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Trophodynamics of *Nemipterus japonicus* (Bloch, 1791) in the trawl landings along the north-east coast of India

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ABSTRACT

The trophodynamics of *Nemipterus japonicus* (Bloch, 1791) along the north-east coast of India was studied during 2012-2015 based on specimens collected from trawl landings at Digha, Paradeep (northern region), Visakhapatnam and Kakinada (southern region). Crustaceans were the preferred prey with index of relative importance (IRI) of 50% in the northern region and 42.4% in the southern region. Among crustaceans, *Oratosquilla* dominated in both the regions followed by crabs and several species of penaeids and nonpenaeids. Finfishes ranked next in importance (IRI% of 32.1 in northern region and 39.9 in southern region) and included *Stolephorus* spp., silverbellies, *Coilia* sp., other clupeids, *Apogon* spp., mackerel, sardines, eels, priacanthids, *Bregmaceros* sp. and sciaenids. Along northern region, in juveniles and preadults, the diet comprised chiefly of crustaceans (IRI% of 72.27 and 52.76), followed by finfishes (IRI% of 15.37 and 27.65). In the southern region, adult fishes exhibited higher preference for finfishes (IRI% of 47.5 to 62.8). Feeding intensity was low throughout the year with close to half (48.23% in northern region and 43.67% in southern region) of the fishes exhibiting empty or trace stomach conditions which increased with an increase in age and size of fish. High similarity of 75.54% in the northern and 84.19% in the southern region was recorded in the diet contents of smaller and moderate sized adults. Annual and seasonal mean similarity in the diet components between the regions was 69.9 and 53%. Prey contents in juveniles between both the regions exhibited a similarity of 59.5%, while preadults and adults recorded similarities of 62.7 and 68.2% respectively.

Keywords: Feeding intensity, Food composition, *Nemipterus japonicus*, North-east coast, Trophodynamics

Introduction

North-east coast of India, comprising the states of West Bengal, Odisha and Andhra Pradesh with a combined coastline of 1612 km, forms a major fishing area of the Bay of Bengal Large Marine Ecosystem (BOBLME). Threadfin breams form one of the major commercially exploited demersal fish resources along this coast. It is mostly landed by trawlnets. Along Andhra Pradesh, mechanised trawlers with overall length ranging from 11-15 m and engine horsepower varying from 90-250 are actively engaged in catching threadfin breams. The codend mesh size of trawlnets is 20-30 mm and they operate at depths from 30-100 m (Rao *et al*., 2008). Threadfin breams enjoy good demand for its meat, for surimi production. Landings of threadfin breams along the north-east coast have increased from 1756 t in 1985 to 23344 t in 2011. On average, it contributed 2.3% of the total trawl landings during 1985-2013 (Ghosh *et al*., 2015). Among the threadfin breams landed off Andhra Pradesh, *Nemipterus japonicus* (Bloch, 1791) formed about 60% of the landings followed by *N. randalli* (33%) while the remaining share was formed by *N. luteus, N. tolu* and *N. peronii* (Maheswarudu *et al*., 2013).

Knowledge on trophic level interactions between prey and predator is necessary for maintaining a healthy population and for sustainably exploiting the stocks. This in turn facilitates deriving suitable management measures for the stock. Earlier studies (Krishnamoorthi, 1971; Murty, 1981; Rao and Rao, 1991) on the food and feeding habits of *N. japonicus* dates back to several decades and were exclusively confined to the southern region of the north-east coast. There are no studies till date on the food and feeding habits from the northern region of the north-east coast. Mesoscale studies have significant impact for the better understanding of predator-prey relations between the fishes and their food organisms, particularly when the study area encompasses a wider region, such as, in the present context, the BOBLME. The present study attempted to assess the trophodynamics of *N. japonicus* along the north-east coast of India following a mesoscale categorisation between the northern and southern regions.

