Article

Habitat ecology and food and feeding of the herring bow crab *Varuna litterata* (Fabricius, 1798) of Cochin backwaters, Kerala, India

P.Lakshmi Devi, **Deepthi Gopi Nair**, **Aneykutty Joseph**
Dept. of Marine Biology, Microbiology & Biochemistry, School of Marine Sciences, Cochin University of Science & Technology, Fine Arts Avenue, Cochin-682016, Kerala, India
E-mail: aneykuttyj@yahoo.co.in

Received 19 July 2013; Accepted 25 August 2013; Published online 1 December 2013

Abstract
Habitat ecology and food and feeding of the herring bow crab, *Varuna litterata* of Cochin Backwaters, Kerala, India were investigated for a period of one year (April 2011-March 2012). Among the 15 stations surveyed, the crabs were found to occur only in 4 stations, which had a close proximity to the sea. Sediment analysis of the stations revealed that the substratum of these stations is sandy in nature and is rich in organic carbon content (0.79% to 1.07%). These estuarine crabs is euryhaline and are found to be distributed in areas with a sandy substratum, higher organic carbon content and more tidal influx. The stomach contents analysis of crabs examined showed that their diet included crustacean remains, plants, sand and debris, fishes, miscellaneous group and unidentified matter. In adults and sub-adults, crustaceans formed the dominant food group, while in juveniles, sand and debris formed the dominant group. From the present study, *V. litterata* was found to be a predatory omnivore capable of ingesting both animal and plant tissues.

Keywords habitat ecology; food and feeding; *Varuna litterata*; Cochin backwaters.

Arthropods
ISSN 2224-4255
URL: http://www.iaees.org/publications/journals/arthropods/online-version.asp
RSS: http://www.iaees.org/publications/journals/arthropods/rss.xml
E-mail: arthropods@iaees.org
Editor-in-Chief: WenJun Zhang
Publisher: International Academy of Ecology and Environmental Sciences

1 Introduction

Varuna litterata, is a grapsid crab, commonly known as the 'herring bow crab'. They usually inhabit the mangroves, estuarine and freshwater environments, in shallow sub tidal regions and usually found under rocks, logs and dead leaves and lives in burrows along the embankments or sides of pools, creeks and shallow banks. *V. litterata* is euryhaline and can be found in rivers, brackish waters or at sea. With its legs shaped as paddles used for swimming, it is sometimes called the 'Paddler crab'. After a flood, it can be washed far away in the sea and observed there drifting with pieces of debris (Bouchard et al., 2011). They are found to prefer areas faced to more oceanic waters (www.sealifebase.fisheries.ubc.ca). It has been reported from all over the Indo-West Pacific (Alcock, 1900; Sakai, 1939, 1976; Barnard, 1950; Crosnier, 1965; Holthius, 1978).

Though there are lots of works being carried out in brachyuran crab fauna throughout the world, the compilation of studies conducted on *V. litterata* is comparatively few in number particularly with reference to India. One of the first studies on *V. litterata* is by Kemp (1915), who reported the mass migration of the megalopae in the Hooghly River near Calcutta, India. A Similar phenomenon was observed in Fiji in 1987 (Ryan and Choy, 1990). Panikker (1951) and Gross et al. (1996) dealt with the osmoregulation in *V. litterata* and proved that they show strong osmoregulation even in 150% seawater. The metabolic effect of eyestalk removal in *V. litterata* was studied by Madhyastha and Rangneker (1974). Behavioral study of *V. litterata* in the coastal waters of Bay of Bengal was carried out by Manna (1988). Tu Chin-Hung (1992) documented the whole zoeal development of *V .litterata*. Jameieson et al. (1996) analysed the spermatozoa ultrastrucure of *V. litterata*. It has been recorded as commercially important species in Bengal, India, where it is eaten by poor people, and its numbers compensate for its small size (Hora, 1933). Rao et al. (1973) also reported it as an edible species and a fishery resource of India. In the West coast of India, *V. litterata* was first collected by Pillai (1951) from the open sea at Trivandrum and later by Chhapgar (1957) from Bombay and Kolak. Dineshbabu et al. (2011) reported the species from waters along Karnataka coast. It was neither reported from Travancore backwaters (Pillai, 1951) nor Vembanad Lake (Roy and Nandi, 2008). Devi et al. (2013) studied the brachyuran crab diversity of Cochin backwaters and reported that this species is available plentifully in certain sampling localities of the area studied. However, little has been reported on the habitat ecology and food and feeding of the grapsid crabs of Indian waters.

Several authors have dealt with the ecological aspects of various crab species. Dahdough-Guebas (1994) studied the feeding ecology and behavioral ecology of some selected crab species from the Kenyan mangroves. Feeding ecology of velvet swimming crab, *Necora puber* was studied by Freire and Gonzalez-Gurriaran (1995), while Lee (2004) dealt with the ecology and behavior of postlarvae and juveniles of *Necora puber*. Mokhtari et al. (2008) dealt with the population ecology of the fiddler crab *Uca lactea annulipes*. Feeding ecology of the American crab *Rithropanopeus harisii* was studied by Hegele-Drywa and Normant (2009). Pandya et al. (2010) studied the spatial distribution and substratum preference of *Macrophthalmus depressus*. Ethnoecology of *Scylla serrata* was studied by Nirmale et al. (2012). Trivedi et al. (2012) studied the diversity and habitat preference of brachyuran crabs in the Gulf of Kutch.

There are several reports on the food and feeding of various species like, *Scylla serrata* (Williams, 1978; Hill, 1976, 1980; Joel and Raj, 1986; Prasad and Neelakantan, 1988) , *Portunus spp* (Hill, 1980; Stephenson et al., 1982; Campbell, 1984; Wassenberg and Hill, 1987; Sumpton and Smith, 1990; Josileen, 2011) , *Thalamita crenata* (H.Milne Edwards 1834) (Canicci et al., 1996) , *Callinectes sp.* (Tagatz, 1968; Paul, 1981; Laughlin, 1982; Stoner and Buchanan, 1990; Rosas et al., 1994). *Chionocetes opilio*, (Wieczorek & Hopper, 1995). Jewett and Feder (1982, 1983) analysed the food of the king crab, *Paralithodes camtschatius* and that of the tanner crab, *Chionocetes bairidi*. The natural diet and feeding habits of two species of *Liocarcinus* was described by Choy (1986) and that of *Cancer* spp. and *Ovalipes ocellatus* was dealt with by Stehlik (1993). However, there is no much information on the habitat preference, diet and preferred food items of *V. litterata*. Hence, the study has been undertaken to investigate the habitat ecology and food and feeding habits of *V. litterata* from Cochin backwaters, Kerala, India.

2 Materials and Methods

2.1 Description of the study area

Cochin backwaters situated at the tip of northern Vembanad Lake is a tropical positive estuarine system extending between $9^0$40’ & $10^0$12’N and $76^0$10’ & $76^0$30’E, with its northern boundary at Azheekode and southern boundary at Thannirmukham bund (Fig. 1). The salinity gradient of Cochin backwaters supports

diverse species of flora and fauna depending on their capacity to tolerate oligohaline, mesohaline or marine conditions. Low lying swamps and tidal creeks, dominated by sparse patches of mangroves with their nutrient rich physical environment, support larvae and juveniles of many commercially important species. Backwaters also act as nursery grounds of commercially important fin fishes and shell fishes. (Menon et al., 2000).

On the basis of salinity, 15 study stations was selected along the study area, namely, Thannermukham, Vaikom, Aroor, Valanthakad, Kandakkadavu, Kumbalanghi, Thevara, Thoppumpady, Barmouth, Marine Science Jetty, Varappuzha, Vallarpadam, Vypin, Munambam and Azheekode. A detailed survey along these stations was conducted to find the availability of this species (Fig. 1).

