Chapter IV

Identification, Population Structure, Micro-habitat and Feeding Behaviour of the Crabs
4.1. Introduction

Mangrove crabs constitute 80% of the total faunal biomass in mangroves (Golley et al., 1962). Crab biomass can attain a density of 80-90 individuals per square meter (Macintosh, 1984, Khan and Ravichandran, 2007). As with the distribution of mangrove plant species, there is considerable variation in the occurrence and diversity of crabs between the eastern and western mangroves (Tomlinson, 1986). Two families of crabs, Grapsidae and Ocypodidae, are particularly associated with mangrove ecosystems. Among these, grapsids are most important with regard to number and play vital role in the overall ecology of mangroves. Study by Tan and Ng (1994) in Peninsular Malaysia, represents the global peak of diversity of mangrove grapsids, recorded 51 species of grapsids, of which 44 were sesarmines.

Data on Indian mangrove crabs are available with regard to limited locations only. Grapsidae and Ocypodidae were the most dominant forms recorded in Indian mangroves. Studies on crab assemblages associated with the Indian mangrove forests are available from mangroves of Gujarat (Saravanakumar et al., 2007; Bandekar et al., 2011; Trivedi et al., 2012 and Shukla et al., 2013), Pondicherry (Satheeshkumar and Khan, 2011 and Satheeshkumar, 2012), Tamil Nadu (Sethuramlingam and Khan, 1991; Khan et al., 2005; Ravichandran and Kannupandi, 2007 and Fredrick and Ravichandran, 2013), West Bengal (Chakraborthy and Choudhury, 1994), Kerala (Dev Roy and Nandi, 2013), Goa (Dev Roy and Nandi, 2013) and Maharashtra (Dev Roy and Nandi, 2013). According to these authors substrate suitability, topography of soil, effects of tidal inundation and distribution of mangrove plants are the possible factors that could influence zonation and abundance of the crabs in the Indian mangroves.

Attempts have also been made to explain the relation between crab density and physical environment. The distribution of some species of *Uca* is associated with the amount of litter and soil texture (Murai et al., 1982). The density of plant cover is found to be more important for *Gecarcoidea lateralis* and *G. natalis*, whereas, water
content in the burrow for *Cardisoma guanhumi* (Herreid and Gifford, 1963; O’Dowd and Lake, 1991 and Jimenez *et al*., 1994). Few studies have explored the relationship of crab density and population structure with the heterogeneity of environment, as it has been demonstrated for *Aratus pisonii* which is positively and significantly correlated with mangrove productivity (Conde and Diaz, 1989). The land crab *G. lateralis* is conspicuous and ubiquitous in the tropical semi-deciduous forest of La Mancha, on the coastal area of Mexico, with a density of one individual per square meter during the rainy seasons (Delfosse, 1990 and Kellman and Delfosse, 1993).

The diversity of the mangrove grapsids is related to the habitat diversity, especially the microhabitats they use and their diet. *Aratus pisonii* is arboreal and forage on live mangrove leaves in the canopy (Warner, 1967). *Sesarma leptosoma* undertaking rhythmic, daily, and vertical migrations between the forest floor and specific host trees is a pattern seemingly influenced more by light intensity than by tides (Vannini *et al*., 1995 and Cannicci *et al*., 1996 a, b).