Materials and methods

Samples of *N. japonicus* were collected randomly every week during 2012-2015 from the trawl landings at Digha (West Bengal), Paradeep (Odisha) and Visakhapatnam and Kakinada (Andhra Pradesh). Samples from Digha and Paradeep were considered as from the northern region, whereas samples from Visakhapatnam and Kakinada were considered as from the southern region. No samples were obtained in the month of May from both the regions due to the seasonal trawl ban. Also, along the northern region, in the month of April, because of severely decreased catches, trawlers rarely ventured out and hence no samples were obtained. Length was recorded to the nearest millimetre (mm) and weight measured to the nearest gram (g), using a digital scale. About 1302 specimens in the length range of 48-319 mm were analysed from the northern region and 1415 specimens in the length range of 46-287 mm were analysed from the southern region. Stomachs were cut open from the individual fish and the contents were processed and preserved for further identification and quantification. Stomach state was assessed based on the distension and the degree of fullness and were classified as empty, trace, ¼ full, ½ full, ¾ full, full and gorged. For the ease of presentation of results and for resolving ambiguities over closely related stomach states, they were merged as empty - trace, ¼ full - ½ full and ¾ full - gorged. The IRI% (Index of relative of importance) (Pinkas *et al*., 1971) was used to assess the diet contents which was evaluated annually and seasonally and between various life history stages (juveniles, preadults and adults). Fishes were classified based on their length and maturity state into different life history stages *viz.,* juveniles (<99 mm), preadults (100-149 mm), smaller adults (150-199 mm), moderate sized adults (200-249 mm) and larger adults (250 mm and larger).

Multivariate analyses on IRI% was carried out using PRIMER v. 6 (Clarke and Gorley, 2006). Variations in the dietary composition within the northern and southern regions were identified from the annual IRI%, seasonal IRI% and life history IRI%, as also the differences between the two regions. Prior to statistical analysis of data, IRI% was square root transformed and Bray-Curtis similarity matrices were constructed and hierarchical cluster analysis was performed. SIMPROF permutation was done to test the cluster significance.

Results

Index of relative importance (IRI%)

In the northern region, crustaceans, finfishes, molluscs, polychaetes and unidentified matter with annual average IRI% of 50, 32.1, 10.3, 1.6 and 6.1 constituted the diet. IRI of various prey items is presented in Table 1. Crustaceans, the most preferred prey, were dominated by *Oratosquilla* sp., followed by *Metapenaeus* sp., crabs, non-penaeids, *Solenocera* sp., *Acetes* sp. and other penaeids. Finfishes formed the second most abundant diet component and comprised silverbellies, *Bregmaceros* sp., *Apogon* spp., eels, *Coilia* sp., *Stolephorus* sp., carangids and mackerel. Molluscs were represented mostly by squids, followed by gastropods and octopus. In juveniles and preadults, diet was formed chiefly of crustaceans (IRI% of 72.27 and 52.76), followed by finfishes (IRI% of 15.37 and 27.65). Juvenile diet consisted of shrimps (IRI% of 36.77) and crabs (IRI% of 12.92). In preadults, *Oratosquilla* sp. (IRI% of 12.92), squids (IRI% of 10.04), crabs (IRI% of 10.04), *Acetes* sp. (IRI% of 8.01) and finfishes like eels (IRI% of 5.63), *Apogon* spp. (IRI% of 4.56) and silverbellies (IRI% of 4.93) were dominant. The diet of smaller, moderate sized and large adults comprised of a mixture of crustaceans (IRI% of 45.56, 44.49 and 46.06) and finfishes (IRI% of 42.17, 41.97 and 30.29). Larger and mature individuals preferred finfishes *viz., Bregmaceros* sp., *Coilia* sp., *Stolephorus* spp., carangids and mackerel.

In the southern region, IRI% of crustaceans, finfishes, molluscs, polychaetes and unidentified matter were 42.4, 39.9, 12.0, 4.4 and 1.3 respectively. IRI of various prey items is given in Table 2. *Oratosquilla* sp. dominated the crustacean components followed by crabs, *Metapenaeus* sp., *Solenocera* sp. and *Acetes* sp. Among finfishes, *Stolephorus* spp., silverbellies, clupeids, *Apogon* spp., mackerel, sardines, eels, priacanthids, *Bregmaceros* sp. and sciaenids were abundant. Squids, octopuses and gastropods constituted the molluscan diet components. Crustaceans formed an annual average IRI of 62.6% in juveniles and 30.7% in larger individuals. Crabs dominated the diet contents of juveniles (IRI% of 49.32), whereas penaeids dominated the diet contents of preadults (IRI% of 20.43). In large adults, *Oratosquilla* sp. was the most abundant food item. Adult fishes exhibited a high preference for finfishes (IRI% of 47.5 to 62.8) *viz., Stolephorus* spp., silverbellies, clupeids, mackerel, sardines, priacanthids, *Bregmaceros* sp. and sciaenids. Eels were preferred by juveniles and preadults, while *Apogon* spp. and juvenile fishes were encountered mostly in moderate sized fishes.

