Saudi Journal of Biological Sciences (2015) **22**, 698–705

King Saud University

Saudi Journal of Biological Sciences

www.ksu.edu.sa
www.sciencedirect.com

ORIGINAL ARTICLE

The natural diet of the mud crab *Scylla olivacea* (Herbst, 1896) in Pichavaram mangroves, India

C. Viswanathan, S.M. Raffi *

Centre of Advanced Study in Marine Biology, Faculty of Marine Sciences, Annamalai University, Parangipettai 608502, India

Received 5 December 2014; revised 23 July 2015; accepted 3 August 2015
Available online 29 August 2015

KEYWORDS

Scylla olivacea;
Mud crab;
Natural diet;
Pichavaram;
Crustaceans

Abstract Food and feeding habits of mud crab *Scylla olivacea* (Herbst, 1896) in Pichavaram mangroves was investigated quantitatively and qualitatively for a period of two years from June 2010 to May 2012. Gut contents from 1737 specimens comprising 843 males and 894 females in the size range between 45 mm and 148 mm were examined. Crustaceans form the predominant food item in a majority of size groups in terms of percentage wet weight and frequency of occurrence, while molluscs showed a preference in few size groups. The other dietary items includes fishes, detritus, mud and sand and miscellaneous. Gut content analysis revealed no significant variation between the quantities of food consumed by both sexes. Feeding intensity was higher in juveniles and sub-adults of both sexes than that of adults, revealing a greater preference to feed on fast moving prey such as crustaceans and fishes. The results of the present study indicate that *S. olivacea* in Pichavaram mangroves exhibited a clear preference for crustaceans.

1. Introduction

The mud crabs belong to genus *Scylla*, a fast growing species that attains larger size among portunids and is widely distributed throughout the coastal zones of the Indo-Pacific region (MacNae, 1968). They represent a valuable component of traditional, small scale coastal fisheries in several tropical and subtropical Southeast Asian countries which stands as a significant commodity that fetches a high price in the international seafood market (BOBP, 1992). Mud crabs form the 'candidate species for aquaculture' owing to its winsome qualities such as faster growth, larger size, high reproductive capacity (fecundity), disease resistance, marketability, adaptability to farming systems etc. Over the last three decades, exploitation of mud crab populations has increased tremendously in many countries in South East Asia.

For the last 50 years, confusion prevails over the taxonomic nomenclature of the genus *Scylla*, and in particular regarding the number of species existing within the genus. Revised taxonomy of the genus *Scylla* through biotechnological approach proved the occurrence of four species (*S. serrata*, *S. tranquebarica*, *Scylla olivacea* and *S. paramamosain*) (Keenan et al., 1998). This recent revision with the aid of molecular tools creates ambiguity over previous works done regarding the identification of species of genus *Scylla*. Most of the earlier

* Corresponding author. Tel.: +91 9443880121.
E-mail address: raffi_cas@yahoo.co.in (S.M. Raffi).
Peer review under responsibility of King Saud University.

ELSEVIER Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.sjbs.2015.08.005

work on mud crabs mention the monospecific term *S. serrata* and as per the revised taxonomy, it unravels the fact that different species of genus *Scylla* might be erroneously treated as *S. serrata*.

The study of food and feeding based upon the analysis of stomach content has become a standard practice (Hyslop, 1980). Stomach content analysis provides important insights into feeding patterns and its quantitative assessment is an important aspect in fisheries management. Natural feeding activities of genus *Scylla* has been well recorded in *S. serrata* (Arriola, 1940; Chacko, 1956; Hill, 1976, 1979; Williams, 1978; Lee, 1992; Joel and Raj, 1986; Prasad and Neelakantan, 1988; Mamun et al., 2008). However, despite the ecological and economical importance of *S. olivacea* little information is available on its food and feeding habits. The present work is the first register on the food and feeding habits of *S. olivacea* from Indian waters, describing its prey and feeding intensity which was carried out separately for males and females of different size groups.

2. Materials and methods

2.1. Sampling and laboratory procedures

Live specimens of *S. olivacea* were collected during the early morning hours from Pichavaram mangrove ecosystem (11° 29′N, 79°46′E) situated between the Vellar and Coleroon estuaries in Tamilnadu, on the south east coast of India, for a period of two years (June 2010–May 2012). The crabs were caught by local fisherman employing gill nets. The species were confirmed as *S. olivacea* from DNA barcoding and morphometric analysis (Viswanathan et al., 2012). The gut content was analyzed for a total of 1737 specimens comprising 843 males (Carapace width (CW) ranging from 45 mm to 148 mm) and 894 females (CW ranges from 45 mm to 140 mm). The collected crabs were recorded for size, sex and weight individually, dissected to weigh the gut contents.