Although there have been some studies of grapsid diversity, investigations on distribution and abundance of grapsids in mangrove forests, at both local and geographic scales are limited. Investigations of temporal patterns are even rarer. Spatial patterns in crab abundance have been studied mainly in Australia, Africa and Hong Kong (Micheli *et al*., 1991; Smith *et al*., 1991; Frusher *et al*., 1994; Lee and Kwok, 2002 and Metcalfe, 2007). The density, diversity and abundance of crabs that occur in mangrove forests change across continents (Smith *et al*., 1991). The abundance and distribution of different species appear to change across intertidal zones, and also along tidal creeks (Frusher *et al*., 1994). The variation in species diversity, distribution, and abundance may change within and between mangrove forests because of the changes in the microenvironments, which may be the reason for a clear cut zonation for mangrove crabs.
Mangrove crabs have a wide range of feeding habits, varying from detritivory, herbivory and carnivory (Lee, 1998). Such differences in feeding behaviour of crabs make it possible to survive in diverse habitats without competition. Many species of mangrove crabs are known to be herbivorous. Some of them are found to feed on crabs and fishes in captivity (Von Hagen, 1977). *Chiromanthes onychophorum* in Malaysia (Malley, 1978), *Neosarmatium meinerti* in South Africa (Emmerson and McGwynne, 1992) and Kenya (Dahdouh-Guebas *et al*., 1997) and *Sesarma smithii* (Giddins *et al*., 1986), *S. messa* (Robertson, 1986 and Micheli, 1993) and *S. erythrodactyla* (Camilleri, 1989) in Australia can consume a great amount of leaf litter of various mangrove species. These crabs probably play an important role in leaf degradation, making mangrove leaves more rapidly available to meiofauna. Ocypodid crabs can feed on mangrove pneumatophores, bark and macro-algae (Wada and Wowor, 1989). The natural diet of *Aratus pisonii* includes fresh *Rhizophora mangle* leaves, caterpillars, crickets and beetles (Beever *et al*., 1979). In Kenyan coast, *N. meinerti* and *Cardisoma carnifex* (Micheli *et al*., 1991) are found to be the important consumers of fallen leaves. Some of them even feed on insects in the mangrove, as in the case of *Metopograpsus latifrons* which has been recorded to prey on the cicada *Meimuna iwasakii* (Nishihira, 1984). However, it is unlikely that the crabs routinely use such highly mobile prey as a major food source. The feeding behaviour of crabs in Indian mangroves is a seldom attempted area except the work of Ravichandran *et al*. (2006). He conducted feeding preference experiments in five grapsid crabs using leaf litter from three mangrove species in Pichavaram mangroves and found that crabs strongly prefer decomposed leaves of *Avicennia marina*. Viewed against the background of the emerging data coming out on feeding behaviour of mangrove crabs from different parts of the world and its importance in understanding the overall ecology of mangrove ecosystem, there exists a wide gap in this area with respect to Indian mangroves.

Recently 26 crab species have been reported in the mangrove forests of Kerala (Dev Roy and Nandi, 2013). However, their spatial distribution, abundance,
temporal variation in crab abundance, relation between crab activity and environment and feeding behaviour have not been evaluated with regard to mangrove forests of Kerala. Such detailed studies are very scanty in Indian context also. It is against this background that the present study is undertaken in three mangrove ecosystems of Kerala namely Kunhimangalam, Mangalavanam and Puthuvypu. The envisaged study attempts to identify the crabs, study their population structure, assess the spatial and temporal variation in crab density, understand the influence of environmental factors on crab density, and to know the micro-habitat preference and feeding behaviour of crabs.

4.2. Methodology

4.2.1. Collection and identification of crabs

The crabs were collected and identified as described in General Methodology (Chapter 2).

4.2.2. Crab density

Crab density was assessed by selecting nine equidistant 1 m² subplots in each of the 10 x 10 m sampling sites as described earlier ie, a total of 30 transects at Kunhimangalam, five at Mangalavanam and 15 at Puthuvypu (Chapter 2). As the crab density involved a long term evaluation at definite intervals, a non intrusive ‘time based visual count method’ was preferred to intrusive methods like ‘pitfall trapping’ and ‘time based capture’ so as to exert only minimum disturbance to the system (Ashton, 1999 and Ashton et al., 2003). This involved 15 minutes crab count in each subplot with adults and juveniles being counted separately. As crabs are sensitive to disturbance, observation was done from a distance of about one meter. Prior to 15 minute recording of the number of crabs in each subplot, a five minutes’ duration was allowed for the crabs to come out of the burrows to resume activities. The number of burrows in each subplot was also recorded. All recordings were done during the diurnal low tide phase, the tidal phase when crabs were active. Density assessment was repeated monthly for
two successive years (2008-2010) at Kunhimangalam, and one year (2008-2009) at Mangalavanam and Puthuvypyu.

4.2.3. Influence of environmental factors on crab density

For this, environmental parameters of the mangrove areas were documented monthly for two years at Kunhimangalam (2008-2010), and one year (2008-2009) at Mangalavanam and Puthuvypyu. The major parameters considered in the study were: rainfall, humidity, water salinity, water pH, water temperature, soil temperature, soil pH and air temperature.

The data obtained were statistically analysed using linear regression model to evaluate the role of environmental factors on crab density.

4.2.4. Food and feeding behaviour of crabs

The food and feeding behavior of dominant crab species were evaluated by direct observation. These observations were conducted not only in the selected study sites but also in the adjoining areas. Care was taken to have minimal disturbance to the normal activity of crabs. A binocular was used wherever close examination was needed. The observations were made in the morning (8-10 am), noon (12-2 pm) and evening (4-6 pm) for a duration of two years (2008-2010) at both the high tide and low tide phases at Kunhimangalam.
4.3. Results

4.3.1. Crabs present in the study areas

Ten crab species were identified at Kunhimangalam, four at Mangalavanam and seven at Puthuvypu mangroves belonging to three families namely Grapsidae, Ocypodidae and Portunidae (Table 11).

