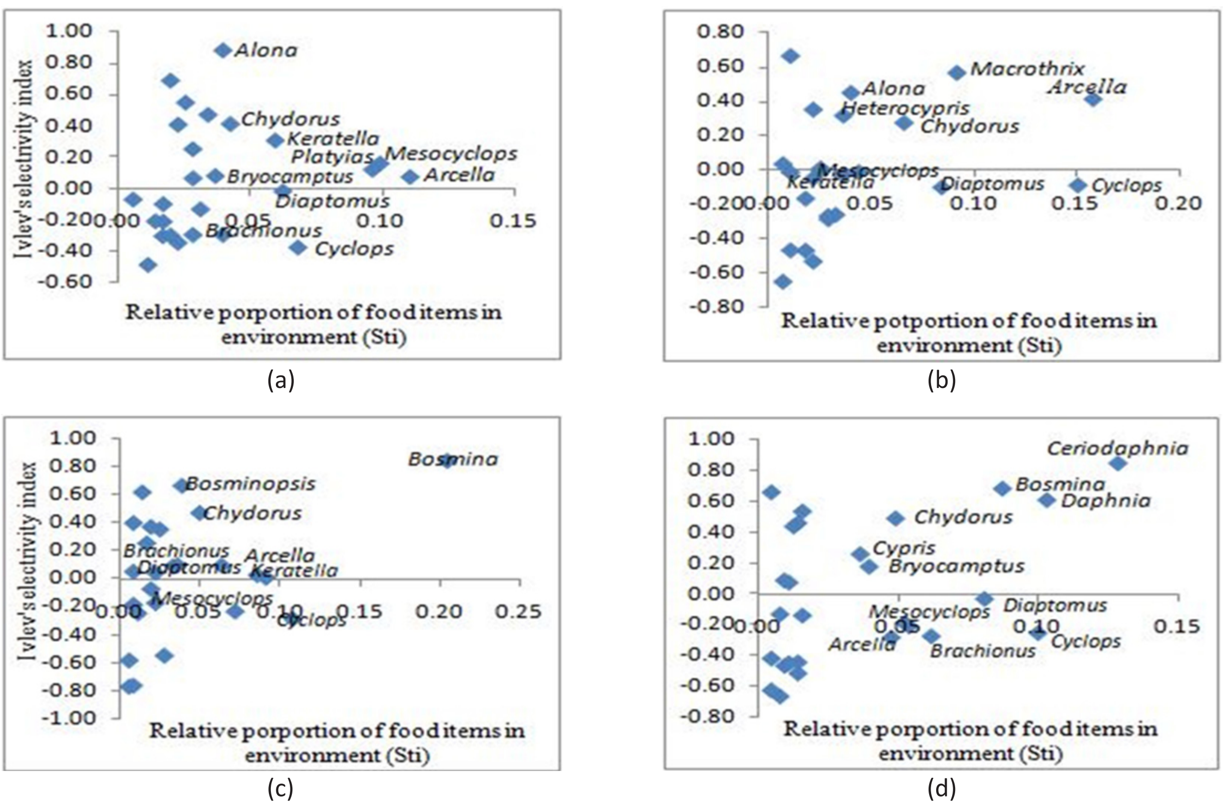

Fig 8. Feeding selectivity (E_i) of *Pachypterus atherinoides* of zooplankton resources during (a) Summer-rainy (b) Rainy-autumn (c) Autumn-winter and (d) Winter-spring in 2014-2015 (Y axis, Ei, Ivlev's electivity index; X axis, relative occurrence of zooplankton in the environment)