Table 1. IRI % of prey items in northern region of north-east coast of India

Months / Diet contents	Jan (n=199)	Feb (n=179)	Mar (n=208)	Jun (n=156)	Jul (n=147)	Aug (n=134)	Sep (n=163)	Oct (n=178)	Nov (n=186)	Dec (n=175)	Pooled (n=1725)
Fishes											
Apogon sp.	0.3	0.8		3.54	5.28	7.57	3.76	0.96	1.19		2.22
Bregmaceros sp.	4.93			7.05	12.17	2.7	1.91	0.9		0.28	2.53
Carangids	0.61		3.46			3.63		9.19	2.16		1.24
Other clupeids		1.9	1.15		4.68	1.83	0.43				0.52
Coilia sp.		1		6.57	1.32	10.92	1.14		1.69		1.51
Eel	0.32	2.74	3.95	0.23	5.72	5.14	0.15	2.79		0.49	1.87
Juvenile fishes			0.81			0.67	0.51	0.94	0.35	0.74	0.41
Lactarius lactarius	0.69		0.44	2.95							0.17
Lizardfish			0.4					1.07		0.72	0.11
Mackerel	0.97	4.95	3.49					1.74	5.34		1.13
Mullets		0.68			1.82	1.23	0.44	1.13			0.31
Myctophids	0.17			0.75		4.83	0.73		0.38		0.42
Nemipterids	0.72	1.61									0.06
Platycephalus sp.		2.49			1.39		3.2	0.56	2.65		0.73
Priacanthids		1.98						4.23			0.14
Ribbonfish				1.54					0.27	1.14	0.15
Sciaenids					1.51			5.4			0.15
Sillago sp.				0.57			2.54		2.38		0.31
Silverbellies	1.99	8.32	1.35	0.75	12.7	8.99	1.79	0.83	7.81		4.39
Squirrel fish	2.29	0.81	0.88		1.27	0.95			0.85		0.59
Stolephorus sp.		6.15			1.21				7.66	5.18	1.16
Upeneus sp.			1.06			0.85		1.18		1.68	0.31
Crustaceans											
Acetes sp.	4.86	1.8						4.2		16.86	1.91
Metapenaeus sp.	22.65	2.1	17.51	3.7	15.38		3.79		17.06	3.56	9.80
Parapenaeopsis sp.	0.52		1.77	0.29		0.44	2.19	1.85		1.15	0.96
Solenocera sp.	3.33		3.63			1.33			8.29	9.78	2.35
Other penaeids	0.48	8.89	4.2		0.94	3.36			11.59	0.31	2.26
Other non-pnaeids	11.83	35.23			1.95			15.61	10.51	4.71	5.95
Oratosquilla sp.	22.53	2.42	2.6	2.05	22.22	10.49	6.05	13.17	0.89	29.81	14.63
Crabs	2.28	2.25	8.09	28.84	1.44		19.1	2.03	7.8	0.46	8.33
Molluscs											
Gastropods		0.9	0.28	2.4		0.72	1.11				0.39
Octopus			0.8	2.59		1.17	0.65	0.65			0.41
Squid	5.85		22.03	5.27	6.08	10.39	23.73	0.63	8.12	0.63	10.05
Polychaetes			0.32	0.48	0.71	0.48	7.02	3.45		0.18	1.04
Digested fish	8.27	4.54	0.47	23.56	1.27	13.65	14.04	9.19	1.43	15.64	12.39
Digested matter	4.22	6.93	19.88	4.22	0.94	1.85		16.13	1.6	2.04	5.95
Digested shrimp	0.19	1.52	1.42	2.65		6.82	5.71	2.18		4.65	3.16