The diagnostic characters of the identified mangrove crab species:

**Sesarmops intermedius** (De Hann, 1835) (Plate 5 A, C)
- Carapace broader than long, bluish with three pairs of strong lateral spines
- The first two pairs of lateral spines prominent
- Front with two distinct ridges
- Two grooves running from front to the gastric region
- Postero-lateral grooves also present
- Propodus and dactylus of chelipeds moderately grained
- Two spines on upper dactylus
- Cardiac region well defined

**Parasesarma plicatum** (Latreille, 1806) (Plate 5 B, D)
- Carapace squary, hairy and broader than long
- Front crenulate, strongly haired
- Four to five cardinal grooves running to posterolateral region
- Chelipeds equal in size, bright red in colour
- Antero-lateral spine absent
- Orbit crescent shaped, ending with sharp lateral spines pointing towards the front
- Propodus and dactylus of chelipeds grainy
- Post frontal margin with four distinct similar lobes separated by narrow grooves.
- Cardiac region well defined

**Pseudosesarma edwardsii** (De Man, 1888) (Plate 5 E)
- Carapace broader than long with dull white horizontal band on the frontal area
- Chelae orange with dark red tip
• Two lateral spines prominent
• Propodus and dactylus equal

*Uca annulipes* (H. Milne Edwards, 1837) (Plate 5 F)
• Carapace broader and convex at the frontal region
• Lateral borders markedly narrowed posteriorly
• Carapace black or brownish black with white transverse markings
• Immovable fingers of the large cheliped in male with an entangled tooth at tip
• Large chela smooth, white to pale pink to dark red

*Uca triangularis* (A. Milne Edwards, 1873) (Plate 6 A)
• Anterior border of carapace about the double the size of lateral borders
• Tip of movable and immovable fingers of the large chela sharply pointed
• Merus of smaller chelipeds posteriorly flattened and tuberculated
• Palm more tuberculated
• Orbits strongly slanting

*Scylla serrata* (Forskal, 1775) (Plate 6 B)
• Carapace width larger than long, smooth and purplish brown
• Frontal lobe pointed and anteriorly projected
• Nine equal sized sharp teeth along the anterolateral borders of the carapace
• Chelae dark red, inflated and smooth
• Outer margin of the carpus with a single sharp spine
• Propodus of cheliped costate

*Thalamita crenata* (Latreille, 1829) (Plate 6 C)
• Carapace width nearly 1.5 times larger than length with greenish grey colour
• Carapace with two transverse ridges on the gastric region
• Front straight, cut in to two equal lobes
• Anterolateral borders of the carapace cut into five equal claw shaped teeth with lateral margins
• Spines of anterolateral border of carapace truncate
Perisesarma bidens (De Hann, 1835) (Plate 6 D)

- Carapace squarish, hairy and broader than long
- Front crenulate, strongly haired
- Four cardinal grooves running to posterolateral regions
- Eye stalk moderate in length

Clistocoeloma balansae A. Miline Edwards, 1874 (Plate 6 E)

- Carapace squarish, broader than long
- Thick spiny form granules on hepatic and branchial regions
- Chelae with hairy grooves on outer surface, interfaces strongly tuberculated

Metapograpsus messor (Forskal, 1775) (Plate 6 F)

- Front more than half of the extreme width of carapace
- Carapace covered with irregularly shaped green markings
- Front broad, lateral margins of carapace markedly convergent posteriorly.
- Chelipeds with light orange red colour
- Front crenulate with four tufts of hairs.
- Walking legs shorter and pointed

Species richness of crabs in the selected mangrove ecosystems were found positively correlated with the species richness of mangrove vegetation present in the area. In the present study, the area with diverse mangrove vegetation (Kunhimangalam) experienced high crab diversity and Mangalavanam with less plant diversity recorded the least crab diversity. Regression analysis revealed a significant positive correlation between species richness of crabs and plants (Figure 6).
Table 11