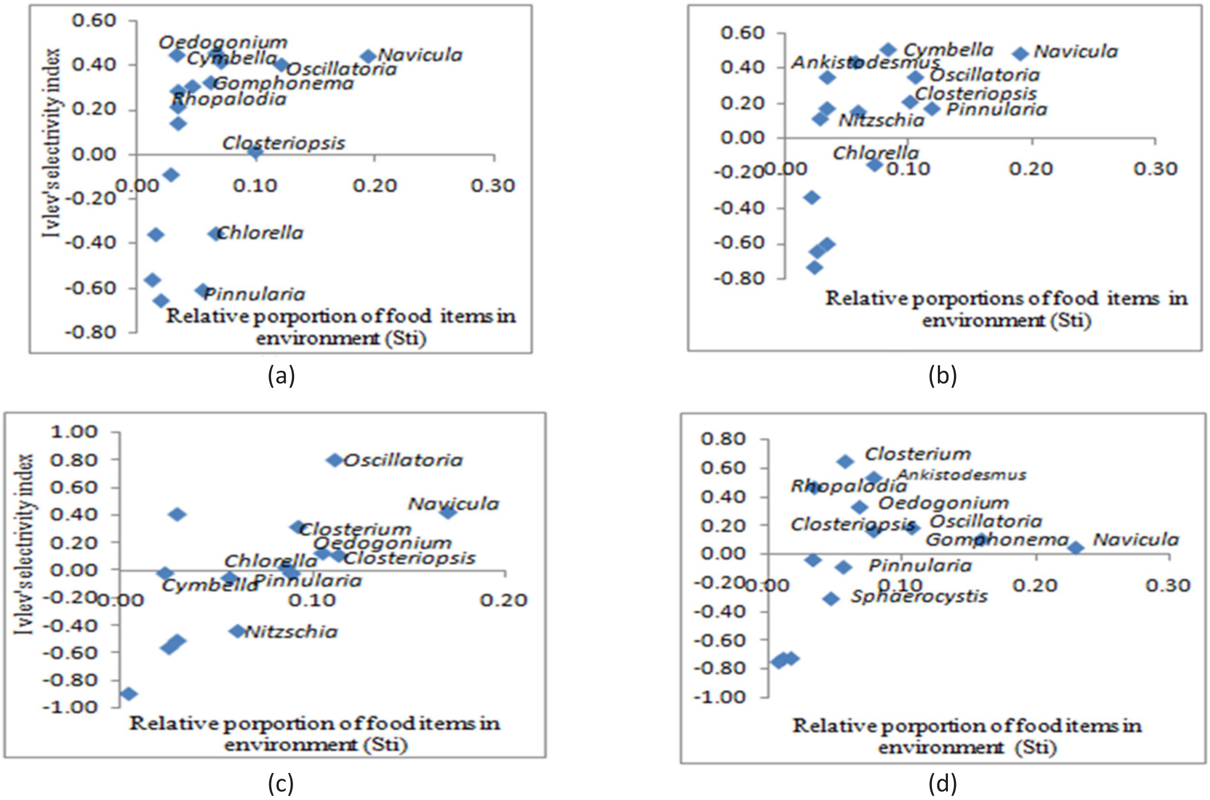

Fig 9. Feeding selectivity (E_i) of *Pachypterus atherinoides* on phytoplankton resources during (a) Summer-rainy (b) Rainy-autumn (c) Autumn-winter and (d) Winter-spring in 2013-2014 (Y axis, Ei, Ivlev's electivity index; X axis, relative occurrence of zooplankton in the environment)