2.2. Data analysis

Based on the gut, seven gut replenishment categories were established using a method modified from Wear and Haddon (1987): empty (when the wall was shrinking; devoid of food particles), trace (gut was filled by trace amount of food components), ¼ full (partially filled), ½ full (half full), ¾ full (when it was partially in distorted condition and the wall being thick), full (when the gut was filled with food normally, its wall being thick and intact) and gorged (gut expanded completely packed with food, with its wall thin and transparent). Analysis of stomach contents was made at room temperature with the aid of a binocular dissecting microscope. According to the rate of fullness, the stomach was allotted points ranging from 0 to 100. For the purpose of comparison, the 'gorged' and 'full' stomach conditions were grouped as 'actively fed'; whereas '¾ full' and '½ full' stomach conditions were grouped as 'moderately fed' and '¼ full' and 'trace' as 'poorly fed'. Based on this, the quantitative scoring method of PP (modified from Williams, 1981) was based on point scores of the relative contribution of each prey category to the total volume of material in each stomach: a prey representing 0–10% of the stomach contents were awarded 10 points; 10–20% were awarded 20 points; 20–40% were awarded 40 points; 40–60% were awarded 60 points; 60–80% were awarded 80 points and 80–100% was awarded 100 points. These points were multiplied by a value dependent on the degree of foregut stomach (¼ full: ½ full: full: gorged). The various components of food were recognized and categorized into major taxa. Semi-digested leafy and algal matters and debris were categorized as detritus. 'Miscellaneous' includes unidentified items and those appeared in a juice form. Mud and sand were easily identified by appearance.

The differences in the food composition between size and sex of *S. olivacea* were tested using a statistical routine named Similarity of Percentage (SIMPER) in PRIMER (ver. 6.1) package developed by the Plymouth Marine Laboratory, UK (Clark and Warwick, 2001). In SIMPER analysis, for the sake of convenience, all the 13 size ranges were pooled into 3 groups as follows: 45–52 mm to 69–76 mm size groups represented as a group I; 77–84 mm to 101–108 mm size groups framed as group II; 109 mm to 141–148 mm size groups (In the case of females, 109 mm to 133–140 mm size groups formed as group III).

3. Results

3.1. Gut content composition

3.1.1. Sizewise variation

The analysis of diet in the gut of different size groups of males and females was consolidated separately (Tables 1 and 2). In males, the results were pooled up and the average was derived; which proved that crustaceans (37.33%) formed the chief food item followed by molluscs (23.62%), fish (14.22%), detritus (11.76%), mud and sand (7.07%) and miscellaneous items (5.16%); whereas in females, crustaceans (34.74%) figured as the prime food item followed by molluscs (23.96%), fish (15.97%), detritus (12.03%), mud and sand (7.63%) and miscellaneous (5%).

3.1.2. Monthwise variation

In males, the results of the monthwise variation in gut contents showed that *S. olivacea* prefers crustaceans as prime food with 34.03%, followed by molluscs with 24.36%, fish with 15.19%, detritus with 12.9%, mud and sand with 6.96% and miscellaneous with 5.88% (Table 3). In females, the results of monthwise variation in food composition reveal that crustaceans (32.83%) forms the major food item followed by molluscs (24.42%), fish (14.93%), detritus (13.54%), mud and sand (6.68%) and miscellaneous items (7.02%) (Table 4).

3.2. Feeding intensity

3.2.1. Size variation

No significant variation was observed in the feeding intensity between different size groups in males. Among the different size groups, the stomach condition was placed in its order of descent as 'empty', 'trace', '¼ full', '½ full', '¾ full', 'full' and 'gorged' with 23.68%, 5.31%, 6.46%, 12.01%, 14.63%, 20.67% and 16.35% respectively (Fig. 1). In general, among

Table 1 Major food groups in various size groups of male crab.