Occurrence mangrove crabs at Kunhimangalam, Mangalavanam and Puthuvypu

<table>
<thead>
<tr>
<th>Family</th>
<th>Crab Species</th>
<th>Kunhimangalam</th>
<th>Mangalavanam</th>
<th>Puthuvypu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grapsidae</td>
<td><em>Sesarmops intermedius</em></td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td></td>
<td><em>Parasesarma plicatum</em></td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td></td>
<td><em>Pseudosesarma edwardsii</em></td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td></td>
<td><em>Perisesarma bidens</em></td>
<td>√</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td><em>Metapograpsus messor</em></td>
<td>√</td>
<td>X</td>
<td>√</td>
</tr>
<tr>
<td></td>
<td><em>Clistocoeloma balansae</em></td>
<td>√</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Ocypodidae</td>
<td><em>Uca annulipes</em></td>
<td>√</td>
<td>X</td>
<td>√</td>
</tr>
<tr>
<td></td>
<td><em>Uca triangularis</em></td>
<td>√</td>
<td>X</td>
<td>√</td>
</tr>
<tr>
<td>Portunidae</td>
<td><em>Thalamita crenata</em></td>
<td>√</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td><em>Scylla serrata</em></td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
</tbody>
</table>

√ = Present   X = Absent
Correlation between spices richness of crabs and mangrove plants in three study areas

\[ y = 1.184x - 2.078 \]
\[ R^2 = 0.986 \]
4.3.2. Crab density

Density of crabs in the three study areas is given in Table 12, 13, 14 and 15. All the 10 crab species (Table 11) were present at Kunhimangalam mangrove area. When compared with crab densities at Puthuvypu and Mangalavanam area the average density was high at Kunhimangalam (9.83 crabs m\(^{-2}\)) (Table 12, 13).

Puthuvypu mangrove area harboured seven species of crabs (Table 11) with an average density of 5.77 crabs m\(^{-2}\), lower than at Kunhimangalam. Mangalavanam harboured only four species of crabs with an average density of 5.43 crabs m\(^{-2}\), lower than Kunhimangalam and Puthuvypu.

Table 12, 13, 14 and 15 show that *Sesarmops intermedius* and *Parasesarma plicatum* has the highest density in all the three study areas. Densities of other crab species (adults) accounting only <1 crabs m\(^{-2}\). This shows that the dominant crab species in all the study areas are *S. intermedius* and *P. plicatum*.

The densities of these two dominant crabs showed distinct spatial and temporal variation. Figure 7, 8, 9, 10, 11 and 12 explain the temporal variation of the density of *Sesarmops intermedius* and Figure 13, 14, 15, 16, 17 and 18 show the temporal variations in the density of *Parasesarma plicatum* at Kunhimangalam mangroves. Similarly, Figure 19, 20 and 21 explain the temporal variation of the density of *Sesarmops intermedius* and Figure 22, 23 and 24 give details of the temporal variations in the abundance of *Parasesarma plicatum* at Puthuvypu. The temporal variation in crab density at Mangalavanam is provided in Table 14. Data on temporal variation of these two crabs revealed that the peak density is during the monsoon season followed by a steep decline (Figure 7 to 24). The spatial variation in density of the *S. intermedius* and *P. plicatum* is apparent not only in different study areas but also between different sites of the study area (Table 16).

When compared with burrow densities at Puthuvypu and Mangalavanam area the average burrow density was high at Kunhimangalam (11.65 burrows m\(^{-2}\)) followed by Mangalavanam (8.87 burrows m\(^{-2}\)) and Puthuvypu (6.83 burrows m\(^{-2}\)) (Table 12, 13, 14, 15).
Table 12
Average crab density (m$^2$) at Kunhimangalam mangroves (2008-2009)

<table>
<thead>
<tr>
<th>Crab Species</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>July</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Average</th>
</tr>
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<tbody>
<tr>
<td><em>Sesarmops intermedius</em></td>
<td>0.07</td>
<td>0.69</td>
<td>2.57</td>
<td>2.43</td>
<td>3.85</td>
<td>2.20</td>
<td>3.06</td>
<td>1.26</td>
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<td>0.63</td>
<td>0.57</td>
<td>0.39</td>
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</tr>
<tr>
<td><em>Parasesarma plicatum</em></td>
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<td>3.00</td>
<td>2.91</td>
<td>5.22</td>
<td>3.26</td>
<td>3.85</td>
<td>3.33</td>
<td>2.30</td>
<td>2.87</td>
<td>3.30</td>
<td>1.35</td>
<td>1.30</td>
<td>2.92</td>
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<td><em>Pseudosesarma edwardsii</em></td>
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<td>0.13</td>
<td>0.19</td>
<td>0.17</td>
<td>0.33</td>
<td>0.06</td>
<td>0.09</td>
<td>0.06</td>
<td>0.06</td>
<td>0.15</td>
<td>0.17</td>
</tr>
<tr>
<td><em>Perisesarma bidens</em></td>
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<td>0.02</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.02</td>
<td>0.19</td>
<td>0.35</td>
<td>0.02</td>
<td>0.04</td>
<td>0.02</td>
<td>0.15</td>
<td>0.17</td>
</tr>
<tr>
<td><em>Uca annulipes</em></td>
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<td>0.13</td>
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<td>0.72</td>
<td>0.28</td>
<td>0.33</td>
<td>0.78</td>
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<td>0.31</td>
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<tr>
<td><em>Uca triangularis</em></td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0.02</td>
<td>0</td>
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<td>0</td>
<td>0.48</td>
<td>0</td>
<td>0.04</td>
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<tr>
<td><em>Scylla serrata</em></td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
<td>0</td>
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<tr>
<td>Juveniles</td>
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<td>8.67</td>
<td>1.09</td>
<td>2.72</td>
<td>0.61</td>
<td>2.19</td>
<td>1.87</td>
<td>7.39</td>
<td>6.24</td>
<td>7.46</td>
<td>3.69</td>
<td>6.80</td>
<td>4.63</td>
</tr>
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</table>
Table 13
Average crab density (m$^2$) at Kunhimangalam mangroves (2009-2010)