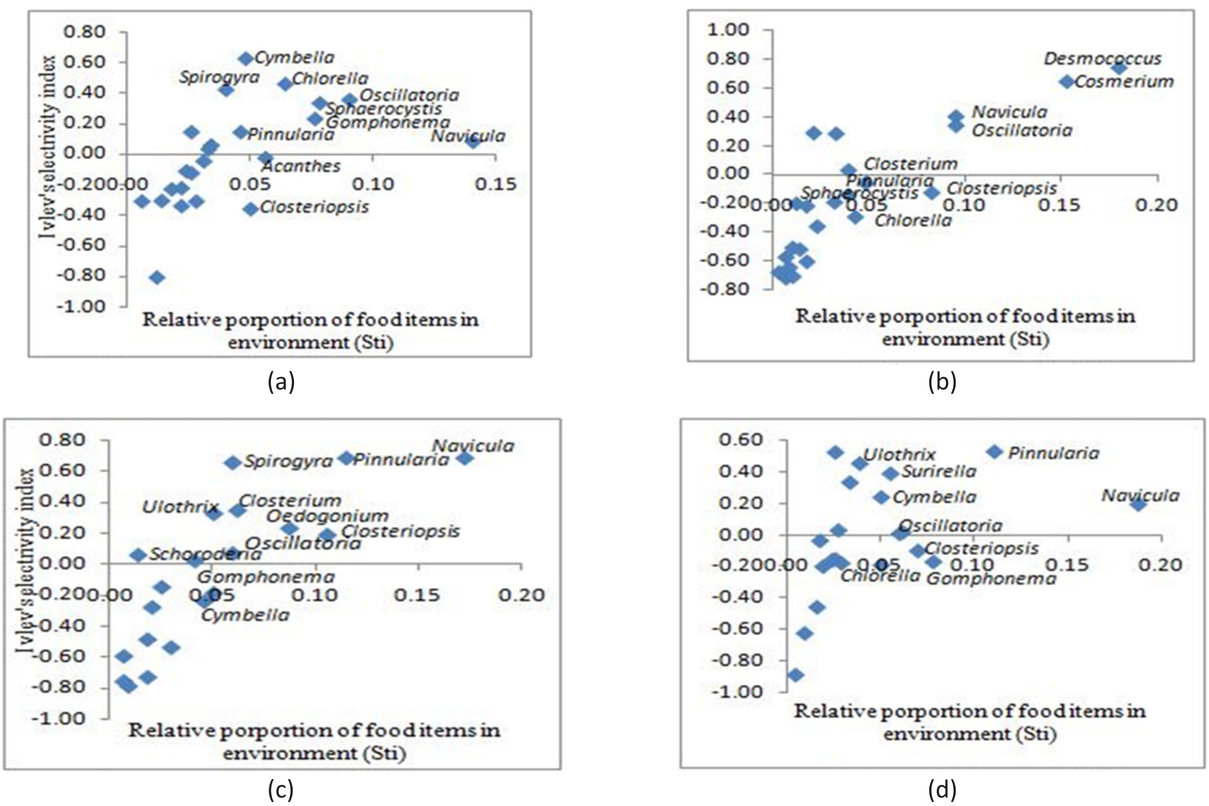

Fig 10. Feeding selectivity (E_i) of *Pachypterus atherinoides* of phytoplankton resources during (a) Summer-rainy (b) Rainy-autumn (c) Autumn-winter and (d) Winter-spring in 2014-2015 (Y axis, E_i, Ivlev's electivity index; X axis, relative occurrence of zooplankton in the environment)

DISCUSSION

The results on diet composition suggested that *P. atherinoides* is carni-omnivore in nature, since a considerable portion (>70%) of gut contents was found to be of animal origin. In general, carnivores consume 75% or more animal food, while omnivores consume both plant and animal food in considerable equal proportion (Das and Moitra, 1963). The planktivore nature of *P. atherinoides*, preferably on zooplankton, was in agreement with findings obtained in the case of *Neotropius atherinoides* (Sengupta and Homechaudhuri, 2011). Besides, ingestion of both animal and plant food items by *P. atherinoides* supported the view of euryphagous nature of catfishes (Thomas, 1966). Earlier, the catfishes *Mystus gulio* and *Clarias liocephalus* were also reported as omnivore (Begum et al.,2008; Yatuha et al., 2012). The share of 11.29% of detritus matter in the gut of *P. atherinoides* might be due to foraging on zoobenthos. In general, detritus in the gut is contributed by the mixture of debris and associated parts of both plant and animal matters (Bowen, 1979). Overall, the percent composition of diet suggested its ability to feed upon wide ranges of food items of animal, followed by plant origin. A similar observation was reported in *Mystus (sperata) seenghala* and *Wallago attu* and *Clarias liocephalus* (Babare et al., 2013; Yatuha et al., 2012).