2.2 Physiochemical parameters

Standard techniques were employed for the analysis of water quality parameters viz. temperature (centigrade thermometer), salinity (salino-refractometer), pH (digital pH meter) and the sediment quality parameters, viz. Organic carbon content (Walkley-Black method, Jackson, 1973) and the sediment texture (particle size analyzer., Sympatec – Germany).

2.3 Food and feeding studies

Specimens of *V. litterata* were collected once a month for a period from April 2011-March 2012. After recording the carapace width (CW), carapace length (CL), total weight and sex for all the captured specimens, the dorsal side of the body was cut open and foregut was removed carefully. A visual estimate of the fullness of the stomach was made immediately after its removal as about 100%, 75%, 50%, 25% and 0% according to the degree of fullness. The foreguts were transferred in 70% alcohol (Williams, 1981) and all the stomachs were subsequently opened and their contents were washed with alcohol into a petridish and gut contents were separated and identified into different food groups under a binocular microscope.

As characteristic of brachyurans, most of the food items were found to be highly crushed down into small fragments and hence only those structures that could be identified were relied upon for determining food composition and evaluation. Gut contents were broadly classified as suggested by Sukumaran and Neelakantan (1997), Josileen (2011).

1) Crustacean remains : Penaeid prawns body parts, appendages, telson, eggs, crabs and stoamatopods.
2) Fish remains : fins, scales, bones and vertebrae.
3) Molluscan remains : gastropods and bivalves.
4) Miscallaneous items : algal filaments, nematodes, polychaetes, ophiuroides and unidentified items.
5) Debris : sand and mud

Only stomachs with food (n=145) were considered for calculation. The whole stomach contents of all the specimens were segregated food-group wise and each group's contribution was assessed visually. Dominance of food groups was evaluated by ranking them by its percentage frequency of occurrence and percentage points (Sukumaran and Neelankantan, 1997). As described in detail by Wear and Haddon (1987), in the Percentage Points method each of the more common food categories (in this study) is given a value, ranging from 0 to 100, according to the percentage of content it represents within each stomach. Then the number of points each category received are weighted according to the real fullness of the stomach in which it was found. For instance, in a stomach half full, containing 25% bivalves and 75% algae, the bivalves were scored 12.5 and algae 37.5 points, respectively (Cannicci et al., 1996).

Frequency of occurrence is calculated by dividing the number of stomachs which contained a food category by the total number of stomachs observed. The following percentages were calculated for each prey type (Williams, 1981):

$$\text{Percentage points for } i^{th} \text{ prey} = \left(\sum_{j=1}^{n} a_{ij}/A \right) * 100$$

Percentage occurrence for i^{th} prey = $(b_i /N)100$

where a_{ij}= the number of points for prey item i in the foregut of the j^{th} crab; A = the total points for all the crabs and all the prey items in all the foreguts examined; N = the number of crabs examined with food in the foregut; and b_i = the number of crabs with foreguts containing prey category i.

3 Results

A detailed survey was conducted along the study area, to find the availability of the species. Among the 15 stations fixed, *V. litterata* was found to occur only in 4 stations namely, Kandakkadavu, Kumbalanghi, Vypin and Munambam. (Fig. 1-higlited with arrow marks). A detailed study was then conducted on the location type, habitat and the physico-chemical parameters of all the 15 stations, to find the peculiarity of the four above said stations and thus draw an inference on the habitat type preferred by the species.

Site 1- Kandakkadavu, which lies at the west part of the backwaters is a typical coastal area ornamented with lush green mangroves. Site 2- Kumbalanghi is a fishing village, and has a very vast backwater stretch, Here; the backwater is in an enclosed condition with a rather narrow opening into the main lake. This site too has a rich diversity of mangroves and mangrove associates. Site 3- Vypin is the biggest among the group of island in the Cochin backwaters and is bound by Arabian Sea on its western side and the backwaters on its eastern side. The station had a luxuriant mangrove patch earlier, but the recent LNG and Petroleum tanks and terminals built at the heartland of mangroves in Vypin has destroyed the vegetation on a mass scale. Site 4- Munamabam is a coastal village, situated at the Northern point of the backwaters, surrounded by Arabian Sea on the West, Periyar on the East and a mouth opening to the sea on the North. The site does not have luxuriant mangrove vegetation, only a sparse patch is found.

3.1 Physiochemical parameters

Water quality and sediment quality parameters of the 15 stations were anlaysed on a monthly basis, however, emphasis is given to those four stations, viz. Kandakkadavu, Kumbalanghi, Vypin and Munambam, where *V. litterata* is found.

In general, a wide fluctuation was observed in the salinity and temperature during the study period. A low salinity was recorded throughout the study area during the monsoon season and it increased during the post monsoon and premonsoon period. However, a wide fluctuation occurred in the salinity during the post monsoon period and the salinity ranged between 0-17 ppt. Highest salinity was observed during the premonsoon period. The salinity ranged from 2-31 ppt with a mean of 12.08 ppt at site-1, Kandakkadavu, 1-22ppt with a mean of 10.5 ppt at site-2, Kumbalanghi; 0-16 ppt with a mean of 6.08 ppt at site-3, Vypin and 4-29 ppt with a mean of 15.83 ppt at site- 4, Munambam during the study period. Temperature too showed a wide fluctuation. Site-1 recorded a temperature range of 23-30^{0}C with a mean 26.91^{0}C, site- 2 recorded a range 25-28^{0}C with a mean of 26.41^{0}C; site-3, 23-27^{0}C with a mean of 25.25^{0}C and site-4 with a range of 28-32^{0}C with a mean of 29.41^{0}C. pH was almost neutral throughout the sites, throughout the study period. It fluctuated between 6.43-7.89 with a mean of 6.78 in site-1, 6.18-7.98 with a mean of 6.96 in site-2, 6.09-7.33 with a mean of 6.71 in site-3 and 7.23-8.21 with a mean of 7.76 in site-4. The range of variation in the salinity, temperature and pH of the study stations, during the study period is presented in Table.1.

Table 1 Range of salinity, temperature and pH of the study stations during the study period.

Sl.No	Sampling stations	Salinity (ppt)	Temperature (^{0}C)	pH
1	Thannermukham	0-13	24-28	6.32-7.58
2	Vaikom	0-12	20-29	6.43-7.9
3	Aroor	0-16	21-29	6.09-7.45
4	Valanthakad	0-16	23-28	6.18-7.98
5	Kandakkadavu	2-31	23-30	6.43-7.89
6	Kumbalanghi	1-22	24-28	6.17-7.98
7	Thevara	0-22	23-29	6.45-7.97
8	Thoppumpady	1-26	25-30	6.56-7.85
9	Bar Mouth	2-28	26-29	6.54-7.94
10	Marine Science Jetty	0-23	25-29	6.50-8.01
11	Varappuzha	0-8	23-28	4.92-7.01
12	Vallarpadam	2-18	28-32	7.09-7.90
13	Vypin	0-16	23-27	6.22-7.11
14	Munambam	4-29	28-32	7.25-8.88
15	Azheeekode	4-33	28-32	7.25-8.88