<table>
<thead>
<tr>
<th>Crab Species</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sesarmops intermedius</td>
<td>0.06</td>
<td>0.61</td>
<td>2.28</td>
<td>2.63</td>
<td>3.24</td>
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<td>2.46</td>
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</tr>
<tr>
<td>Parasesarma plicatum</td>
<td>1.91</td>
<td>2.85</td>
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<td>3.94</td>
<td>4.09</td>
<td>3.59</td>
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<td>0.87</td>
<td>1.28</td>
<td>1.37</td>
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<tr>
<td>Metapograpsus messor</td>
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<td>0.06</td>
<td>0.02</td>
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<tr>
<td>Perisesarma bidens</td>
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<td>0.02</td>
<td>0.02</td>
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<td>Uca triangularis</td>
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<td>0</td>
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<td>0.06</td>
<td>0.04</td>
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<td>0</td>
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<td>0</td>
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<td>0.01</td>
</tr>
<tr>
<td>Juveniles</td>
<td>5.59</td>
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<td>1.69</td>
<td>1.39</td>
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<td>4.94</td>
<td>8.13</td>
<td>3.20</td>
<td>6.48</td>
<td>4.36</td>
</tr>
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</table>
### Table 14
Average crab density (m²) at Mangalavanam mangroves (2008-2009)

<table>
<thead>
<tr>
<th>Crab Species</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Average</th>
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</thead>
<tbody>
<tr>
<td><em>Sesarmops intermedius</em></td>
<td>2.11</td>
<td>2.78</td>
<td>3.22</td>
<td>2.33</td>
<td>1.00</td>
<td>0.44</td>
<td>0.44</td>
<td>0.67</td>
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<td>0.78</td>
<td>2.11</td>
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<td><em>Parasesarma plicatum</em></td>
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<td>1.77</td>
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<td>0</td>
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### Table 15
Average crab density (m²) at Puthuvypu mangroves (2008-2009)

<table>
<thead>
<tr>
<th>Crab Species</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
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<th>Jun</th>
<th>Jul</th>
<th>Average</th>
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</thead>
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<td>Burrows</td>
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<td>6.78</td>
<td>5.89</td>
<td>7.11</td>
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<td>7.67</td>
<td>7.11</td>
<td>5.8</td>
<td>6.83</td>
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</tbody>
</table>
Figure 7
Temporal variation in *S. intermedius* density at Sk 1

Figure 8
Temporal variation in *S. intermedius* density at Sk 2

Figure 9
Temporal variation in *S. intermedius* density at Sk 3

Figure 10
Temporal variation in *S. intermedius* density at Sk 4
**Figure 11**
Temporal variation in *S. intermedius* density at Sk 5

**Figure 12**
Temporal variation in *S. intermedius* density at Sk 6

**Figure 13**
Temporal variation in *P. plicatum* density at Sk 1

**Figure 14**
Temporal variation in *P. plicatum* density at Sk 2
Figure 15
Temporal variation in *P. plicatum*
density at Sk 3

Figure 16
Temporal variation in *P. plicatum*
density at Sk 4

Figure 17
Temporal variation in *P. plicatum*
density at Sk 5

Figure 18
Temporal variation in *P. plicatum*
density at Sk 6
Figure 19
Temporal variation in *S. intermedius* density at Sp 1

Figure 21
Temporal variation in *S. i* density at Sp 3

Figure 22
Temporal variation in *P. plicatum* density at Sp 1
Figure 23
Temporal variation in *P. plicatum*
density at Sp 2