The long oesophagus, swollen stomach and short intestine possessed by this species is the characteristic of carnivorous fish. The swollen stomach and short intestine proved carnivory where well-developed stomach allowed mastication and mechanical breakdown of animal food (Dasgupta, 2000; Naguib et al., 2011; Bana-Khojasteh, 2012).

Like the alimentary tract, the number, size and spacing of gill rakers are closely related to food habit of fish and form a part of structural adaption to feeding (Hyatt, 1979; Mummert and Drenner, 1986). *P. atherinoides* has 33-35 numbers of densely placed, elongated and needle-like gill rakers. The functional role of such arrangement of gill rakers is to retain and accommodate more planktonic items during filter feeding. Earlier, Abuzinadah (1995) and Delariva and Agostinho (2001) reported such features of gills in planktivorous fishes. They also reported that fishes with generalist herbivore nature posses shorter gill rakers than the planktivores, whereas the carnivorous fishes have limited, widely spaced, long, hard and pointed gill rakers. MacNeill and Brandtt (1990) also reported that gill rakers with intense spacing could serve as an efficient filtering device and be better adapted to retain small prey during filter feeding. The wider ranges of food of *P. atherinoides* could also support such feeding nature. It is clear that although the organization of the alimentary tract of *P. atherinoides* did not support planktivory, the morphology of gill rakers, however, suggested a secondary adaptation for carnivore filter-feeding habit.

The maximum RLG was 0.511±0.029 mm, which indicated a carnivore habit. Al Hussaini (1949) enlisted the RLG values for carnivorous (0.5-2.4), omnivorous (1.3-4.3) and herbivorous (3.7-6.0) fishes. Carnivorous fishes possess short intestine because animal originated feeds are more readily digested than plant originated feeds; whereas in herbivorous fishes, the intestine is long and highly coiled (Dasgupta, 2000; Abbas, 2010). Maximum GSI during WS (or February to April) might be due to intense feeding during the pre-spawning period. The lower GSI values during SR (or summer-rainy) could be related to breeding activities. A decrease in GSI during the breeding season in fish is not uncommon (Joadder, 2006; Begum et al., 2008; Gupta and Benerjee, 2013).

The wide spectrum of food items recorded in the gut of *P. atherinoides* was found to be of three categories viz. total plankton followed by zooplankton and phytoplankton encountered in floodplain wetlands. Both Levins' and Hurlbert's diet breadths were higher in case of zooplankton, compared to phytoplankton and total plankton as a resource. This finding confirmed the carnivory nature of *P. atherinoides* on zooplankton. In this regard Saikia and Das (2009), in case of common carp, opined that the higher diet breadth supports more selective feeding, whereas lower diet breath indicates either resource partitioning (Haroon and Pittman, 2000) or less affinity to the resource considered. In the present case, Levins' measure of *P. atherinoides* showed higher diet breadth with zooplankton compared to the total plankton as a resource. Therefore, it suggests a higher affinity of the fish towards zooplanktonic food. Similarly, the estimated Hurlbert's diet breadth with zooplankton as a resource is a repetition of the result of Levins' diet breadth. Hence, a strong affirmation can be made on the fact that the *P. atherinoides* utilizes zooplankton as prey in the studied environment. Among the three food resources, Hurlbert's diet breadth was narrow for phytoplankton indicating it as a less preferred food. Interestingly, the Levins' and Hurlbert's diet breadths during SR or WS were higher due to the high selectivity of resources by the fish from the environment. Variations of diet breadths with season due to the resource availability in the environment may not be ignored (Petraitis, 1979).