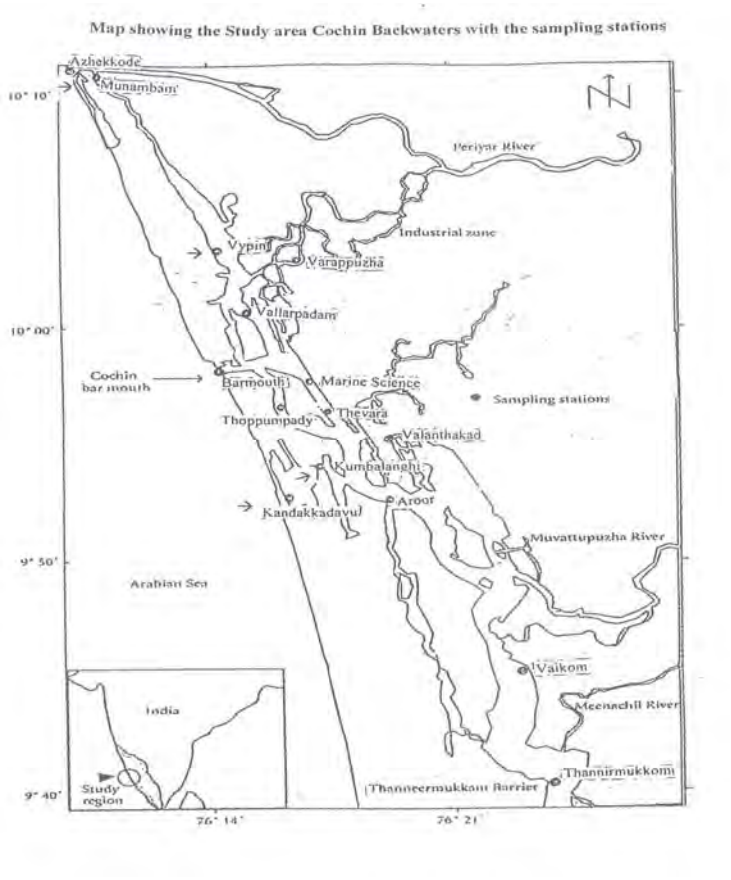

Fig. 1 Map of the study area, Cochin Backwaters with the sampling stations.

The sediment analysis of the sampling stations revealed three types of sediments in the study area- sandy, silty and clayey. The substratum of 5 stations, viz Vaikom, Kandakkadavu, Kumbalanghi, Vypin and Munambam was found to be sandy in nature and its composition is 53.77%, 50.24%, 63.94%, 43.81% and 48.32% respectively . The stations with a silty substratum are Thanneermukham, Valanthakad, Thevara, Varappuzha and Azheekode with a composition of 45.83%, 43.05%, 48.99%, 41.98% and 53.06% respectively and the 4 stations, viz Aroor Thoppumpady, Marine Science Jetty and Vallarpadam was found to be clearly clayey in nature with a composition of 62.39%, 44.91%, 56.43% and 49.01% respectively. The substratum of the station Barmouth is found to have an equal composition of silt and clay (40.91% silt and 40.8% clay). The percentage composition of sand, silt and clay of the sampling stations are given in Fig.2. The sediment of the stations showed varying amount of organic carbon content. Out of the 15 stations, Aroor (1.08), Valanthakad (1.04), Kandakkadavu (1.00), Kumbalanghi (1.02), Vallarpadam (0.99), Vypin (1.07) and Munambam (0.79) recorded higher organic carbon content, owing to the litter fall from the mangroves while Thanneermukham (0.66), Thevara (0.59), Thoppumpady (0.57), Barmouth (0.67), Marine Science Jetty (0.73) and Azheekode (0.72) exhibited medium organic carbon content. Vaikom (0.49) and Varappuzha (0.48) are the two stations which reported least amount of organic carbon. Luxuriant mangrove patches are observed from Aroor, Valanthakad, Kandakkadavu, Kumbalanghi, Vallarpadam, Vypin and some sparse patches from Munambam. The average organic carbon content of the sampling stations are given in Fig.3

3.2 Food and feeding studies

The stomach contents of *V. litterata* appeared to contain highly digested matter and hence identification of food organisms was found difficult. However, the natural diet of the animal was found to consist mainly crustacean remains, fish, plants, sand and debris and miscellaneous group of items but could not find the molluscan remains. Out of the total 321 stomachs analyzed, 13.79% were 100% full, 6.89% were 75% full, 9.65% were 50%full, 24.13% were 25% full and 45.15% were empty. The month wise and size wise details on the stomach fullness are given in Fig.4 and Fig.5.

When percentage of frequency of occurrence is analyzed, the crustacean remains comprised 98.46% ; sand and debris 81.53% ; plant remains 44.61%, and the miscallaneous items comprised 23.07%.(Fig.6). The points of major food groups (size wise and month wise) were estimated and the results are depicted in Fig.7& Fig.8. In percentage of points method using the overall sample, crustacean remains was the most dominant food. It was found in almost all stomach analyzed and consisted primarily of decapods (parts of shrimp rostrum, exoskeleton, appendages etc.), amphipods, isopods and stomatopods. The maximum percentage of points (93.33%) was observed in July. In different size groups, crustacean remains varied from 5.68% to 88.23%.

The second dominant item of food was sand and debris. It ranges from 4.19% to 56.1% in different months. The maximum amount was found in the month of September and the least was observed in July. Percentage points varied from 5.41% to 72.41% in various size groups, the maximum found in size class 1.5 – 2.5 cm class and minimum found in 3.5 – 4.0 cm size class. This group consists mainly of sand particles and detritus especially of plant origin.

The third predominant item of food was plant remains. It ranges from 0% to 21.65% in different months. The maximum amount plant remains was found in the gut during May and no remains found in the gut during September. Percentage points varied from 1.27% to 18.09 % in various size groups, the maximum found in size class 3.5 – 4.0 cm class and minimum in 4.0 – 4.5 cm size class. This group consists mainly of algal filaments, mangrove leaf litter and other partially digested matter.

The fourth predominant item of food was fish remains. It ranges from 0% to 18.75% in different months. The maximum amount was found in November , while no fish remains is recorded in January, September and December .In various size class, percentage points varied from 0% to 4.11%, the maximum found in size class

2.5 – 3.0 cm class and minimum found in 1.5 – 2.0 cm size class. This group consists mainly of fins, spines, scales, bones and vertebrae.

The fifth predominant item of food was miscellaneous items. It was rarely found in the analyzed stomachs. It ranges from 0% to 43.75% during the study period. The maximum amount was found in January and no such content was observed in the month of October. Percentage points varied from 0% to 25%, the maximum found in size class 4.0 – 4.5 cm class and no miscellaneous items found in 1.5 – 2.0 cm size class. This group consists mainly of nematodes, helminthes, polychaetes and other unidentified matter.

When the quantity of food and points of major food groups' sex wise were estimated, the results showed that there is no significant difference, that it is almost similar.

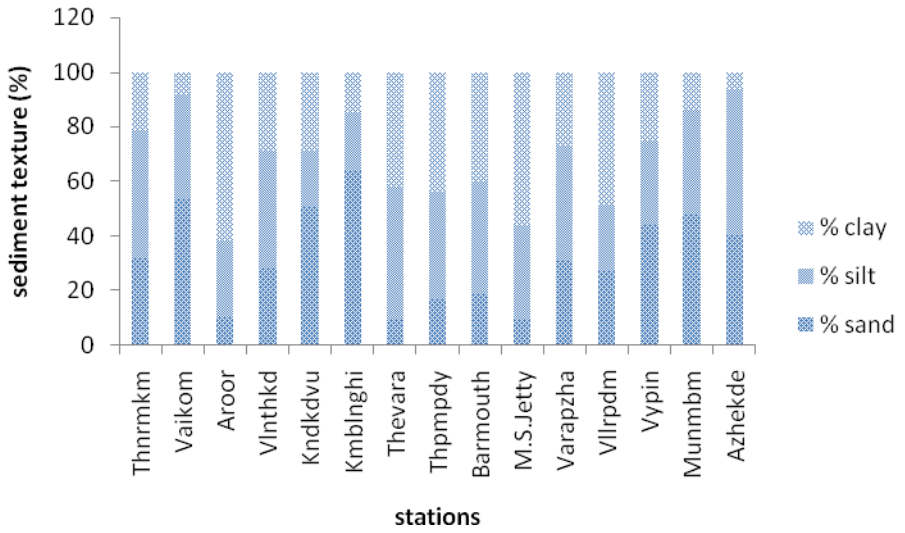

Fig. 2 Percentage composition of sand, silt and clay in the sediments of the study stations.