Size group (in mm)	Crustaceans	Molluscs	Fish	Detritus	Mud and Sand	Miscellaneous
45–52	43.45	10.1	15.85	19.1	7.85	2.55
53–60	45.05	10.4	14.55	17.9	9.15	2.1
61–68	43.15	12.45	20.1	12.5	7.25	3.35
69–76	41.25	12.9	20.65	12.55	8.7	3.55
77–84	38.75	17.3	18.75	13.45	7.7	3.45
85–92	41.55	19.6	15.85	8.45	6.1	7
93–100	40.75	26.15	13.7	7.25	5.25	5.95
101–108	38.25	27.3	11.2	9.15	6.1	7.65
109–116	31.35	33.7	12.25	8.45	7.5	5.4
117–124	30.45	34.2	12.2	10.9	6.05	5.55
125–132	31	35	11.95	10	5.6	5.9
133–140	29.75	34.4	9.05	12.5	7.55	6.3
141–148	30.55	33.65	8.8	10.75	7.2	8.4
Average	37.33	23.62	14.22	11.76	7.07	5.16

*Values in percentage.

Table 2 Major food groups in various size groups of female crab.

Size group (in mm)	Crustaceans	Molluscs	Fish	Detritus	Mud and Sand	Miscellaneous
45–52	37.8	12.7	15.9	17.55	10	3.65
53–60	34.6	15.05	17.7	19.55	9.65	2.55
61–68	37.35	15.5	21.3	12.65	8.85	4.1
69–76	36.85	15.45	20.9	12.6	9.5	4.65
77–84	37.85	15.45	20.2	13.95	6.25	5.75
85–92	39.65	21.05	16.2	8.95	5.35	8.45
93–100	35.3	25.9	15.85	7.55	7.95	6.5
101–108	38.65	28.1	12.75	8.25	5.9	5.85
109–116	31.9	34.7	13.05	8	7.9	4.05
117–124	29.4	33.95	13	10.95	6.55	5.75
125–132	28.35	35.55	13.85	11.1	6.7	3.7
133–140	29.2	34.15	11.05	13.35	7	5
Average	34.74	23.96	15.97	12.03	7.63	5

*Values in percentage.

Table 3 Major food groups in various months of male crabs.

Months	Crustaceans	Molluscs	Fish	Detritus	Mud and Sand	Miscellaneous
Jun	31.2	27.9	14.05	12.25	6.9	7.15
Jul	27.95	31.9	14.15	12.05	7.85	5.55
Aug	28.95	33.05	11.05	12.25	7.7	6.3
Sep	28.65	32.05	9.2	12.5	7.95	7.6
Oct	29.85	32.65	9.55	13.3	8.35	5.75
Nov	31.95	32.3	10.75	8.4	9	7.25
Dec	34.7	32.75	9.85	7.4	6	8.75
Jan	35.9	13.9	18.05	21.9	6.45	3.55
Feb	34.75	12.2	19.75	22.2	6.35	4.4
Mar	40.75	13.65	21.55	12	7	4.25
Apr	42	14.55	23.65	9.45	4.7	4.8
May	41.75	15.5	20.75	11.2	5.3	5.3
Average	34.03	24.36	15.19	12.90	6.96	5.88

*Values in percentage.

the various size groups of females, the stomach condition was placed as 'empty' (21.56%), 'trace' (5.77%), '¼ full' (10.18%), '½ full' (13.67%), '¾ full' (14.70%), 'full' (19.70%) and 'gorged' (13.82%) (Fig. 2).

3.2.2. Monthwise

The condition of stomach content monthwise in male *S. olivacea* was 'empty', 'trace', '¼ full', '½ full', '¾ full', 'full' and 'gorged' with 23.03%, 4.74%, 8%, 12.51%, 13.37%, 23.25%

Table 4 Major food groups in various months of female crabs.

Months	Crustaceans	Molluscs	Fish	Detritus	Mud and Sand	Miscellaneous
Jun	29.35	26.95	12.05	13.35	8.8	9.3
Jul	27.9	31.05	14.4	11.95	8.6	5.9
Aug	28.15	31.95	11.75	13.05	6.95	7.6
Sep	27.75	32.3	10.8	13.95	7	7.75
Oct	28.5	32.7	10.05	13.85	7.8	6.4
Nov	31.7	34.3	10.65	9.95	5.25	7.65
Dec	33.25	31.6	11.15	7.55	5.15	10.4
Jan	36.7	15.55	14.65	20.6	6	5.45
Feb	32.65	12.5	18.45	22.8	6.9	6
Mar	38.6	12.3	20.8	14.95	7.1	6.1
Apr	41	15.6	22.1	9.15	5.5	5.85
May	38.5	16.35	22.35	11.35	5.2	5.9
Average	32.83	24.42	14.93	13.54	6.68	7.02

*Values in percentage.