Feeding strategies by *P. atherinoides* for both zooplankton and phytoplankton resources exhibited a strong selection of moderately encountered items, whereas moderate selection of abundantly encountered items in the environment. It is an indication that in the case of *P. atherinoides* the selection and avoidance of prey items are not necessarily influenced by abundance or rarity of a particular food organism in gut and environment. *P. atherinoides* showed preferences towards some organisms irrespective of their abundance in the environment. It further indicates the possible involvement of other feeding mechanisms (e.g. chemosensory) while selecting food organisms. Among zooplankton, only in case of *Testudinella* a strong rejection was observed which was not understood.

CONCLUSIONS

It has become evident from the present study that zooplankton is an important resource as natural food for *P. atherinoides*; other food from plant origin were also preferred by this fish in floodplain wetlands studied. This outcome questions the well-established fact that *P. atherinoides* exclusively exhibits carnivory feeding habits. On the other hand, it clearly describes a herbivory intention by *P. atherinoides* over carnivory. Existence of such an alternative and partial phytoplanktivorous preference may be a temporary adjustment or a phenomenon of widening resource accessibility, but such nature of preference on a wide spectrum of food resources denotes plasticity to the feeding behaviour of *P. atherinoides*. Such a wide spectrum of food in its diet points it to be a potential candidate species for aquaculture, because it would not require expensive animal protein in its feed. Furthermore, such feeding nature of small fish species could be a significant aspect from the evolutionary point of view. However, it requires addressing other modes of food selection and related physiological mechanisms to draw a clearer explanation.

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SAŽETAK

EKOLOGIJA ISHRANE *Pachypterus aherinoides* (ACTINOPTERYGII; SILURIFORMES; SCHILBEIDAE): MALE SLATKOVODNE RIBE IZ POPLAVNIH MOČVARNIH PODRUČJA SJEVEROISTOČNE INDIJE

Istraživana je ekologija ishrane *Pachypterus aherinoides* iz poplavnih močvarnih područja u slivu rijeke Subansiri, Assam, u sjeveroistočnoj Indiji dvije godine zaredom (2013-2015). Analiza sadržaja crijeva potvrdila je prisutnost 62 roda planktonskih organizama zajedno s ostalim tvarima animalnog podrijetla. Organizacija probavnog trakta i maksimalna relativna srednja duljina crijeva (0,511 ± 0,029 mm) ukazivali su na mesojedne hranidbene navike vrste. Vrhunac gastrosomatskog indeksa (GSI) u zimsko-proljetnim i ljetno-kišnim sezonama ukazivao je na promjenu intenziteta hranjenja. Nadalje, veća širina ishrane iskorištenih resursa (Levins i Hurlbert) te usporedba zooplanktona s fitoplanktonom i ukupnim planktonom potvrdio je zooplanktivornu naviku vrste. Grafički prikazi rezultata strategije ishrane također ističu veću preferenciju zooplanktonu u odnosu na fitoplankton. Organizacija škržnih listića vrste naznačila je sekundarnu modifikaciju crijeva prema mesojedima ili specijaliziranim zooplanktivorima. Dakle, riba je vjerojatno 'meso-svejed' koja ima preferencije naspram zooplanktonu.

Ključne riječi: širina ishrane, strategija ishrane, *Pachypterus aherinoides*, plankton, Indija

REFERENCES

Abbas, A. (2010): Food and feeding habits of freshwater catfish, (Bleeker) *Eutropiichthys vacha*. Indian Journal of Scientific Research, 1, 83-86.

Abuzinadah, O. A. (1995): Gill Raker Morphology in Some Red Sea Fishes of Different Feeding Preferences. Joural of King Abdulaziz University (Marine Science), 6, 93-122.

Al-Hussaini, A. H. (1949): On the functional morphology of the alimentary tract of some fish in relation to difference in their feeding habits: anatomy and histology. The Quarterly Journal of Microscopic Science, 90, 109-139.

Amundsen, P. A., Gabler, H. M., Staldvik, F. J. (1996): A new approach to graphical analysis of feeding strategy from stomach contents data modification of the Costello (1990) method. Journal of Fish Biology, 48, 607-614.