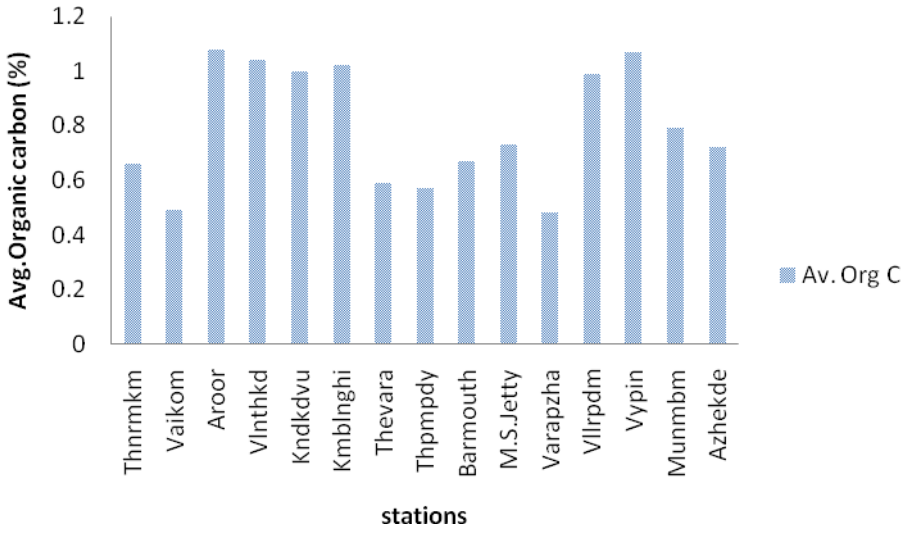

Fig. 3 Average organic carbon content in the sediments of the study area.

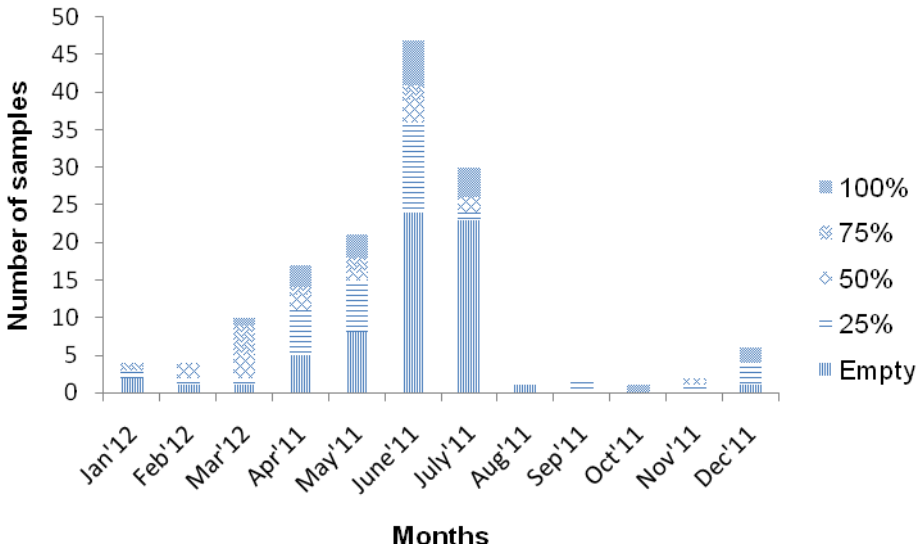

Fig. 4 Stomach fullness during various months in *V.litterata*.

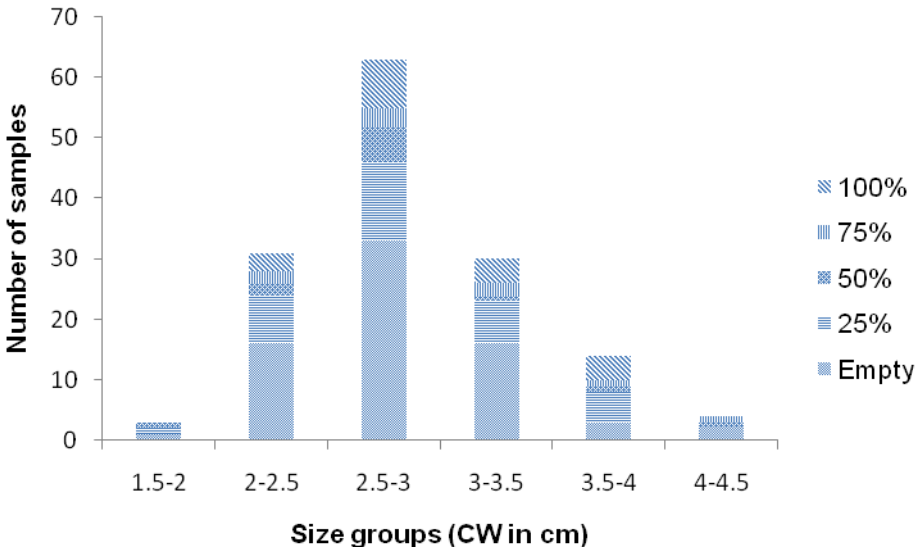

Fig. 5 Stomach fullness in various size groups in *V.litterata.*

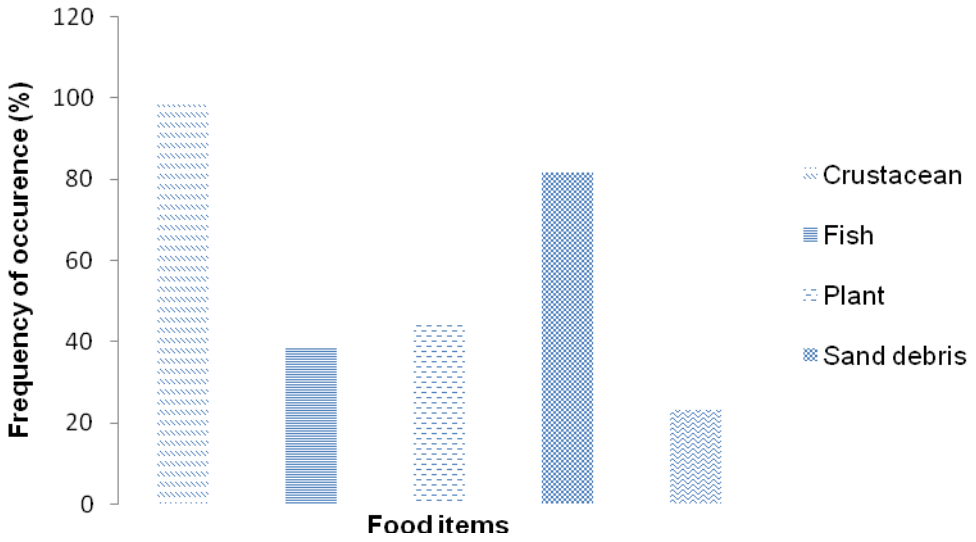

Fig. 6 Frequency of occurrence of food items in the gut content of *V.litterata*.

