Indian J. Fish., 59(3) : 25-31, 2012

Site specific differences in food and feeding biology of *Nemipterus japonicus* (Bloch, 1791) along Indian coast

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ABSTRACT

Feeding biology of populations of a typical demersal carnivorous fish species, *Nemipterus japonicus* (Japanese threadfin bream) from four different locations of India was studied on the basis of percentage number, percentage weight and occurrence of food items. The basic indices *viz.,* percentage number, gravimetric index and percentage occurrence were used to calculate preference indices like the index of relative importance (IRI) and index of preponderance (IP). Percentage similarity index (PSI) and dietary breadth (DB) were used for investigating the site specific variation in food and feeding biology from 4 sites *viz*., Mumbai and Cochin from the west coast and Chennai and Kakinada from the east coast of India. Some important food items like squid, lizard fish, *Solenocera* sp. and polychaetes which were common in other locations, were not reported from Kakinada samples. The PSI and DB indicated marked variations in feeding biology of populations from different sites on the east and west coast. Similarity index was maximum between Mumbai and Cochin while the second highest value was between Kakinada and Chennai. A narrow spectrum of food items was observed for Kakinada and Chennai populations in contrast to a broader spectrum for Cochin and Mumbai populations. The west coast individuals revealed abundance of shrimps, while east coast individuals showed abundance of crabs in the diet. The analysis reflected a coastwise variation in the food items of the species.

Keywords: Dietary breadth, Index of preponderance, Index of relative importance, Japanese threadfin bream, *Nemipterus japonicus*, Percentage similarity index

Introduction

Japanese threadfin bream, *Nemipterus japonicus* (Bloch, 1791) is a demersal species abundant in the muddy or sandy bottom along all the coastal stretches of India. This tropical species live in schools, generally close to bottom normally around depth zones of 50-100 m with high concentration in 80-100 m. It feeds mainly on small fishes, crustaceans, molluscs (mainly cephalopods), polychaetes and echinoderms. Food and feeding biology of *N. japonicus* suggests a carnivorous feeding behaviour with preference to crustaceans (Kuthalingam, 1966; Euzen, 1989; Vivekanandan, 1990). Gopal and Vivekanandan (1991) reported occurrence of *Acetes* sp., shrimps and crabs in the diet of this species off Veraval coast. Bakhsh (1994) from Jizan region of the Red Sea indicated preference for crustaceans with shrimps, crabs and copepods in the food contents of *N. japonicus* along with the occurrence of traces of gastropods, bivalve shells, polychaetes, fish eggs, algae, fish scales and detritus. Vinci (1982) reported the presence of anchovy in the stomachs of this species from Kerala coast. Krishnamoorthi (1971) reported *Squilla* sp., crabs, caridean prawns, squids and other teleosts in that order of abundance. Rao (1964) reported crabs and prawns as major food items off Waltair. The diet of *N. japonicus* off Veraval in Gujarat comprised mainly crustaceans *viz*.., *Acetes* spp., penaeid prawns, crabs, *Squilla* sp., deep sea prawns, juveniles of fishes such as flatheads, lizard fishes and fish larvae (Manojkumar, 2004). Raje (2002) reported it to be a carnivore feeding on crustaceans, teleosts, annelids, molluscs and echinoderms in the stomach contents from Veraval. The frequently reported food items are *Acetes* sp., *Solenocera* sp., crabs, *Squilla* sp., sciaenids, *N. randalli*, *N. japonicus*, *Lactarias lactarias*, *Apogon* sp., *Secutor* sp., *Myctophum* sp., *Trichiurus* sp., *Cynoglossus* sp., *Saurida* sp., *Bregmaceros* sp., *Leiognathus* sp. and fish larvae. Polychaetes like *Nereis* sp., cephalopods like squids, cuttlefishes and octopus are also reported in the diet.

The cannibalistic behaviour of this species was detailed by Kuthalingam (1966); Raje (2002) and Sudheesan *et al.* (2009).