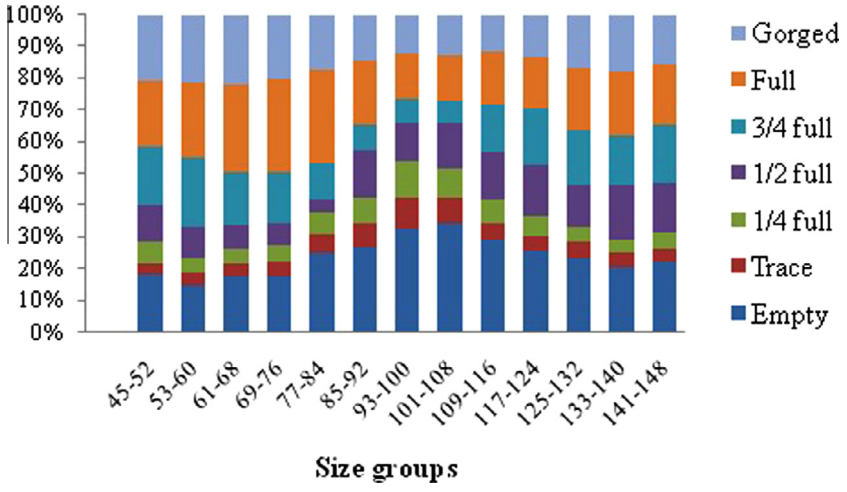

Figure 1 Gut fullness (feeding intensity) in various size groups of male crab.

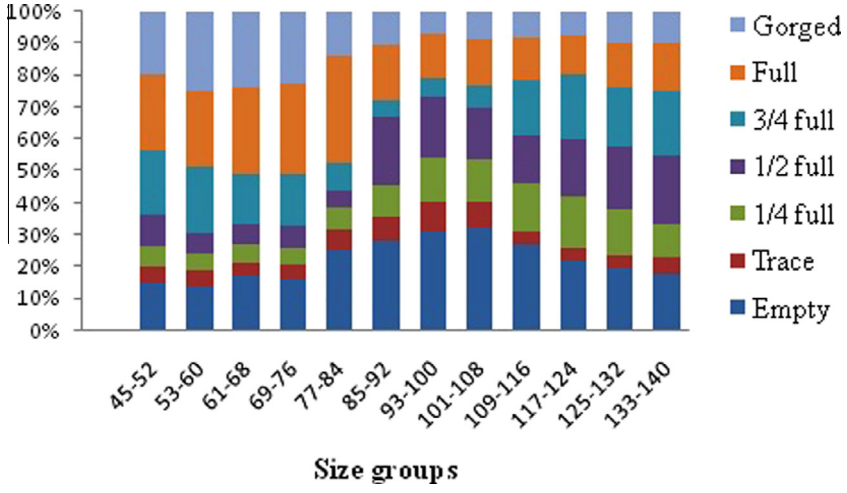

Figure 2 Gut fullness (feeding intensity) in various size groups of female crab.

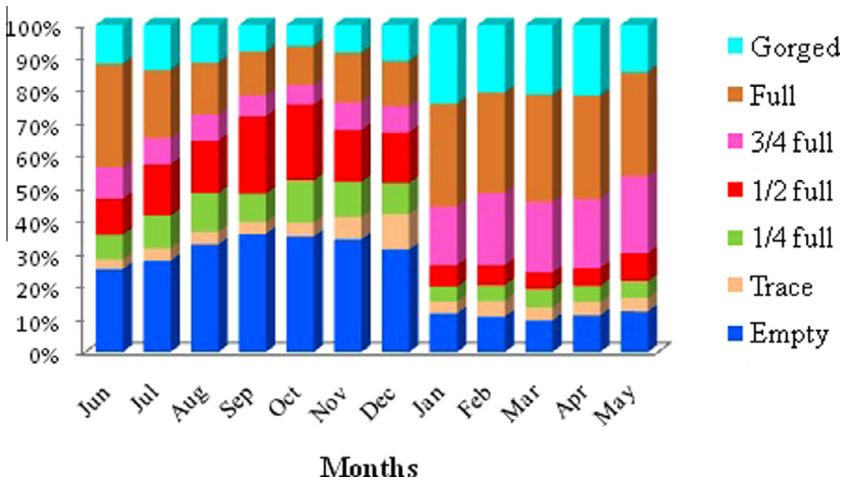

Figure 3 Gut fullness (feeding intensity) during various months of male crabs.