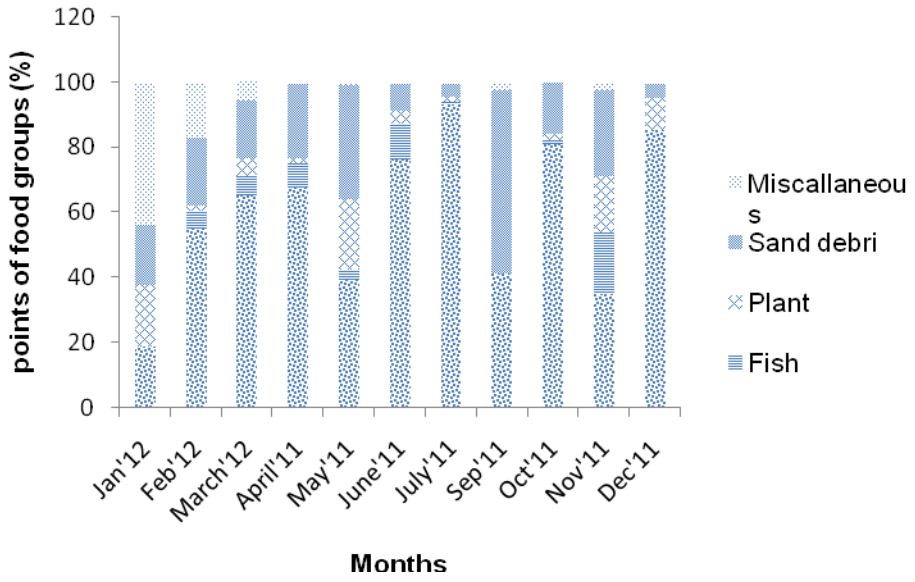

Fig. 7 Percentage points of major food groups during various months in *V.litterata*.

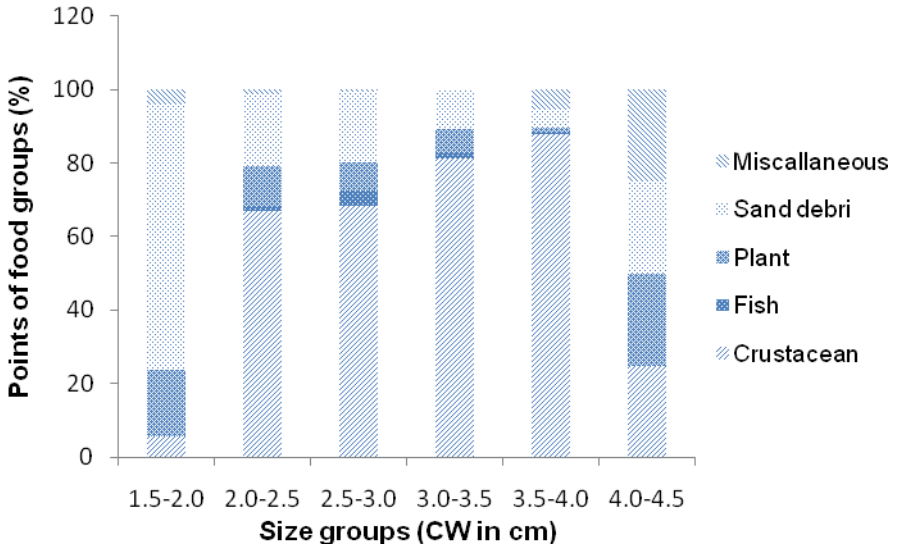

Fig. 8 Percentage points of major food groups in various size groups of *V.litterata*.

4 Discussion

In the present study, *V. litterata* is found to occur only in four stations among the 15 stations surveyed, namely Kandakkadavu, Kumbalanghi, Vypin and Munambam, which exhibited a sandy substratum with high organic carbon content and good tidal influx due to more proximity to the sea. The higher amount of organic carbon in the sediments can be attributed to the litter fall from mangroves. Vaikom is one another station observed to have a sandy substratum, but when the organic carbon content of the sediment is considered, it exhibited a lower value. The lower organic carbon content may be due to the absence of mangrove patches in the area. It also exhibits poor tidal influx, since it is much away from the sea. Besides, these four stations, where *V. litterata* is found to be available, mangrove patches are also observed from three other stations viz. Aroor, Valanthakad and Vallarpadam. The substratum of these three stations too recorded high organic carbon content. However, no *V. litterata* samples were found from these stations. This may be due to the sediment texture prevailing in these three stations, Aroor being clayey and Valanthakad and Vallarpadam being silty in nature. These stations also records lower tidal influx due to the distance from the sea.

V. litterata inhabit mangrove regions (http://mangrove.nus.edu.sg/pub/seashore/text/197.htm) and prefer areas faced by more tidal waters, (www.sealifebase.fisheries.ubc.ca), which is in complete agreement with the present study. The four stations where the crabs are found to occur are mangrove regions with a close proximity to the sea. Though stations like Barmouth, Thevara, Thoppumpady, Marine Science Jetty and Azheekode are also closer to the sea, the substratum characteristics, amount of organic carbon in the sediments and the absence of mangrove patches make it unsuitable for the species. Therefore, the present study reveals that *V. litterata* is an inhabitant of mangrove regions with sandy substratum, rich in organic carbon and prefer areas with close proximity to the sea having good tidal influx.

There is remarkable fluctuation in the physico chemical parameters, temperature and salinity of the study stations during the study period, however, the stations showed a neutral pH during the period. The occurrence of *V. litterata* in the study area throughout the study period shows that, it has a wide range of tolerance to temperature and salinity. This remarkable species is euryhaline and can live in both fresh water and saltwater,

being found not only in streams and ponds far inland, but also in mangroves, and the edge of the shore (http://mangrove.nus.edu.sg/pub/seashore/text/197.htm). Panikker (1951) reported that they are able to regulate their internal salinities and can accomplish osmoregulation in a variety of salinity and temperature combinations to a certain extent. Gross et al. (1996) proved that they show strong osmoregulation even in 150% seawater.

Knowledge on natural diet is essential for studies of its nutritional requirements, its interactions with other organisms and its potential for culture (Williams, 1981). Though the diet of decapods is primarily macroscopic items, their mouth parts and gastric mill ossicles reduce the food to small fragments and hence the identification of food types and quantities is often difficult. The points method and the occurrence method are the only methods which can be applied readily to the analysis of the gut contents in crabs. The structure of each type of food and the way in which it is manipulated prior to ingestion, however, affect the accuracy of the percentage points and, to a lesser extent, percentage occurrence of some types of food. Percentage points is an approximate volume measure and since the soft parts of most foods rapidly become unrecognizable after ingestion, it is inaccurate for most foods. The points method is however is suitable for foods which are ingested in large recognizable pieces or in their entirety. Percentage occurrence is a measure of the regularity of inclusion of a food in the diet of a sample. It is inaccurate only for foods which have no recognizable hard parts but it may give an inflated relative importance to small food items.

In the present study, it was observed that *V. litterata* is an opportunistic omnivore, crustaceans being the most dominant item followed by sand and debris and plant remains. Crabs are opportunistic omnivores with preferences for animal prey, but rarely fed on more mobile prey such as fish and prawns (Williams, 1982). Warner (1977) is also of the opinion that crabs carry over the primitive behavior of being opportunistic omnivores with a preference of animal food in conjunction with predatory propensity. On comparing it with the studies conducted by other workers in different crabs, Sukumaran and Neelakantan (1997) reported that *P. pelagicus* from the Mangalore coast preferred crustaceans followed by fishes and molluscs. Josileen (2011) observed a similar result for the *P. pelagicus* collected from Mandapam coast All studied crabs are reported to consume mixed diets of molluscs, crustaceans, fishes, polycheates etc. (*S. serrata:* Hill, 1976*;* Joel and Raj, 1986; Prasad and Neelakantan, 1988), *C. sapidus:* Laughlin, 1982*; S. tranquebarica:* Joel and Raj, 1986;*Thalamita crenata:* Cannici et al., 1996).