N. japonicus has a small mouth opening, villiform teeth only on the jaws, soft gill rakers with bristles, small stomach and long intestine adapted for small preys (Sudheesan *et al.,* 2009). The adaptation is also significant in preventing the escape of the prey (Krishnamoorthi, 1971; Rao and Rao, 1991). *N. japonicus* is undoubtedly a carnivore which actively predates by sight, feeding substantially on crustaceans, molluscs, annelids and echinoderms (Krishnamoorthi, 1971; Vivekanandan, 2001). The present study forms the first attempt to investigate the site specific feeding preferences of *N. japonicus* along the Indian coast.

Materials and methods

In order to sort out the site specific variation in food and feeding of *Nemipterus japonicus* along Indian coast, sampling locations were selected in four maritime states of India, such as Maharashtra (Mumbai - New Ferry Wharf) and Kerala (Cochin-Cochin Fisheries Harbour) from the west and Tamil Nadu (Chennai-Chennai Fisheries Harbour) and Andhra Pradesh (Kakinada- Kakinada Fishing Harbour) on the east coast. Fish samples were collected from commercial landings of all the four selected locations from August 2010 to April 2011. A total of 385 intact samples from different regions like Chennai (98), Mumbai (89), Kakinada (112) and Cochin (86) were collected. *N. japonicus* was identified following the description given by FAO species identification sheets (FAO, 1983). Site specific differences in the diet composition were analysed using the following indices and methods:

1) Vacuity index (%), VI = 100 x (number of empty stomachs / number of stomachs examined)

2) Percentage occurrence, Co = 100 x (number of stomachs with a certain food item / number of stomachs examined)

3) Percentage number , Cn = 100 x (number of food item concerned / total number of food items observed)

4) Gravimetric index, Cw = 100 x (weight of certain food item / total weight of all food items)

This was calculated on the basis of total stomach weight

Methods for food preference studies used in the present study were the following:

1) Index of relative importance, IRI = (% Cn + % Cw) x Co

2) Index of preponderance, IP= [(Co x Cw) / Σ (Co x Cw)] x 100

For further discrimination of the site specific differences, two more indices were worked out which are the relative comparison measures. To measure the diet similarity between sites, the percentage similarity index, PSI (Cowen, 1984) was calculated.

3) $PSI=\sum_{i=1}^{s} min\,[(P_{i,1}), (P_{i,2})]$

where, S = the total number of species in the two sites.

$P_{i,1}$ = Proportion of species 'i' in the first site

$P_{i,2}$ = Proportion of species 'i' in the second site.

To compare the evenness of the prey utilisation at each site, dietary breadth, DB (Cowen, 1984) was calculated as:

4) $DB = 1 / \sum_{i=1}^{s} Pi^2$

where, P_i = Proportion of species 'i' in the diet

For calculations of both PSI and DB, the proportions of the specific prey weight to the total stomach content weight were calculated. All the computations of different preference and similarity indices were completed using PROC MEANS procedure of SAS software (SAS Institute, 2009).

Results and discussion

Feeding biology of Japanese threadfin bream, *N. japonicus,* from four different locations was studied on the basis of percentage number, percentage weight and occurrence of each food item. The analyses were carried out for fish samples ranging from a total length of 9.18 cm to 24.6 cm. The total length ranges for samples collected from Mumbai, Cochin, Chennai and Kakinada were 10.20-24.3 cm, 9.18-24.5 cm, 9.96-24.6 cm and 9.51-22.76 cm respectively. The major food items were shrimps including *Acetes* sp., *Solenocera* sp., crabs (unidentified), *Squilla* sp., fishes comprising *Bregmaceros* sp., *Secutor* sp., *Nemipterus randalli, Callionemus* sp., lizard fish, ribbon fish, trigger fish, atherinids, flatheads, sardines, sciaenids, eels, cephalopods such as squids, cuttlefishes and octopus, sponge, *Sargassum* sp. and polychaetes. Occurrence of fish scales in the food contents was only observed in samples collected from Mumbai coast. Unspecified digested materials were also found among the food contents. In the eighty nine specimens of *N. japonicus* analysed from the Mumbai region for gut contents, a total of 237 different food items were recorded (Table 1). The total stomach contents weighed 66.90 g. Thirty two fishes were found with empty stomachs. Comparatively better feeding condition was reported for the Mumbai samples as per the vacuity index, VI (35.96%). Percentage number (Cn) wise analysis of food items indicated the dominance of crustaceans with values of 43.6%, 17.3%, 4.1%, 1.23% and