Babare, R. S., Chavan, S. P., Kannewad, P. M. (2013): Gut Content Analysis of *Wallago attu* and *Mystus* (S*perata seenghala*) The Common Catfishes from Godavari River System in Maharastra State. Advances in Bioresources, 4, 123-128.

Bana-Khojasteh, S. M. (2012): The morphology of the post gastric alimentary canal in teleost fishes: A brief review. International Journal of Aquatic Science, 3, 71-88.

Begum, M., Alam, M. J., Islam, M. A., Pal, H. K. (2008): On the food and feeding habit of an estuarine catfish (*Mystus gulio*, Hamilton) in the south-west coast of Bangladesh. University Journal of Zoology, Rajshahi University, 27, 91-94.

Bowen, S. H. (1979): A nutritional constraint in detritivory by fishes: The stunted population of *Sarotherodon mossambicus* in Lake Sibaya. Ecological Monographs, 49, 17-31.

Das, S. M., Moitra, S. K. (1963): Studies on the food and feeding habits of some freshwater fishes of India. IV. A review on the food and feeding habits, with general conclusions. Ichthyologica, 11, 107-115.

Dasgupta, M. (2000): Adaptation of the alimentary tract to feeding habits in four species of fish of the genus Channa. Indian Journal of Fisheries, 47, 265-269.

Dasgupta, M. (2009): Adaptation of the alimentary tract to feeding habits in the weed eating fish (grass carp) *Ctenopharyngodon idella* (Val.) Journal of Crop and Weed, 5, 197-202.

Delariva, R. L., Agostinho, A. A. (2001): Relationship between morphology and diets of six neotropical loricariids. Journal of Fish Biology, 58, 832-847.

Desai, V. R. (1970): Studies on the fisheries and biology of *Tor tor* (Ham.) from river Narmada. Journal of Inland Fisheries Society of India, 2, 101-112.

Desikachary, T. V. (1989): Atlas of Diatom (1st ed.). Madras, India: Madras Science foundation.

Edmondson, W. T. (1992): Freshwater Biology (2nd ed.). New Delhi, India.: International books and periodicals supply services.

Fatima, M., Khan, A. A. (1993): Cyclic changes in the gonads of *Rhingomugil corsula* (Ham.) from river Yamuna India. Asian Fisheries Science, 6, 23-29.

Gupta, S., Banerjee, S. (2013): Food and Feeding Habit of *Amblypharylngodon mola* (Hamilton- Buchanan, 1822) in West Bengal, India. International Journal of Scientific Research, 2, 67-71.

Haroon, A. K. Y., Pittman, K. A. (2000): Niche measures and feeding strategies of *Barbados gonionotus* Bleeker and *Oreochromis* spp. from a rice field in Bangladesh. Bangladesh Journal of Fisheries Research, 4, 13-26.

Hurlbert, S. (1978): The measurement of niche overlap and some relatives. Ecology, 59, 67-77.

Hyatt, K. D. (1979): Feeding strategy. In: Hoar WS, Randall DJ, Brett JR, eds. Fish physiology, New York: Academic Press, 71-117.

Ibrahim, S., Muhammad, M. A., Ambak, M. Z., Zakaria, A. S., Mamat, M. M., Isa, M., Hajisamae, S. (2003): Stomach content of six commercially important demersal fish in the South China Sea. Turkish Journal of Fisheries and Aquatic Sciences, 3, 11-16.

Ivlev, V. S. (1961): Experimental ecology of the feeding of fishes. New Haven, United States: Yale University Press.

Jacobs, J. (1974): Quantitative measurement of food selection (a modification of the forage ratio and Ivlev's Electivity Index. Oecologia, 14, 413-417.

Joadder, A. R. M. (2006): Food and feeding habits of *Gagata youssoufi* (Rahman, 1976) from the river Padma in Rajshahi. University Journal of Zoology, Rajshahi University, 25, 69-71.