Presence of debris and detritus in the stomach contents of *V. litterata* suggested that these crabs are omnivorous consuming plant as well as animal components. The detritus found in the stomachs examined mainly belonged to plant matter. It is increasingly recognized that coastal and estuarine food chains are based to a significant extent on detritus and dissolved organic matter produced from the breakdown of rooted and attached macrophytes of intertidal and shallow subtidal habitats. In the present study, the specimens have been collected from the sites where there is lush green mangrove patches. Therefore the detritus of plant origin found in the gut content of the crabs will be owing to the mangrove leaf litter of the area. Ground-dwelling grapsid crabs have been reported to be the main consumers of fresh mangrove litter, particularly in Indo-Pacific systems (Lee, 1998; Ravichandran et al., 2009) and have identified as keystone species in the tropical Indo-west Pacific mangrove ecosystems (Ajmal Khan and Ravichandran, 2008). Fresh mangrove litter has low nutrient (C/N ratio > 50) and high feeding deterrent (e.g. soluble tannins) content, making it an unattractive staple food item (Wolcott & O'Connor, 1992). Some grapsid crab species prefer leaf litter with specific C/N ratios (Lee, 1993), while others feed indiscriminately (Micheli, 1993). From the present study, it is observed that *V .litterata* inhabit areas which are rich in organic carbon content. The presence of considerable amount of sand particles in the gut is in total agreement with the sediment texture of the study sites, since sand was the main constituent of the sediment in all the four study sites. Therefore, it is obvious to find good amount of

sand particles in the gut contents, which may be ingested accidently while gleaning the food particles from the substratum.

Molluscs form an important component in the gut contents of most of the omnivorous crabs, like *Scylla serrata* (Hill, 1976) and *Portunus pelagicus* (Sukumaran and Neelakantan, 1997; Josileen, 2011). In contradictory to their findings no molluscan remains were found in the gut contents of *V. litterata* throughout the study. This can be attributed to the cheliped strength of the crabs. The chelipeds of *V. litterata* may not be strong enough to crush the shells of the molluscs or it is also possible that, the crabs do not prefer sedentary organisms like molluscs. Arimoro and Idoro (2007) also reported the absence of molluscs from the gut contents of *Callinectes amnicola*, but they have not furnished the possible reasons for the absence of molluscs. Generally feeding takes place every day throughout the year except during few days of moulting and mating when feeding ceases or it is at its minimum. The study period has been divided into premonsoon, monsoon and post monsoon and the majority of the empty stomachs encountered in the study were during the period from April to July, i.e., during the late premonsoon and early monsoon period. Choy (1986) reported empty stomachs in gravid females and parasitized crabs during the winter. He also observed the newly moulted crabs having empty stomachs during the summer season. Jewett and Feder (1982) reported that in king crab *Paralithoides* sp, feeding increases immediately after spawning during spring and summer. In contrast to this, Jewett and Feder (1983) observed that the tanner crabs, *Chionocetes bairdi* feed more intensely during the nonspawning periods (i.e., November to February). The presence of empty stomachs during the late premonsoon and early monsoon period in the present study indicates that *V. litterata* breeds during this period. Kemp (1915) observed that every year at the commencement of monsoon, the waters of Hooghly river near Calcutta, India, teem with the megalopes of *V. litterata*. The behavioural study of *V. litterata* carried out by Manna (1988) in the coastal waters of Bay of Bengal reports that *V. litterata* occur abundantly once in a year on the new moon day of July from midnight to 0900 hours. On that day numerous crabs float on the surface of water embracing themselves like clustering balls. This unusual physiological behavior is possibly due to the sudden increase of hormonal levels stimulating them for mating. Tu, Chin Hung (1992) observed that the features of ovaries of *V. litterata* caught from Kao-ping river, change from brown and inseparable to black and disperse the diameter increase from 0.2mm to 0.32 mm during March to June. This further proves that this species breeds during the late premonsoon and the monsoon periods. However, no berried females were captured from the study area, during the period of study. Kemp (1915) observed mass migration of megalopes in the Hughli river near Calcutta as well as the Gangetic delta and stated that the adult migrate to the estuaries to breed. However, he could not find any ovigerous females of *V. litterata* from the Chilka lake, which is in accordance to the present study. He reported that they are found to occur in myriads , where the current is sluggish and in small creeks. The sampling sites from where the *V. litterata* samples are observed and captured have good tidal influx and are open waters, devoid of any creeks. This fact gives the evidence for the absence of ovigerous females in the samples collected from the study area, Cochin backwaters.

In the present study, there is remarkable variation in stomach fullness and stomach contents in various size groups. It was observed that the maximum number of empty stomachs among the specimens analysed were between the size class of 2.5 – 3.0 carapace width. This size class may be considered as the optimum size of breeders, since majority of the crabs belonging to this size class were found in the period from April-July, which is supposed to be the breeding season of *V. litterata*. The number of empty stomachs were found to decrease in lower size classes. It is observed that the crabs of class 1.5- 2.0 and 2.0- 2.5 carapace width exhibited stomachs almost filled with food. Balasubramanian (1993) reported that the feeding intensity is comparatively low among adult crabs of *Charybdis smithii*. Jewett and Feder (1983) concluded that small crabs feed more intensively than larger crabs since moulting efficiency among smaller crabs is greater and

energy demand is more. It is observed that the juvenile crabs (1.5-2.0 class carapace width) consumed more amount of sand and the debris, followed by plant remains. Crustaceans formed the most dominant food in the larger crabs. Difference in diet composition in different size groups could be related to the change in cheliped strength and foraging behavior (Sukumaran and Neelakantan, 1997). It is not possible to confirm from the stomach contents whether the prey had been alive or not when preyed. Caine (1974) had explained a prey catching mechanism in the portunid crab *Ovalipes guadulpensis*, but Hill (1976) could not observe such technique in *S. serrata. Gaetice depressus*, a grapsid crab has been described to be capable of suspension feeding (Depledge, 1989).

There was no significant difference in the quantity of the food consumed by males and females in the present study, as reported by Williams (1981), Jewett and Feder (1982), Sumpton and Smith (1990), Wieczorek and Hooper (1995) and Josileen (2011).

Crabs occupy different niches and inhabit many different habitats in a variety of geographical areas and this is reflected in the variety of food consumed by them. (Chande et al., 1999; Dahdough-Guebas et al., 1999; Kyomo, 1999; Bryceson and Massinga, 2002). The feeding strategies of the crabs are found to be diverse, and the type of food consumed is significantly dependent on the locality inhabited as reported by Hegele-Drywa and Normant (2009). Freire and Gonsalez-Gurriaran (1995) states that the diet variability of the crab is influenced by its habitat. *Varuna litterata*, a grapsid crab, is observed to be an inhabitant of regions dominated by mangrove patches and are found to be distributed in areas with a sandy substratum and higher organic carbon content. They are euryhaline in nature; however, prefer areas with close proximity to the sea and with good tidal influx. The gut content analysis of the crabs revealed that its habitat has a great influence on its food and feeding habits. Their diet included crustaceans, detritus, fishes, sand, debris and miscellaneous items. Crustaceans were the most dominant food item, followed by sand and debris, detritus of plant origin, fish remains and miscellaneous food items. The sand and debris found in its gut can be correlated with the sandy substratum they prefer to thrive. The guts also contained good amount of plant remains, which can be attributed to the mangrove leaf litter in their habitat. However, no molluscs were recorded from the dietary components of the species. From the present study, it is concluded that *V. litterata* is an opportunistic omnivore capable of ingesting both animal and plant tissues, with a preference to diets of animal origin.