Table 1. Analysis of gut contents of *N. japonicus* from Mumbai coast

Food items	N	OC	W	Cn	Cw	Co	IRI	IP	Rank
DG	39	40	5.41	16.05	4.95	44.9	943.9	23.29	2
Fishes*	6	5	2.14	2.47	1.95	5.62	24.85	1.149	9
Shrimp*	42	23	17.77	17.28	16.2	25.8	866.5	43.95	1
Acetes sp.	106	17	6.69	43.62	6.12	19.1	950.2	12.24	3
Solenocera sp.	10	10	6.34	4.12	5.8	11.2	111.4	6.818	4
Apogon sp.	3	3	2.06	1.24	1.88	3.37	10.5	0.663	10
Bregmaceros sp.	6	6	5.72	2.47	5.23	6.74	51.91	3.691	6
Squids	9	7	5.19	3.7	4.75	7.87	66.47	3.909	5
Lizard fish	1	2	2.29	0.41	2.1	2.25	5.64	0.493	12
Atherinids	2	2	0.25	0.82	0.22	2.25	2.35	0.053	16
Sciaenids	1	1	1.35	0.41	1.23	1.12	1.84	0.145	14
Fish scale	3	3	0.12	1.24	0.11	3.37	4.55	0.04	18
Secutor sp.	1	1	0.43	0.41	0.4	1.12	0.91	0.047	17
Squilla sp.	1	1	0.53	0.41	0.49	1.12	1.01	0.057	15
Crabs	3	3	1.48	1.24	1.35	3.37	8.72	0.477	13
Cuttlefish	4	3	3.96	1.65	3.62	3.37	17.74	1.276	7
Nemipterids	2	2	2.5	0.82	2.29	2.25	6.99	0.539	11
Eels	4	4	2.71	1.65	2.47	4.49	18.52	1.164	8

N - Number of food item, OC - Occurrence of food item, W - Weight of the food item
DG - Unspecified digested material, * unidentified

0.41% for *Acetes* sp., unidentified shrimps, *Solenocera* sp., crabs and *Squilla* sp. respectively. Fishes like *Bregmaceros* sp., eels, *Apogon* sp., atherinids, sciaenids, lizard fish, nemipterids, *Secutor* sp. and unidentified fishes were also recorded in the diet. Cephalopods like squids and cuttlefishes were present in the diet. Gravimetric index (Cw) of the stomach contents also supported the significance of crustaceans. The Cw values for the major crustacean food items were found to be 16.25%, 6.12%, 5.79%, 1.35% and 0.48% for unidentified shrimps, *Acetes* sp., *Solenocera* sp., crab and *Squilla* sp. respectively. Percentage occurrence (Co) also supports the importance of crustaceans especially shrimps in the diet with values of 25.84%, 19.1%, 11.23%, 3.37% and 1.12% for unidentified shrimps, *Acetes* sp., *Solenocera* sp., crabs and *Squilla* sp. respectively. Index of relative importance (IRI) clearly gives dominance of shrimps like *Acetes* sp. (950.2), *Solenocera* sp. (111.4) and other unidentified shrimps (866.5). The index of relative importance (IRI) of each prey item was estimated for food-containing fish as a linear combination of its numerical importance (N), volumetric importance (V), and frequency of occurrence (F) (Pinkas *et al*., 1971; Cailliet and Ebeling, 1990; Vivekanandan, 2001). Ranks allocated for the food items based on the index of preponderance (IP) are; 1) shrimps (unidentified), 2) digested materials (unspecified), 3) *Acetes* sp., 4) *Solenocera* sp. and 5) squid. The index of preponderance (Needham, 1962) provides a definite and measurable basis for grading the various food elements on a relative scale as it gives a combined picture of frequency of occurrence as well as bulk.