Figure 24
Temporal variation in *P. plicatum*
density at Sp 3
Table 16

Site wise densities (the highest recorded) of the dominant crabs (m²) *Sesarmops intermedius* and *Parasesarma plicatum* in the selected study areas

<table>
<thead>
<tr>
<th>Crab species</th>
<th>Kunhimangalam</th>
<th>Puthvypu</th>
<th>Mangalavanam</th>
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<tr>
<td><em>Sesarmops intermedius</em></td>
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<td>Sk 1</td>
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<td>Sk 2</td>
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<td>Sk 3</td>
<td>1.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sk 4</td>
<td>0.22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sk 5</td>
<td>0.22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sk 6</td>
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</tr>
<tr>
<td>Sp 1</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Sp 2</td>
<td>8.11</td>
<td>Sm 1</td>
<td>3.22</td>
</tr>
<tr>
<td>Sm 1</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Sm 8</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| *Parasesarma plicatum* | | |
| Sk 1 | 1.78 | | |
| Sk 2 | 1.22 | | |
| Sk 3 | 0.89 | | |
| Sk 4 | 13.33 | | |
| Sk 5 | 10.67 | | |
| Sk 6 | 4.00 | | |
| Sp 1 | 9.33 | | |
| Sp 2 | 0.56 | Sm 1 | 3.33 |
| Sm 1 | | | |
4.3.3. Influence of environmental factors on crab density

The results of regression analysis revealed that out of the eight environmental factors considered, salinity and rainfall were the major factors influencing the density of mangrove crabs (Figure 25, 26, 27, 28). Water salinity in the study areas ranged from 0 to 30 ppt because of the well distributed rainfall and consequent fresh water inflow. The highest salinity, 30 ppt was observed during pre-monsoon period (March and April). Rainfall in the study areas ranged from 0 to 1610.8 mm. The highest rainfall was 1610.8 mm, recorded at Kunhimangalam mangrove area in July 2008. The lowest rainfall, 0.0 mm, was recorded during summer months of March and April.

As in Kunhimangalam, salinity and rainfall were found to influence crab density at Mangalavanam and Puthuvypu also.
Influence of salinity on the density of *Sesarmops intermedius* in Kunhimangalam mangroves with respect Sk 1, the *S. intermedius* dominant site

**Figure 25**

- **a. 2008-2009**
  
  \[ y = -0.211x + 6.738 \]
  
  \[ R^2 = 0.713 \]

- **b. 2009-2010**
  
  \[ y = -0.266x + 7.714 \]
  
  \[ R^2 = 0.679 \]

Influence of salinity on the density of *Parasesarma plicatum* in Kunhimangalam mangroves with respect Sk 4, the *P. plicatum* dominant site

**Figure 26**

- **a. 2008-2009**
  
  \[ y = -0.398x + 11.86 \]
  
  \[ R^2 = 0.861 \]

- **b. 2009-2010**
  
  \[ y = -0.378x + 11.24 \]
  
  \[ R^2 = 0.855 \]
Figure 27

Influence of rainfall on the density of *Sesarmops intermedius* Kunhimangalam mangroves with respect Sk 1, the *S. intermedius* dominant site

a. 2008-2009

![Graph 1](image1.png)

b. 2009-2010

![Graph 2](image2.png)

Figure 28

Influence of rainfall on the density of *Parasesarma plicatum* in Kunhimangalam mangroves with respect Sk 4, the *P. plicatum* dominant site

a. 2008-2009

![Graph 3](image3.png)

b. 2009-2010

![Graph 4](image4.png)
4.3.4. Food and feeding behaviour of crabs

4.3.4.1. *Sesarmops intermedius*

*Sesarmops intermedius* inhabited just beyond the line of tidal reaches. The burrows of this species showed subaerial networks. The highest density of their burrows were 33 m⁻². Burrow density was higher in areas covered by tree canopies and lesser in light gaps, as they were highly sensitive to light and use mangrove leaves as main food source.

*Sesarmops intermedius* mainly fed on mangrove leaves and tree seedlings. Food consisted of green and senescent leaves of *Avicennia officinalis*, *Excoecaria agallocha* and *Rhizophora mucronata*. This crab very rarely fed on coconut and *Pandanus* leaf parts, which were available beyond the line of tidal reaches. They were also found feed on small twigs of mangrove plants and occasionally on dead crabs.