Table 2. IRI % of prey items in southern region of north-east coast of India

Diet contents \ Months	Jan (n=189)	Feb (n=194)	Mar (n=172)	Apr (n=164)	Jun (n=172)	Jul (n=178)	Aug (n=181)	Sep (n=167)	Oct (n=184)	Nov (n=176)	Dec (n=193)	Pooled (n=1970)
Fishes												
Apogon sp.	4.65	2.7	0.36	1.24		2.57	2.7	3.24	1.88	4.04	1.43	2.93
Ariomma indica	0.28						0.4	0.65	0.14			0.08
Bregmaceros sp.	0.55	0.16			0.19	2.26	2.82	7.88	0.14		1.12	1.00
Carangids			0.38	0.56			0.46	0.52	0.3	0.81		0.19
Eels	0.73		0.29	2.47	0.15	5.55	4.11	2.71		2.79		1.27
Juvenile fishes	7.74	5.96	12.08			0.2	0.11		0.31		10.37	2.46
Lactarius lactarius	0	0.12	0.42		2.24	4.82				1.32		0.34
Lizardfish	0.15	0.31				0.3					2.51	0.14
Mackerel	7.26		0.39	0.68	0		10.34	3.42	2.38	0.44	1.85	2.16
Myctophids	2.75	2.6	1.66			0.41	0.33	2.49	0.19			0.86
Nemipterus sp.	0.2	0.74	1.93				1.28		0.41		0.26	0.34
Other clupeids	1.19	1.34	5.21	0.47	7.89	11.23	1.66	5.41	3.5		4.9	4.25
Priacanthids	2.02	0.98		0.45	0	0.47		0.33	1.49	0.41	4.36	0.88
Sardines		2.06		1.75		9.73		1.22	0.32	3.89	3.1	1.35
Sciaenids	1.74			4.07		0.5	1.28				3.93	0.60
Sillago sp.			0.21				0.33		0.98			0.07
Silverbellies	0.17	3.25	7.88	1.11	1.65		10.58	10.55	6.15		2.54	4.45
Squirrel fish					0.35		1.35		0.15			0.07
Stolephorus sp.	14.39	6.19		0.72	0.48	6.14		0.34	16.54	2.1	5.46	4.64
Upeneus sp.		1.42	0.34	0.53	0.69		0.45		0.28	2.09	0.81	0.56
Crustaceans												
Acetes sp.	8.2								2.12	6.38	4.27	1.01
Metapenaeus sp.	1.73	2.59	7.98		3.2	8.15	4.01	9.73	5.25	13.45	5.06	6.58
Other penaeids	0.96	19.5	9.58	4.89		4.24	4.45	16.61	10.8	4.52	8.28	9.17
Solenocera sp.	9.42	8.73					0.99	0.18	0.94	5.01	17.33	2.97
Crabs	18.71	4.66	16.53	38.24	7.66		12.76	3.91	3.26	1.44	0.96	9.93
Oratosquilla sp.	2.12	4.01	3.92	1.52	31.18	21.97	2.76	7.57	4.61	14.8	4.77	9.71
Molluscs												
Gastropods		0.26	0.57		0.4			1.48	20.6	5.19		1.18
Octopus	2.03		2.18	2.96	0.35		0.73	1.01	2.07	1.93		1.12
Squids	3.91	1.68	18.25	8	7.18	0.16	27.2	8.75	0.97	5.88	5.31	8.66
Polychaetes	0.75				2.64	5.12	0.5	2.37	0.41	4.33	1.04	1.25
Digested fish	5.04	23.25	2.43	16.54	10.16	12.05	5.43	5.47	2.12	13.19	5.93	11.63
Digested matter	1.1	1.37	0.4	13.8	11.7	1.98	2.96	3.06	7.27	5.08		4.22
Digested shrimp	2.23	6.15	7.02		11.9	2.16		1.12	4.43	0.93	4.41	3.91

Feeding intensity

Fishes with empty-trace state of stomach were dominant in the northern (48.23%) and southern (43.67%) regions, followed by the ¼ full-½ full (36.25% and 39.51%) and ¾ full-gorged (15.51% and 16.82%) states. Feeding intensity was low in most months (Figs. 1 and 2) and showed an increase with increase in size of the fish, in both the regions, with moderate sized and large adults exhibiting high feeding intensity (Figs. 3 and 4).

Cluster analysis

Cluster analysis indicated that diet contents of smaller and moderate sised adults in both the regions are significantly similar ($p<0.05$). The similarity values were 75.54% in the northern region and 84.19% in the southern region (Fig. 5 and 6). Seasonally, in both the regions, food components were similar, with no specific diet trends recorded over the season. Between various months in the northern region, diet similarity varied from 35.85 to 58.88%. Highest similarity was observed between August and September and lowest between October and November. In the southern region, similarity between months varied from 46.9 to 71.9% with maximum similarity between August and September and minimum between July and August. Annually, strong similarity in food composition was observed. It varied between years from 73.01 to 80.07% in the northern region and from 78.5% to 81.35% in the southern region.