Eighty six specimens from Cochin region were analysed and a total number of 197 different food items were recorded (Table 2). The total stomach content quantified was 93.92 g and empty stomachs were 15 in number. Better feeding condition was recorded as per VI (17.44%). The Cn values reflected crustacean dominance with 31%, 8.63%, 7.1%, 6.6% and 3.04% for unidentified shrimps, crabs, *Solenocera* sp., *Squilla* sp. and *Acetes* sp. respectively. Fishes like *Bregmaceros* sp., *N. randalli*, lizard fish, eels, flathead, ribbon fish, *Callionemus* sp., atherinids, trigger fish and unidentified fishes were also there in the diet. Polychaete worms, squids and octopus also have shown their presence in the diet. The Cw values for the major crustacean food items were found to be 10.82%, 5.8%, 7.84% and 6% for unidentified shrimps, crabs, *Solenocera* sp. and *Squilla* sp. respectively. The Co values for different food items also revealed the importance of crustaceans, mostly unidentified shrimps (41.9%) in the diet. The IRI values clearly depicted crustacean dominance especially of unidentified shrimps (1749). Other major food items which contributed to the stomach contents were *Squilla* sp. (161.2), *Solenocera* sp. (121.7), crabs (117.4), unidentified fishes (102.85), squid (78.9), *Bregmaceros* sp. (67.81) and flathead (49.83). Ranks allocated for the food items on the basis of IP are: 1) shrimps

Table 2. Details of gut contents of *N. japonicus* from Cochin coast

Food items	N	OC	W	Cn	Cw	Co	IRI	IP	Rank
DG	27	27	5.46	13.7	3.69	31.4	546	12.42	2
Fishes*	12	10	4.08	6.09	2.75	11.63	103	3.44	7
Shrimps*	61	36	16	31	10.8	41.86	1749	48.56	1
Acetes sp.	6	1	0.33	3.05	0.22	1.16	3.8	0.03	18
Solenocera sp.	14	7	11.6	7.11	7.84	8.14	122	6.84	4
Atherinids	1	1	1.42	0.51	0.96	1.16	1.71	0.12	16
Bregmaceros sp.	8	8	4.78	4.06	3.23	9.3	67.8	3.22	9
Callionemus sp.	3	3	3.45	1.52	2.33	3.49	13.4	0.87	12
Crabs	17	7	8.58	8.63	5.8	8.14	117	5.06	5
Eels	5	4	4.06	2.54	2.74	4.65	24.6	1.37	10
Flatheads	5	5	8.93	2.54	6.03	5.81	49.8	3.76	6
Lizard fish	2	2	1.85	1.02	1.25	2.33	5.26	0.31	15
Octopus	1	1	0.21	0.51	0.14	1.16	0.76	0.02	19
Polychaete	5	4	1.92	2.54	1.3	4.65	17.8	0.65	13
Ribbonfish	3	3	1.76	1.52	1.19	3.49	9.46	0.45	14
Squilla sp.	13	11	8.89	6.6	6.01	12.79	161	8.24	3
Squid	10	8	5.04	5.08	3.41	9.3	78.9	3.4	8
Triggerfish	1	1	0.67	0.51	0.46	1.16	1.12	0.06	17
Nemipterus randalli	3	3	4.75	1.52	3.21	3.49	16.5	1.2	11

N - Number of food item, OC - Occurrence of food item, W - Weight of food item
DG - Unspecified digested material, *unidentified

(unidentified), 2) digested materials (unspecified), 3) *Squilla* sp., 4) *Solenocera* sp. and 5) crabs.

Ninety eight specimens of *N. japonicus* from Chennai region were analysed for gut contents and a total of 210 different food items were observed (Table 3). The total stomach contents amounted 85.18 g with 28 empty stomachs. Good feeding condition was observed as per the VI (28.57%). The Cn value indicates the importance of crustaceans especially crabs and unidentified shrimps (40% and 15.24%) . The Cn values obtained for the other major food items were : lizard fish (4.3%), squid (3.81%), atherinids (2.4%), eel (1.9%) and unidentified fishes