These crabs exhibited a kind of exploratory behaviour as they examined all novel objects about one meter around their burrow. Materials examined and found suitable for handling were translocated to the burrows (Plate 7 A, B, C). They had a natural instinct to translocate any materials to their burrows irrespective whether they were edible or not. In natural ecosystem, they mainly translocated fallen leaves of mangrove plants. Leaf translocation was found to be almost species specific. They preferred more *Excoecaria agallocha* leaves to other plant species. While foraging, when two crabs accidentally confront, they exhibited a chelate display for 2-3 minutes before moving to their respective territory. While on feeding around their burrow areas, they held the leaf in one chela and used the other for cutting and tearing off leaves into small pieces starting from margin. First and second pair of ambulatory legs were also used to handle food materials. Both chelate legs were usually used to feed on small twigs and roots of mangrove plants and to place the food into the buccal cavity. Before taking into buccal cavity food materials were cut or scrapped into small pieces by mandibles and maxillaries. Besides the leaves and plant parts, these crabs also fed on detritus/organic matter. Both chelipeds were used intermittently or alternatively one at a
time to take up detritus laden mud to the buccal cavity. They did not spit out any detritus mixed mud as done by fiddler crabs.

Senescent yellow leaves were picked up from the ground as soon as they fell. When green leaves fell accidently they were also translocated by the crabs to their burrows (Plate 7 A, B, C). Often crabs competed for fallen leaves where they occurred in more numbers. Mostly it was found that the fallen leaves were taken by the crab which was nearest to their burrow. *Sesarmops intermedius* was also seen feeding on the leaves even without translocating them into the burrow when the surround area happened to be calm and quiet and there were no competitors and predators. They seemed to have preference to fresh green leaves for yellow senescent and grey dry leaves. Grey dry leaves were the least preferred and hence rarely taken when green or senescent leaves were available.

*Sesarmops intermedius* activities were at its peak during monsoon season and initial two months of post monsoon, and less active in pre-monsoon and end of post-monsoon. They were rarely found outside their burrows in noon time. During the post monsoon period many crabs closed their burrow openings with slush to maintain moisture inside the burrows and within their body during which they did not show any preference to fresh, senescent or drying leaves. They took which ever leaves that they came across first. During monsoon they supplement their food with propagules and newly established seedlings (Plate 8 A, B). Mostly they uprooted the seedlings or cut from basal part and translocated them to the burrows.

*Sesarmops intermedius* was highly sensitive to disturbances in the surroundings. But they appeared to be not sensitive to normal sound, human audible range. Disturbances of falling of a mangrove leaf from the canopy itself were enough to make them rush to their burrows. After that they came back to the mouth of their burrows and keenly explored the surroundings.

Excavation of their burrows in the field and captive condition revealed that they had a highly branched burrow system with more than one opening on the forest
floor. Decomposed mangrove leaves were observed in their burrow network. They made more number of burrows in captive condition than in the natural habitat. They took refuge inside the burrows during high tide or inundation time to avoid predators like fishes.

4.3.4.2. *Parasesarma plicatum*

*Parasesarma plicatum* was found in the low intertidal areas. They fed on detritus, decaying leaves and small twigs of some mangrove plants, green leaves of *Avicennia officinalis* (Plate 7 D), flower and buds of *Aegiceras corniculatum*, dead crabs, fishes and weak crabs of the same species (cannibalism). They also fed on barks of pneumatophores, silt and algae matter covered on pneumatophores, and propagules of *A. corniculatum* (Plate 8 D).

*Parasesarma plicatum* did not feed constantly at a single spot, but changed the spot of feeding very frequently. Their foraging territory was restricted to almost three meter radius from their burrows. Generally, they were found in the aerial root system of *Avicennia officinalis* or *A. marina* (Plate 8 C) and were less frequent in *Rhizophora mucronata* growing areas. They were found in large numbers in and around the basal parts of the trunks of the plants like, *A. officinalis*, *Kandelia candel*, and *Bruguiera cylindrica*.

During feeding *Parasesarma plicatum* used chelate appendages to handle the food. The crabs used the second pair of walking legs on either side to hold leaf materials prior to taking by the chelate legs. During high tides and inundation *P. plicatum* climbed on trees (Plate 7 F, G) and rarely fed on leaves occurring up to a height of four meter. Some crabs found remaining on the tree trunks at the air water interface collecting and feeding materials floating on water surface. When water receded, these crabs were found collecting materials from the scum left behind.

*Parasesarma plicatum* though mostly dependent on detritus and decomposing leaves, exhibited a remarkable degree of cannibalism (Plate 7 E).
cannibalism it used its chelate legs to break open the carapace of the dead crabs and fed on the internal musculature with the help of chela and the first and second pairs of walking legs. When crabs were disturbed during the course of cannibalistic activity, they moved away holding the meal in one chelae in captive condition.