Acknowledgements

The first author is thankful to Kerala State Council for Science, Technology and Environment, Sastra Bhavan, Pattom, Trivandrum, Kerala, India for the KSCSTE Research Fellowship. The authors are thankful to Dept. of Marine Biology, Microbiology & Biochemistry, School of Marine Sciences, Cochin University of Science & Technology for providing the necessary facilities to carry out this work.

References

Ajmal Khan S, Ravichandran S. 2008. Brachyuran crabs. In: UNU-INWEH-UNESCO International training course on coastal biodiversity in marine ecosystems (Kathiresan K and Ajmal Khan S, eds). 372-389, Annamalai University, CAS in Marine Biology, Parangipettai, India

Alcock A. 1900. The Brachyura Catometopa oe Grapsoidea : Materaials for a carcinological fauna of India, No.6. Journal of Asiatic society of Bengal, 69(3): 279-456

Arimoro FO, Idoro BO. 2007. Ecological studies and biology of *Callinectes amnicola* (Family Portunidae) in the lower reaches of Warri river, Delta state, Nigeria. World Journal of Zoology, 2(2): 57-66

Barnard KH. 1950. Descriptive catalogue of South African Decapod Crustacea (Crabs and shrimps). Annuals of South African Museum, 38:1-837, figs 1-154

Balasubramanian CP. 1993. Studies on the deep water crab *Charybdis (Goniohellenus) smithii* Macleay from the seas around India. PhD Thesis, Cochin University of Science and Technology, India

Bouchard.J, Poupin J, Cleva R, et al. 2011. Land, mangrove and freshwater decapod crustaceans of Mayotte region (Crustacea: Decapoda). Atoll Research Bulletin No.XXX

Bryceson I, Massinga A. 2002. Coastal resources and management systems influenced by conflict and migration: Mecufi Mozambique. Ambio, 31: 512- 517

Caine RA. 1974. Feeding of *Ovalipes guadulpensis* and morphological adaptations to a burrowing existence. Biological Bulletin. Woods Hole, 147: 550-559

Campbell GR. 1984. A comparative study of adult sexual behaviour and larval ecology of three commercially important Portunid crabs from the Moreton Bay of Queensland, Australia. Ph.D Thesis, University of Queensland, Brisbane, Australia

Canicci SF, Dahdoug-Guebas F, Anyona D, et al. 1996. Natural diet and feeding habits of *Thalamita crenata* (Decapoda, Portunidae). Journal of Crustacean Biology, 16(4): 678-683

Chande AI, Nikundiwe AM and Kyomo. 1999. The status of the crab fishery at Mzinga Creek, Dar es Salaam. In: Fisheries and stock assessment in traditional fisheries sector: the information needs (Jiddawi NS and Stanley RS, eds). 81-87, Proceedings of the National Workshop on the artisanal fisheries sector, Zanzibar, Tanzania

Chhapgar BF. 1957. Marine crabs of Bombay State. Contribution No.1, Taraporevala, Marine Biological Station, India

Choy SC. 1986. Natural diets and feeding habits of the crab *Liocarcinus puber* and *L.holsatus* (Decapoda, Brachyura, Portunidae). Marine Ecology Progress Series, 31: 87-99

Crosnier A. 1965. Crustaces Decapodes Grapsidae – Faune de Madagascar, 18: 1-143, figs 1-260, pls 1-11

Dahdough-Guebas F. 1994. Kenyan mangrove crabs – Feeding ecology and behavioural ecology of some selected species. Ir Thesis 76 + ann. Pp, Vrije Universiteit Brussel, Brussel, Belgium

Dahdough-Guebas F, Giuggioli M, Oluoch A, et al. 1999. Feeding habits of non-ocypodid crabs from two mangrove forests in Kenya. Bulletin of Marine Science, 64: 291-297

Depledge MH. 1989. Observations on the feeding behavior of *Gaetice depressus* (Grapsidae, Varuninae) with special reference to suspension feeding. Marine Biology, 100: 253-259

Devi PL, Joseph A and Ajmal Khan S. 2013. Diversity of Brachyuran Crabs of Cochin Backwaters, Kerala, India (In press)

Dineshbabu AP, Durgekar RN, Zacharia PU. 2011. Estuarine and Marine decapods of Karnataka-inventory. Fishing Chimes, 30(10 & 11): 20-24

Freire J, Gonzalez-Gurriaran E. 1995. Feeding ecology of the velvet swimming crab *Necora puber* in mussel raft areas of the Ria de Arousa (Galicia, NW Spain). Marine Ecology Progress Series, 119: 139-154

Gross W, Robert J, Lasiewski C, et al. 1996. Salt and water balance in selected crabs of Madagascar. Comparative Biochemistry and Physiology, 17(2): 641-660

Hegele-Drywa J, Normant M. 2009. Feeding ecology of the American crab *Rithropanopeus harrisii* (Crustacea: Decapoda) in the coastal waters of the Baltic sea. Oceanologia, 51(3): 361-375

Hill BJ. 1976. Natural food, fore-gut clearance rate and activity of the crab *Scylla serrata*. Marine Biology, 34: 109-116

Hill BJ. 1980. Effect of temperature on feeding in crab *Scylla serrata*. Marine Biology, 59(3): 189-192

Holthius LB. 1978. A collection of decapods crustacean from Sumba, Lesser Sunda Islands, Indonesia.

Zoologische Verhandelingen, Leiden, 162: 1-55

Hora SL. 1933. A note on the bionomics of two estuarine crabs. Proc. Zool.Soc.London, pp 881-884, pls i-ii.

Jackson ML. 1973. Soil Chemical Analysis. Printice-Hill of India Private Limited, New Delhi, India

Jamieson BGM, Guinot D, Richer De Forges B. 1996. Contrasting spermazoal ultrastructure in two thoracotreme crabs, *Cardisoma carnifex* (Gercarcinidae) and *Varuna litterata* (Grapsidae) (Crustacea, Brachyura). Invertebrate Reproduction and Development, 29: 111-126

Jewett SC, Feder HM. 1982. Food and feeding habits of the king crab *Paralithodes camtschatica* near Kodiak Island, Alaska. Marine Biology, 66: 243-250

Jewett SC and Feder HM. 1983. Food of the tanner crab *Chionocetes bairdii* near Kodiak Island, Alaska. Journal of Crustacean Biology, 3(2): 196-207

Joel DR and Raj PJS. 1986. Food and feeding of the two species of *Scylla* (de Haan) Portunidae: Brachyura. Journal of Marine Biological Association of India, 28(1-2): 178-183

Josileen J. 2011. Food and feeding of the Blue Swimmer Crab, *Portunus pelagicus* (Linnaeus, 1758) (Decapoda, Brachyura) along the coast of Mandapam, Tamil Nadu, India. Crustaceana, 84(10): 1169-1180

Kemp SW. 1915. Fauna of the Chilka lake. Crustacea Decapoda. Indian Museum, 5: 199-325

Kyomo J. 1999. Distribution and abundance of crustaceans of commercially importance in Tanzania Mainland coastal waters. Bulletin of Marine Science, 65: 321-335

Laughlin RA. 1982. Feeding habits of the blue crab *Callinectus sapidus* Rathbun, in the Apachicola Estuary, Florida. Bulletin of Marine Science, 32: 807-822

Lee SY. 1993. Leaf choice of the sesarmid crabs *Chiromanthes bidens* and *C.affinis* in a Hong Kong Mangal. In: Proceedings of the International Conference on Marine Biology of Hong Kong and South China Sea (Morton B, ed.). 597-604, University of Hong Kong. October 1990. Hong Kong University Press, Hong Kong