Table 3. Details of gut contents of *N. japonicus* from Chennai coast

Food items	N	OC	W	Cn	Cw	Co	IRI	IP	Rank
Fishes*	16	11	12.64	7.62	8.82	11.22	184.6	6.57	4
Crabs	84	45	26.96	40	18.8	45.92	2701	57.31	1
Squid	8	7	6.59	3.81	4.6	7.14	60.08	2.18	5
Shrimps*	32	19	13.32	15.24	9.3	19.39	476	12	3
Sardine	2	2	2.23	0.95	1.55	2.04	5.12	0.21	8
Sponge	1	1	0.09	0.48	0.07	1.02	0.55	0.005	13
Sargassum sp.	1	1	0.07	0.48	0.05	1.02	0.54	0.003	14
Polychaete	4	3	1.2	1.91	0.84	3.06	8.4	0.17	9
Eels	4	2	1.5	1.91	1.04	2.04	6.02	0.14	10
Atherinids	5	5	4.18	2.38	2.92	5.1	27.05	0.99	7
Flatheads	1	1	0.87	0.48	0.6	1.02	1.1	0.04	12
Lizardfish	9	6	5.08	4.29	3.54	6.12	47.93	1.44	6
Bregmaceros sp.	1	1	0.91	0.48	0.64	1.02	1.136	0.04	11
DG	42	42	9.55	20	6.66	42.86	1143	18.94	2

N - Number of food item, OC - Occurrence of food item, W - Weight of food item
DG - Unspecified digested materials, * unidentified

(7.62 %). Fishes like sardine, *Bregmaceros* sp. and flathead also contributed to the diet. Polychaete worms were also recorded in the diet along with the accidental occurrence of *Sargassum* sp. and sponge. The Cw values recorded for important food items were : crabs (18.82%), shrimps (9.3%), squid (4.6%), lizard fish (3.54%), atherinids (2.92%), sardine (1.55%) and unidentified fishes (8.82%). The Co values also reveals the significance of crabs and shrimps (45.92%, 19.39%) in the diet. The IRI clearly shows the dominance of crustaceans like crabs and shrimps (2700.7, 475.7) in the diet along with unidentified fishes (184.6) and squid (60). Ranks allocated based on the IP values are: 1) crabs), 2), digested materials (unspecified), 3) shrimps, 4) fishes (unidentified) and 5) squid.

From the 112 specimens of Japanese threadfin breams analysed from Kakinada region, a total number of 168 different food items were recorded (Table 4). The total stomach contents weighed 64.17 g with 68 empty stomachs. Poor feeding condition was reported based on VI (60.71%). The Cn values calculated for the major crustacean food items were : crabs (23.81%), unidentified shrimps (17.86%), *Squilla* sp. (5.36%) and *Acetes* sp. (1.2%). Fishes like eels (4.8%), *N. randalli* (2.98%) and unidentified species (2.98%) also contributed to the diet. Absence of cephalopods in the diet contents was an interesting observation. The Cw values obtained for the major crustacean food items were : crabs (19.5%), shrimps (11.84%), *Squilla* sp. (4.6%) and *Acetes* sp. (0.16%). The Co values support the significance of crustacean food items in the diet with major contribution by crabs and shrimps (25.9% and 17.9%). The IRI showed dominance of crustaceans especially crabs and shrimps (1120.7 and 530.3) in the diet. Ranks allocated on the basis of IP values are: 1) digested materials (unspecified), 2) crabs, 3) shrimps, 4) *Squilla* sp. and 5) *N. randalli.*

Percentage similarity index (PSI) is a measure which is used for the comparison of food and feeding biology of different organisms or different populations of a specific organism. Thus it depicts the similarity in feeding habits and priority of food items of different species or different populations of a particular species. The calculated values for PSI between different stocks have been presented in Table 5.

Analysis of diet of fish from different regions clearly showed that, Cochin samples were the most diverse with 19 distinct food items followed by Mumbai (18), Chennai (14) and Kakinada (8). The results clearly indicated the complete dominance of crustaceans like shrimps, crabs

Table 4. Details of gut contents of *N. japonicus* from Kakinada coast

Food items	N	OC	W	Cn	Cw	Co	IRI	IP	Rank
DG	69	68	13	41.1	12	60.71	3224	48.23	1
Crabs	40	29	21.1	23.8	19.5	25.89	1121	33.29	2
Shrimps*	30	20	12.8	17.9	11.8	17.86	530.3	13.96	3
Nemipterus randalli	5	4	4.26	2.98	3.93	3.57	24.68	0.93	5
Fishes*	5	4	2.52	2.98	2.33	3.57	18.94	0.55	7
Squilla sp.	9	8	4.98	5.36	4.6	7.14	71.11	2.17	4
Eels	8	3	5.29	4.76	4.89	2.68	25.84	0.86	6
Acetes sp.	2	1	0.18	1.19	0.17	0.89	1.21	0.01	8