Between the regions, annual mean similarity in the diet components was 69.9±2.32% with values ranging from 66.47 to 71.49%. Seasonally, mean similarity was 53±5.5% with a range of 44.7 to 61.54%. Maximum

Fig. 1. Seasonal feeding intensity in northern region of north-east coast of India

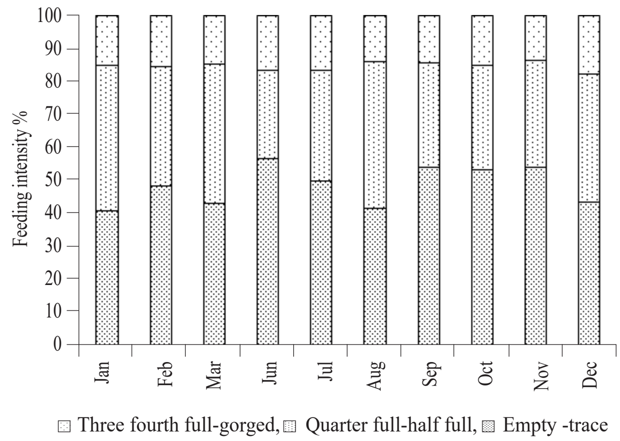

Fig. 2. Seasonal feeding intensity in southern region of north-east coast of India

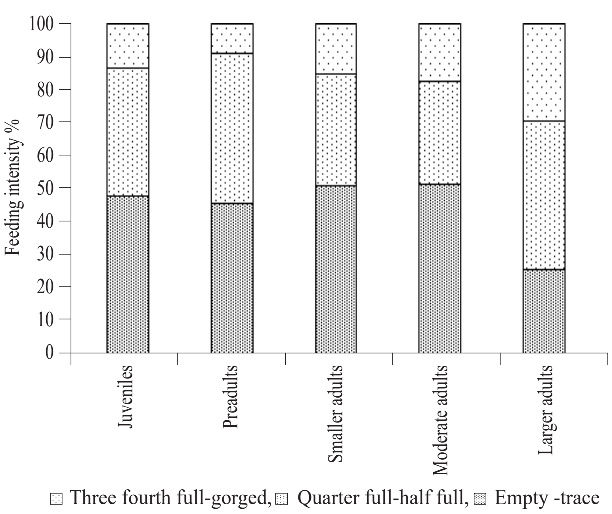

Fig. 3. Feeding intensity based on life history stage in northern region of north-east coast of India

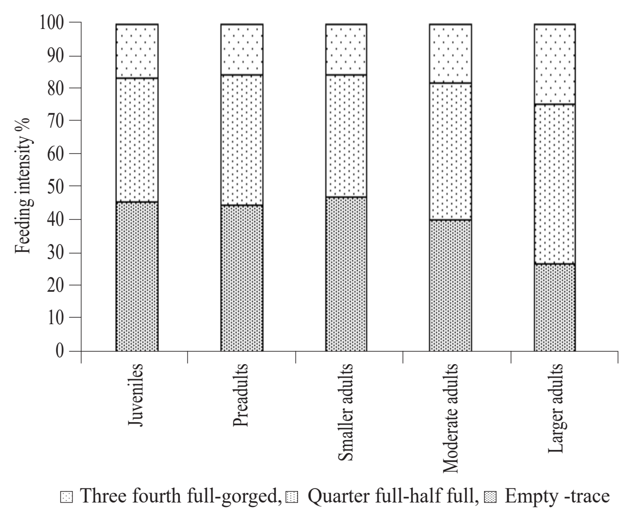

Fig. 4. Feeding intensity based on life history stage in southern region of north-east coast of India

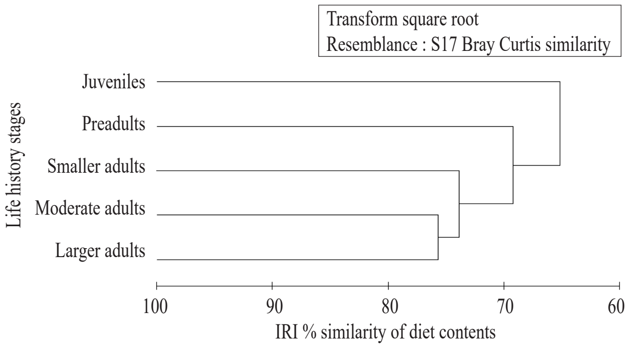

Fig. 5. IRI% similarity during different life history stages in northern region of north-east coast of India