Khan, M. S., Ambak, M. A., Mohsin, A. K. M. (1988): Food and feeding biology of a tropical catfish, *Mystus nemuru* with reference to its functional morphology. Indian Journal of Fisheries, 352, 78-84.

Lackey, J. B. (1938): The manipulation and counting of river plankton and changes in some organisms due to formalin preservation. Public Health Reports, 53, 2080-2093.

Levins, R. (1968): Evolution in Changing Environments; Some Theoretical Explorations. Princeton, United States: Princeton University Press.

MacNeill, D., Brandt, S. (1990): Ontogenetic shifts in gill-raker morphology and predicted prey capture efficiency of the alewife, *Alosa pseudoharengus*. Copeia, 1, 164-171.

Michael, R. G., Sharma, B. K. (1988): Indian Cladocera (Crustacea: Branchiopoda: Cladocera). Fauna of India and adjacent countries series, Calcutta, India: Zoological Survey of India.

Mummert, J. R., Drenner, R. W. (1986): Effect of size on filtering efficiency and selective particle ingestion of filter feeding clupeid. Transactions of the American Fisheries Society, 115, 522-528.

Naguib, S. A. A., Shabaka, H. A. E. I., Ashour, F. (2011): Comparative histological and ultrastructural studies on the stomach of *Schilbe mystus* and the intestinal swelling of *Labeo niloticus*. Journal of American Science,7, 251-263.

Offem, B. O., Samsons, Y. A., Omoniyi, I. T. (2009): Trophic ecology of commercially important fishes in the Cross river, Nigeria. Journal of Animal and Plant Sciences, 19, 37-44.

Ojeda, F. P. (1986): Morphological Characterization of the Alimentary Tract of Antarctic Fishes and its relation to Feeding habits. Polar Biology, 5, 125-128.

Pentecost, A. (1984): Introduction to Fresh water Algae. Slough Berkshire, England: Richmond Publishing Co. Ltd.

Petraitis, P. S. (1979): Likelihood Measures of Niche Breadth and Overlap. Ecology, 60, 703-710.

Roberts, T. R. (1992): Revision of the striped catfishes of Thailand misidentified as *Mystus vittatus* with descriptions of two new species (Pisces: Bagridae). Ichthyological Exploration of Freshwaters, 3, 77-88.

Saikia, S. K., Das, D. N. (2009): Feeding ecology of common carp (*Cyprinus carpio* L.) in a rice fish culture system of the Apatani plateau (Arunachal Pradesh, India). Aquatic Ecology, 43, 559-568.

Samad, M. A., Galib, S. M., Flowra, F. A. (2009): Fish drying in Chalan beel area. Bangladesh Journal of Scientific and Industrial Research, 44, 461-466.

Sengupta, S., Homechaudhuri, S. (2011): Comparison of trophic niche and digestive enzymes of four species of catfishes of the Punarbhaba River in India. Indian Journal of Fisheries, 58, 79-85.

Shiel, R.J. (1995): A guide to identification of rotifers, cladocerans and copepods from Australian inland waters. C.R.C.F.E. Identification Guide No. 3. Murray-Darling Freshwater Research Centre, Albury: Cooperative research centre for fresh water ecology, Australia.

Talwar, P. K., Jhingran, A.G. (1991): Inland fishes of India and adjacent countries, New Delhi, Bombay and Calcutta: Oxford and IBH Publishing Co. Pvt. Ltd.

Thomas, J. D. (1966): On the biology of the catfish *Clarias senegalensis* in a man-made lake in the Gahnian Savanna with Particular reference to its feeding habits. Journal of Zoology, 148, 476-514.

Wotton, R. J. (1998): Ecology of Teleost Fishes (2nd ed.). Dordrecht: Kluwer Academic Publisher.

Yatuha, J., Kang'ombe, J., Chapman, L. (2012): Diet and feeding habits of the small catfish, *Clarias liocephalus* in wetlands of Western Uganda. African Journal of Ecology, 51, 385–392.