N - Number of food item, OC - Occurrence of food item, W - Weight of food item
DG - Unspecified digested materials, *unidentified

Table 5. PSI and DB for the gut contents of *N. japonicus* from different coasts

Location	PSI	Similarity	Dietary breadth (DB)
Chennai	-	-	5.79 (Narrow)
Cochin	-	-	11.274 (Wide)
Kakinada	-	-	4.81 (Narrow)
Mumbai	-	-	8.33 (Wide)
Chennai and Cochin	0.30275	Medium	-
Chennai and Kakinada	0.36304	High	-
Chennai and Mumbai	0.261336	Low	-
Cochin and Mumbai	0.371432	High	-
Kakinada and Mumbai	0.254796	Low	-
Cochin and Kakinada	0.33324	Good	-

and *Squilla* sp. in the food contents of Japanese threadfin bream along Indian coast with dominance of shrimps comprising *Acetes* sp. and *Solenocera* sp. in samples from west coast and crabs in the east coast samples. *Acetes* sp. was absent in the food contents of Cochin samples. *Squilla* sp. showed moderate preference in Cochin and Kakinada populations. Unidentified fishes marked dominance after crabs and shrimps in the diet of Chennai samples. Shrimp was dominant in the stomach contents of this species all along the Indian coast while the second position was observed for crabs. The related species *N. randalli* juveniles were recorded in the diet of Cochin and Kakinada samples. The diet analysis of Mumbai samples showed the presence of *Bregmaceros* sp. Eels and squids were observed in samples from all the regions and cuttlefishes only from Mumbai samples. Flatheads and callionemids were noticed only from Cochin region. Occurrence of fish scales in the diet was an interesting observation in the stomach contents of Mumbai samples. The whole analyses reflect the existence of site specific variation in the food items. Based on the condition of the stomach and diversity of food items, Cochin population was observed with high DB and very low VI. Mumbai samples also showed better condition with respect to the VI and DB values. Chennai and Kakinada populations were observed with low levels of DB. The diversity of feeding and resorting to the secondary prey items may be considered as an adaptation toward increasing the range of food supply of a population, by enabling the species as a whole to assimilate a variety of diets (Nikolskii, 1969).

High similarity has been observed between Cochin and Mumbai stocks based on percentage similarity index for food and feeding biology followed by Chennai and Kakinada. This indicates that coastwise differences exist in feeding biology and habitat for the Japanese threadfin bream along the Indian coast (Table 5). Least similarity was observed between Kakinada and Mumbai samples followed by Chennai and Mumbai. Moderately better similarity was observed in Cochin and Kakinada stocks. The Kakinada stock was observed to have very less divergence (DB = 4.81) compared to other stocks, while Cochin samples reported the maximum value of DB (11.274). Mumbai and Chennai samples showed DB values of 8.33 and 5.79 respectively. Thus there are clear evidences of the coastwise (east and west) differences based on DB and PSI (Table 5). Fishes are known to exhibit large components of environmentally induced morphological variations (Allendorf, 1987; Wimberger, 1992), which reflect different feeding biology. Moreover spatial variation in the food and feeding biology of California sheephead was quoted by Cowen (1984), using the percentage similarity index (PSI). Environmental factors, such as temperature, and salinity, food availability and swimming patterns might significantly determine the feeding biology of the threadfin bream, particularly between the Arabian Sea and the Bay of Bengal populations, which experience very specific environmental conditions (Kumar *et al.,* 2010). Based on the results of the study it can be concluded that there exist complex food and feeding patterns in specific locations or coasts for the Japanese threadfin bream along Indian coast. So the present study might give an insight to focus on investigations based on spatial regime.

Acknowledgements

This study was carried out with financial and technical support from the Central Institute of Fisheries Education (Indian Council of Agricultural Research), India. We extend our sincere gratitude towards the Director and faculty of CIFE for the same. We owe a great deal to the faculty of the Central Marine Fisheries Research Institute for helping with sample collection of this study.

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Date of Receipt : 27.11.2011
Date of Acceptance : 22.05.2012