and 14.28% respectively (Fig. 3). The month wise pooled data on the intensity of feeding in males portrays that the percentage of poorly fed crabs ranged from 9% (Jan) to 30% (December); moderately fed to range between 28% (June) and 46% (September); actively fed observed with the minimum percentage (29%) in October and maximum percentage (63%) in January (Table 5).

Table 5 Feeding intensity (percentage of fullness) of the mud crab *S. olivacea*.

Month	Poorly fed		Moderately fed		Actively fed	
	Male	Female	Male	Female	Male	Female
Jun	14	16	28	30	58	54
Jul	20	18	32	36	48	46
Aug	24	28	35	36	41	36
Sep	19	26	46	45	36	29
Oct	27	24	44	50	29	26
Nov	27	24	37	42	37	34
Dec	30	21	34	46	36	33
Jan	9	11	28	34	63	55
Feb	11	13	31	34	58	53
Mar	11	11	29	39	60	50
Apr	10	12	31	36	59	52
May	10	11	37	42	53	47

In females, the pooled data for the feeding intensity showed that the percentage fullness of stomach showed empty (22.96%), trace (4.44%), ¼ full (8.99%), ½ full (14.86%), ¾ full (14.87%), full (20.72%) and gorged (12.33%) (Fig. 4). Monthwise data on feeding intensity clearly indicate that the poorly fed crabs were minimal (11%) in March and May and maximum (28%) in July; moderately fed crabs were minimal (30%) in June and maximum (50%) in October; actively fed crabs were minimal (26%) in October and maximum (55%) in January month (Table 5).

3.3. SIMPER analysis between size groups

The results of SIMPER analysis for male crabs are tabulated in Table 6. The order of average dissimilarity between the groups was 14.63% between group I and II, 15.22% between group II and III, and 25.48% between group I and III. The dissimilarity between lowest size groups (group I) and highest size

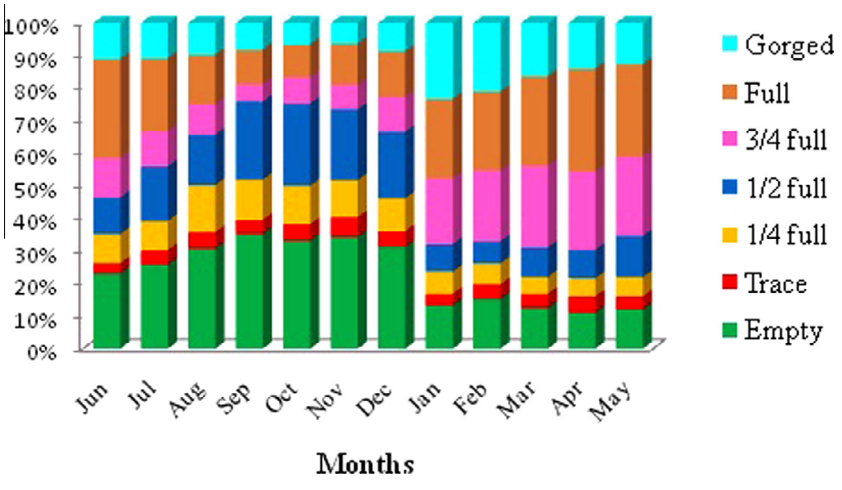

Figure 4 Gut fullness (feeding intensity) during various months of female crabs.

Table 6 SIMPER analysis describing the average dissimilarity in food items between different groups of male crab.