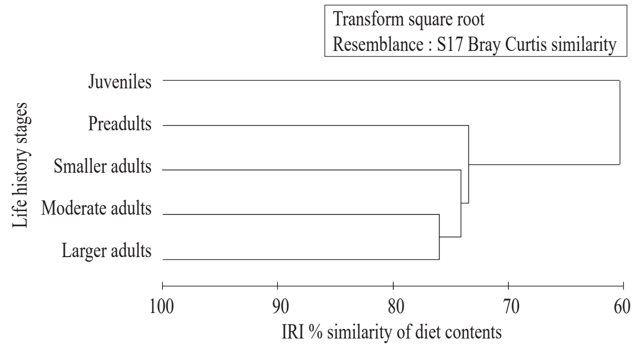

Fig. 6. IRI% similarity during different life history stages in southern region of north-east coast of India

similarity was in March and minimum similarity was in October. Prey contents in juveniles between both the regions exhibited a similarity of 59.5%, while preadults and adults recorded similarities of 62.7 and 68.2%.

Discussion

Nemipterus japonicus is a carnivorous species feeding predominantly on benthic organisms. Among crustaceans which is its preferred food item, *Oratosquilla* sp., crabs and several species of penaeids and nonpenaeids were seen in the diet. Rao and Rao (1991) also reported *Oratosquilla* sp., crabs and penaeids to be the most important food items of *N. japonicus*. Krishnamoorthi (1971) stated it to be an active predator and a sight feeder, preying mostly on crustaceans. Crustaceans have been reported as the preferred prey item of *N. japonicus* by several other authors from various locations (Kuthalingam, 1965; Gopal and Vivekanandan, 1991; Manojkumar *et al*., 2015). Finfishes represented by both pelagic and demersal species were found in the stomach contents and was the second most important food item. Juveniles and preadults preferred mostly crustaceans whereas adults fed equally on crustaceans and finfishes. Similar observation on smaller individuals preying on crustaceans and larger individuals preying on finfishes was reported by Manojkumar *et al.* (2015). Demersal finfishes were mostly preyed upon by juveniles and preadults whereas, pelagic finfishes were consumed by adults. Juveniles and preadults are therefore, purely benthic in nature, but adults live in the column. Juveniles and preadults inhabit depths ranging from 10 to 30 m, while adults prefer open waters (Kuthalingam, 1965) and this explains the differences in feeding components between juveniles, preadults and adults. From the diet composition study, it is inferred that the occurrence of crustaceans and finfishes in the stomach contents is inversely proportional, with the contribution of crustaceans decreasing and finfishes increasing with increase in size of the fishes. Hence, *N. japonicus* progressively transforms its preference from a crustacean diet to a mixture of crustacean and piscivorous diet with age. As a consequence of increase in mouth and body size of the fish, ontogenic shifts in diet contents permits it to catch a wide range of prey sizes and types (Labropoulou *et al.,* 1997). Higher IRI% for semi-digested or unidentifiable fishes indicate rapid digestive capability of the fish.

Feeding intensity was lower with close to half of the fishes possessing empty to trace amount of food in stomachs. Similar records on a preponderance of empty stomachs throughout the season were reported earlier by Krishnamoorthi (1971), Gopal and Vivekanandan (1991), Manojkumar (2004) and Manojkumar *et al*. (2015). However, in contrast to the findings of these authors, in the present study with increase in size, feeding intensity increased. Nearly half of the larger adults had their stomachs quarter to half-full and remaining half had their stomachs three-quarter-full to gorged. With increase in age and size of the fish, several morphological alterations happen resulting in enhanced mouth gape/aperture along with improved locomotive ability of the fish, thereby increasing their efficiency in catching prey (Ghosh, 2014).

The annual and seasonal diet composition was more similar in the southern region than the northern region. Annual and seasonal variations, whatever recorded in the diet, reflected the seasonal abundance and availability of prey groups. In the southern region, preference for finfishes in the diet was more. However in both the regions, the food composition of smaller, moderate sized and larger adults were significantly similar. This reflected on the fact that all adults shared the same prey components, as reported earlier by Rao and Rao (1991) and Manojkumar *et al*. (2015).

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