Lee SY. 1998. Ecological role of grapsid crabs in mangrove ecosystems: A Review. Marine and Freshwater Research, 49: 335-343

Lee JT. 2004. Ecology and behavior of postlarvae and juveniles of the velvet swimming crab Necora puber (L.). PhD Thesis, University of Plymouth, UK

Madhyastha MN, Rangneker PV. 1974. Metabolic effects of eyestalk removal in the crab *Varuna litterata* (Fabricius). Hydrobiologia, 48(1): 25-31

Manna AK. 1988. Behavioural study on a small edible crab *Varuna litterata* in the coastal water of Bay of Bengal. Environment and Ecology, 6(3): 754-755

Menon NN, Balchand AN, Menon NR. 2000. Hydrobiology of the Cochin backwater System – A Review. Hydrobiologia, 430: 149-183

Micheli F. 1993. Feeding ecology of mangrove crabs in North eastern Australia: Mangrove litter consumption by *Sesarma messa* and *Sesarma smithii.* Journal of Experimental Marine Biology and Ecology, 171:164-186

Mokhtari M, Savari A, Rezai H, et al. 2008. Population ecology of the fiddler crab, *Uca lactea annulipes* (Decapod: Ocypodidae) in Sirik mangrove estuary, Iran. Estuarine, Coastal and Shelfscience, 76: 273-281

Nirmale VH, Gangan SS, Yadav BM, et al. 2012. Traditional knowledge on mud crab; Ethnoecology of *Scylla serrata* in Ratnagiri coast, Maharashtra. Indian journal of Traditional Knowledge, 11(2): 317-322

Pandya PJ , Vachharajani, Kauresh D. 2010. Spatial distribution and substratum preference of the brachyuran crab *Macrophthalmus depressus* (Decapoda:Ocypodidae) along the lower estuarine mudflat of Mahi River, Gujarat, India. Crustaceana, 83(9): 1056-1067

Panikker NK. 1951. Physiological aspects of adaptations to estuarine conditions. Proceedings of Indo-Pacific

Fish. 168-175, Cronulla, Australia

Paul RK. 1981. Natural diet, feeding and the predatory activity of the crab *Callinectes arcuatus* and *C.toxotes* (Decapoda, Brachyura, Portunidae). Marine Ecology Progress Series, 6: 91-99

Pillai NK. 1951. Decapoda (Brachyura) from Travancore. Bull. Cent. Res. Inst. Univ. of Travancore, Trivandrum Series C, 2(1): 1-46

Prasad PN, Neelakantan B. 1988. Food and feeding of the mud crab *Scylla serrata* (Forskal) (Decapoda, Portunidae) from Karwar waters, Indian Journal of Fisheries, 35(3): 164-170

Ravichandran S, Ajmal Khan S, Balasubramanian T. 2009. Role of Crabs in the Mangrove Environment. ENVIS publication, CAS in Marine Biology, Annamalai University, Parangipettai, India

Rao PV, Thomas MM, Rao S. 1973. The crab fishery resources of India. Proceedings of Symposium on Living Resources of the Seas around India. 581-591, India

Rosas C, Lazaro-Chavez E, Buckle-Ramirez F. 1994. Feeding habits and food niche segregation of *Callinectes sapidis*, *C.rathbunae* and *C.similis* in a sub-tropical coastal lagoon of the Gulf of Mexico. Journal of Crustacean Biology, 14(2): 371-382

Roy MKD, Nandi NC. 2008. Brachyuran biodiversity of some selected brackish water lakes of India. Proceedings of Taal 2007: The 12th World Lake Conference, 496-499, India

Ryan PA, Choy SC. 1990. Obseravtions on the upstream migration of *Varuna litterata* (Fabricius) megalopae (Decapoda, Brachyura, Grapsidae) in Fiji. Crustaceana, 58(3): 237-249

Sakai T. 1939. Studies on the Crabs of Japan. IV. Brachygnatha, Brachyryncha. 365-741, pls 42-111, Yokendo, Tokyo, Japan

Sakai T. 1976. Crabs of Japan and the Adjacent Seas. Pp I-XXIX, 1-773, 3 maps (English volume); pp 1-16, pls 1-251 (plates volume); pp 1-461 (Japanese Volume). Kodansha, Tokyo, Japan

Stehlik LI. 1993. Diets of the brachyuran crabs *Cancer irroratus*, *C.borealis* and *Ovalipes ocellatus* in the New York Bight. Journal of Crustacean Biology, 13(4): 723-735

Stephenson W, Chant D, Cook SD. 1982. Trawled catches in Northern Moreton Bay.1. Effects of sampling variables. Memoirs of the Queensland Mueseum, 20: 375-386

Stoner AW, Buchanan BA. 1990. Ontogeny and overlap in the diets of four *Callinectes* species. Bulletin of Marine Science, 46: 3-12

Sukumaran KK, Neelakantan B. 1997. Food and feeding of *Portunus (Portunus) sanguinolentus* (Herbst) and *Portunus (Portunus) pelagicus* (Linnaeus) (Brachyura: Portunidae) along Karnataka Coast. Indian Journal of Marine Science, 26: 35-38

Sumpton WD, Smith GS. 1990. Effect of temperature on the emergence activity and feeding of male and female sand crabs *(Portunus pelagicus*). Australian Journal of Marine and Freshwater Research, 41(4): 545-550

Tagatz ME. 1968. Biology of the blue crab *Callinectes sapidus* Rathbun in the St.Jones River, Florida. Fishery Bulletin U.S. Fish and Wildlife Service, 67: 17-33

Trivedi JN, Gadhavi MK, Vachharajani KD. 2012. Diversity and habitat preference of brachyuran crabs in Gulf of Kutch, Gujarat, India. Arthropods, 1(1): 13-23

Tu Ching-Hung. 1992. Studies on the larval culture of *Varuna litterata.* Master's Thesis, Institute of Marine Biology, National Sun Yat-Sen University, Kaohsiung, Taiwan

Warner GF. 1977. The Biology of Crabs. Paul Elek (Scientific Books), London, UK

Wassenberg TJ, Hill BJ. 1987. Feeding by the sand crab *Portunus pelagicus* on material discarded from Prawn trawlers in Moreton Bay, Australia. Marine Biology, 95: 387-393

Wear RG, Haddon M. 1987. Natural diet of crab *Ovalipes catharus* (Crustacea, Portunidae) around Central

and Northern New Zealand. Marine Ecology Progress Series, 35: 39-49

Wieczorek SK, Hooper RG. 1995. Relationship between diet and food availability in the snow crab *Chionocetes opilio* (Fabricius) in Bonne Bay, Newfoundland. Journal of Crusacean Biology, 15(2): 236-247

Williams MJ. 1978. Opening of bivalve shells by the mud crab *Scylla serrata* Forskal. Australian Journal of Marine and Freshwater Research, 29: 698-702

Williams MJ. 1981. Methods for analysis of natural diet in Portunid crabs (Crustacea: Decapoda: Portunidae). Journal of Experimental Marine Biology and Ecology, 52: 103-113

Williams MJ. 1982. Natural food and feeding in the commercial sand crab *Portunus pelagicus* Linnaeus, (Crustacea: Decapoda: Portunidae) in Moreton Queensland. Journal of Experimental Marine Biology and Ecology, 59: 165-176

Wolcott DL, O'Connor NJ. 1992. Herbivory in crabs: adaptations and ecological considerations. American Zoologist, 32: 370-381

http://mangrove.nus.edu.sg/pub/seashore/text/197.htm

http://www.sealifebase.fisheries.ubc.ca/summary/speciessummary.php?id=83977