Food items	Group I	Group II	Average dissimilarity = 14.63%			
	Avg. Abund.	Avg. Abund.	Avg. Diss.	Diss/SD	Contrib %	Cum.%
Molluscs	12.48	23.23	5.41	2.32	36.97	36.97
Detritus	15.55	9.78	2.99	1.66	20.43	57.41
Fish	18.43	15.30	2.03	1.37	13.88	71.29
Miscellaneous	3.20	6.33	1.61	1.53	11.01	82.30
Crustaceans	41.15	38.15	1.55	1.28	10.57	92.86
	Group I	Group III	Average dissimilarity = 25.48%			
Molluscs	12.48	33.92	10.77	8.55	42.27	42.27
Crustaceans	41.15	29.54	5.83	4.97	22.88	65.16
Fish	18.43	10.92	3.77	2.38	14.80	79.95
Detritus	15.55	10.66	2.46	1.45	9.64	89.59
	Group II	Group III	Average dissimilarity = 15.22%			
Molluscs	23.23	33.92	5.38	2.50	35.33	35.33
Crustaceans	38.15	29.54	4.33	7.85	28.44	63.77
Fish	15.30	10.92	2.39	1.62	15.69	79.46
Detritus	9.78	10.66	1.13	1.77	7.41	86.88
Miscellaneous	6.33	6.98	1.11	1.24	7.31	94.18

Table 7 SIMPER analysis describing the average dissimilarity in food items between different groups of female crab.

Food items	Group I	Group II	Average dissimilarity = 12.99%			
	Avg. Abund.	Avg. Abund.	Avg. Diss.	Diss/SD	Contrib%	Cum.%
Molluscs	13.85	22.95	4.60	1.74	35.44	35.44
Detritus	15.93	10.18	3.01	1.79	23.18	58.62
Fish	18.78	16.05	1.80	1.37	13.83	72.45
Mud and Sand	9.40	6.25	1.59	1.96	12.23	84.69
Miscellaneous	3.40	5.78	1.20	1.75	9.24	93.93
	Group I	Group III	Average dissimilarity = 22.75%			
Molluscs	13.85	34.48	10.42	14.69	45.79	45.79
Crustaceans	37.45	30.18	3.68	4.95	16.15	61.95
Fish	18.78	12.40	3.21	2.55	14.12	76.07
Detritus	15.93	11.05	2.49	1.48	10.95	87.02
Mud and Sand	9.40	5.65	1.89	3.34	8.32	95.34
	Group II	Group III	Average dissimilarity = 14.57%			
Molluscs	22.95	34.48	5.80	2.24	39.80	39.80
Crustaceans	38.08	30.18	3.98	4.27	27.30	67.10
Fish	16.05	12.40	1.96	1.47	13.46	80.56
Detritus	10.18	11.05	1.42	1.64	9.72	90.28

groups (group III) was found to be higher. Between groups I and II, the food items are characterized as crustaceans, fish, detritus, molluscs and miscellaneous. Between groups I and III, the food items such as crustaceans, fish, detritus and molluscs are characterized. Between groups II and III, the food items are characterized as crustaceans, molluscs, fish, detritus and miscellaneous.

In females, the order of average dissimilarity between the groups was 12.99% between group I and II, 14.57% between group II and III and 22.75% between group I and III (Table 7). The dissimilarity between the lowest (group I) and highest size group (group III) was found to be higher. Between groups I and II, the food items are characterized by molluscs, detritus, fish, mud and sand and miscellaneous. Between groups II and III, the food items are characterized by molluscs, crustaceans, fish and detritus. Between groups I and III, the food items are characterized by molluscs, crustaceans, fish, detritus and mud and sand.

4. Discussion

The results of the present study of food and feeding in males and females of *S. olivacea* indicated that this species is an elite carnivore. This was confirmed by the high occurrence of fragments of crustacean appendages, pieces of shells, spats of molluscs and scales of fishes in the gut. Previous studies on other mud crab species also support the presence of such food items in the stomach (Hill, 1976; Kathirvel, 1981; Joel and Raj, 1986; Mohapatra et al., 2005). Warner (1977) stated that crabs were

opportunistic omnivores with a preference for animal food and with predatory tendencies. In addition, he opined that portunids tend to be mainly carnivores and retain the ability to deal with a variety of food stuffs with predominance to a carnivorous diet.

The present study from Pichavaram mangroves revealed that the crustaceans form the principal food component in the stomach of *S. olivacea*. This was in agreement with the findings of Mamun et al. (2008) where mud crabs (*S. serrata*) off Bangladesh waters consume crustaceans as its major food component (44.48%). Kathirvel (1981) reported a higher percentage of crustacean remains (78.4%) in the gut of *S. serrata* from Cochin backwaters. Kathirvel and Srinivasagam (1992) recorded crustaceans as the chief food item in *S. serrata* from Ennore estuary (46.3%) and Pulicat Lake (46.6%) of southeast coast of India. The major crustacean food items in its diets were grapsid crabs and *Penaeus* spp. The molluscan prey includes *Littorina scabra*, *Crassostrea madrasensis* and *Pila globosa* which are common in Pichavaram mangroves (Kasinathan and Shanmugam, 1988) while fishes includes *Gerres abbreviatus* and *Ambassis gymnocephalus*. There was no significant difference recorded between the quantity of food consumed by males and females except slight variations, as reported earlier by Mohapatra et al. (2005). The present findings revealed that the stomach of juveniles and sub-adults are predominated by crustaceans and fishes. This was supported by Joel and Raj (1986), where they postulated that the ability of the juveniles to capture fast-moving prey like fishes, prawns, etc. may be linked to the long, slim and sharp toothed chelae with a relatively higher proportion of fast contracting muscles that are well adapted for the rapid snapping movements. Warner (1977) emphasized that portunids has the ability to capture faster moving prey.

Hill (1979) investigated the feeding strategy of the predatory crab *S. serrata* from the South African estuaries concluded that major prey of *S. serrata* were bivalves and small sized crabs. Joel and Raj (1986) highlighted that molluscs formed the major food item for *S. serrata* off Pulicat Lake. Similar findings were observed by Jayamanne (1992) in *S. serrata* and *S. tranquebarica* from Srilankan waters and Mohapatra et al. (2005) from Chilka lagoon. Prasad and Neelakantan (1988), studied the food and feeding of *S. serrata* from Karwar waters reported that fish accounted for 23.57%, crustaceans as 18.37% and detritus as 35.7% in its gut. Lee (1992) studied the natural food of *S. serrata* from Queensland (Australia) and he reported that molluscs contributes to the tune of 50% and crustaceans 21%, whereas the fish remains were rarely found in the stomach. However, these findings are contradictory with the present results; which might be due to the availability and distribution of prey in the Pichavaram mangrove region. The quality and quantity of food ingested into the foregut depend upon the type of biotope in which the crab inhabits and the volume of the gut (Prasad et al., 1988).

This work reveals that majority of crabs with empty stomach were encountered either in berried condition or in advanced stages of ovarian development (gravid), where the ovary occupies 3/4th of the body cavity and also during egg incubation where females stop feeding. Feeding intensity was higher in juveniles and subadults of both sexes than that of adult crabs. Thus, it can be concluded that the mud crab *S. olivacea* in Pichavaram mangroves is highly carnivorous in nature with crustaceans forming the principal food item followed by molluscs and fishes.

Acknowledgements

We are grateful to the authorities of the Annamalai University for the necessary facilities provided and to the Ministry of Environment and Forest (MoEn&F) Govt. of India for the financial support (No. 22-9/2008-CS-I). We thank Dr. Deepak Samuel for critical evaluation of the manuscript.

References

Arriola, F.J., 1940. A preliminary study of the life history of *Scylla serrata* (Forskal). Philippines J. Sci. 73, 437–456.

BOBP, 1992. Report of the seminar on the Mud crab culture and trade held at Surat Thani, Thailand, November 5–8, 1991. In: Angell, C. A. (Ed.). Bay of Bengal Programme, Madras, India, pp. 246.

Chacko, P.I., 1956. Studies on the Green crab *Scylla serrata* (Forskal). Annual Report of the Marine Biological Station, Ennur for 195–56, Department of Fisheries, Madras, Fish, Station Rep. Yr. Bk., pp. 18–19.

Clark, K.R., Warwick, R.M., 2001. Changes in Marine Communities: An Approach to Statistical Analysis and Interpretation. PRIMER-E: Plymouth, Plymouth, U.K, pp. 190.

Hill, B.J., 1976. Natural food, foregut clearance rate and activity of the crab, *Scylla serrata*. Mar. Biol. 34, 109–116.

Hill, B.J., 1979. Aspects of the feeding strategy of the predatory crab *Scylla serrata*. Mar. Biol. 55, 209–214.

Hyslop, E.J., 1980. Stomach contents analysis: a review of methods and their application. J. Fish Biol. 17, 415–429.

Jayamanne, S.C., 1992. Mud crab fishery in Srilanka. In: Angell, C.A. (Ed.), The Mud Crab. Report on seminar on 'Mud crab culture and trade' (Rep. No. 51), Surat Thani, Thailand, November 5–8, 1991. Bay of Bengal Programme, Madras, India, pp. 41–48.

Joel, D.R., Raj, P.J.S., 1986. Food and feeding of the two species of *Scylla* (De Haan) (Portunidae: Brachyura). J. Mar. Biol. Assoc. India 28 (1–2), 178–183.

Kasinathan, R., Shanmugam, A., 1988. Overexploitation of molluscan fauna in the Vellar estuary and Pitchavaram mangroves. Galaxea 7, 303–306.

Kathirvel, M., 1981. Present status of taxonomy and biology of *Scylla serrata*. In: Workshop on 'Crustacean biochemistry and physiology' conducted by CMFRI and University of Madras, Madras, pp. 1–13.

Kathirvel, M., Srinivasagam, S., 1992. Resource and exploitation of mud crab *Scylla serrata* (Forskal) from India. In: Angell, C.A. (Ed.), The mud crab. Report on Seminar on 'Mud Crab Culture and Trade' (Rep. No. 51), Surat Thani, Thailand, November 5–8, 1991. Bay of Bengal Programme, Madras, India, pp. 85–94.

Keenan, C.P., Davie, P.J.F., Mann, D.L., 1998. A revision of the genus *Scylla* de Haan, 1833 (Crustacea: Decapoda: Brachyura: Portunidae). Raffles Bull. Zool. 46 (1), 217–245.

Lee, C., 1992. A brief overview of the ecology and fisheries of the mud crab *Scylla serrata* in Queensland. In: Angell, C.A. (Ed.), The Mud Crab. Report on Seminar on 'Mud Crab Culture and Trade' (Rep. No. 51), Surat Thani, Thailand, November 5–8, 1991. Bay of Bengal Programme, Madras, India, pp. 65–70.

MacNae, W., 1968. A general account of the fauna and flora of mangrove swamps and forests in the Indo-West Pacific region. Adv. Mar. Biol. 6, 73–270.

Mamun, A., Begum, M., Mia, M.Y., Alam, M.J., 2008. Food and feeding habits of the mud crab *Scylla serrata* (Forsskal) in Bangladesh. J. Bangladesh Soc. Agric. Sci. Technol. 5 (3&4), 141–144.

Mohapatra, A., Mohanty, R.K., Bhatta, K.S., Mohanty, S.K., 2005. Food and feeding habits of the mud crab *Scylla serrata* (Forskal) from Chilika Lagoon. J. Inland Fish. Soc. India 37 (2), 1–7.

Prasad, P.N., Neelakantan, B., 1988. Food and feeding of the mud crab *Scylla serrata* (Forskal) (Decapoda: Portunidae) from Karwar waters. Indian J. Fish. 35 (3), 164–170.

Prasad, P.N., Sudharshana, R., Neelakantan, B., 1988. Feeding ecology of the mud crab *Scylla serrata* (Forskal) from Sankari backwaters. J. Bombay Nat. Hist. Soc. 85 (1), 79–89.

Viswanathan, C., Elumalai, V., Suresh, T.V., Pravin kumar, M., Jaganathan, K., Raffi, S.M., 2012. Genetic characterization in mudcrabs (*Scylla* spp.) of Pichavaram mangroves based on Cytochrome Oxidase Subunit I (COI). In: Veera Ravi, A., S. Ravikumar, N. Rajendran, S. Elango Subramanian, V. Saravanan and A. Sivakumar (Ed.), Proceedings of International Conference on Environmental Security for Food and Health (ICESFH-2012) held at Kanyakumari during 16th–18th, February 2012, pp. 169–170.

Warner, G.F., 1977. The Biology of Crabs. Elek Science Ltd., London, pp. 1–202.

Wear, R.G., Haddon, M., 1987. Natural diet of the crab *Ovalipes catharus* (Crustacea, Portunidae) around central and Northern New zealand. Mar. Ecol. Prog. Ser. 35, 39–49.

Williams, M.J., 1978. Opening of bivalve shells by the mud crab *Scylla serrata* (Forskal). Austr. J. Mar. Freshwater. Res. 29, 699–702.

Williams, M.J., 1981. Methods for analysis of natural diet in portunid crabs (Crustacea: Decapoda: Portunidae). J. Exp. Mar. Biol. Ecol. 52, 103–113.