*Parasesarma plicatum* grazed on mangrove pneumatophores. They shred and ate the algal biomass. During monsoon, crabs were actively involved in feeding in between rains. When water level went up they climbed on the vegetation and became less active and when water receded they descended from tree trunks or from long pneumatohores and continued to fed on detritus material. Tree climbing behavior in *P. plicatum* at the time of inundation and at high tides was found as an efficient mechanism to evade potential predators like puffer fishes and eel fishes that invaded their habitat along with the incoming water.

4.3.4.3. *Uca annulipes*

They inhabited the burrows on mangrove mud flats where soil was sandy. Their burrows had round openings and could be identified easily from the mouth of their burrows with several bolus of sand in radial pattern with grooves. These grooves were formed due to the bolus of sand spitted out from the buccal cavity after they consumed the detritus from the swallowed sand. Their burrows were vertical and almost at right angle to the soil surface.

*Uca* usually fed on the mudflats enriched with detritus (*Plate 8 E*). Males used smaller chelate leg for gathering mud from the ground, while the large chelae were kept at a distance guarding the frontal area of crabs. This ensured the feeding process without any disturbance. Females used both chelae for feeding. The sand particles and other unpalatable materials were pushed away from the buccal cavity. The materials were rolled into ball like structures with the help of first and second pairs of walking legs. One bolus was formed out of four or five pick up of detritus material. Possibly, this bolus was glued with some slimy material from the buccal cavity. While feeding,
crabs moved in straight line placing the sand bolus on the ground out of the mouth along the margin of the moving path. This regular deposition of sand bolus at frequent interval by these crabs made a characteristic bioturbation structure on the mangrove forest floor. Unlike other mangrove crabs they did not feed on leaves or any other plant material.

4.3.4.4. *Pseudosesarma edwardsii*

They lived in burrows amidst litter and pneumatophores. They were also encountered amidst decomposing logs and branches of mangrove trees. They were also found inhabited in areas slightly away from mangrove vegetation where fallen coconut leaves were deposited and decayed. They fed on decaying leaves, detritus, scrapings of pneumatophores and small worms from decaying logs. Feeding was comparatively slow and at short intervals. They found to consume young seedlings of *Avicennia officinalis* by cutting the stem just above the cotyledon. Feeding on fresh or fallen leaves of mangroves by this crab was not observed.

4.4. Discussion

The present investigation recorded a total of 10 species of brachyuran crabs (6 grapsids, 2 ocypodids and 2 portunids) from three study areas. The 10 species formed 38.46% of the 26 mangrove crabs recorded from Kerala (Dev Roy and Nandi, 2013) and 7.25% of the 138 mangrove crabs (Bhatt and Kathiresan, 2011) reported from India. When compared with the reports of 22 species of crabs from Pondicherry (Satheeshkumar, 2012), 19 species from Kachchh (Trivedi *et al.*, 2012), 38 species from Pichavaram and 38 species from artificially developed mangroves at Vellar estuary (Khan *et al.*, 2005), the species richness is low in Kunhimangalam, Mangalavanam and Puthuvypu.

Among the 10 species recorded from the study areas, *Scylla serrata* and *Thalamita crenata* were carnivorous. All others were predominantly herbivores with occasional carnivory. Though all the species were not present in all the study areas,
Sesarmops intermedius and Parasesarma plicatum were seen throughout and were the most abundant species. In India, P. plicatum is reported from Andhra Pradesh (Bouillon et al., 2004 and Dev Roy and Nandi, 2013), Tamil Nadu (Khan et al., 2005 and Dev Roy and Nandi, 2013), Orissa (Dev Roy and Nandi, 2013), Gujarat (Saravnakumar et al., 2007 and Trivedi et al., 2012), Goa (Deshmukh, 1994) and Kerala (Dev Roy and Nandi, 2013). Parasesarma plicatum was distributed throughout Indo-West Pacific region (Rahayu and Ng, 2010). Sesarmops intermedius is not reported elsewhere from India but found in Andaman Sea to Indonesia, China, Taiwan, Japan and Korea.

Both burrowing and non-burrowing crabs were observed in the study areas. The burrowing behavior is correlated with food habit and anti-predatory strategy. Sesarmops intermedius preserved food (mainly leaf litter) within their burrows and fed them after decaying. But Parasesarma plicatum fed litter directly from the mangrove floor. Parasesarma plicatum avoid their predators like puffer fish, eel fish and Scylla serrata during continuous inundation at monsoon season by climbing on trees. There they mainly feed on detritus material attached to tree trunks. This shows that feeding behaviour and antipredatory strategy are closely related. Different strategies have been reported among crabs with respect to burrowing behaviour. But those crabs which do not have burrowing habits (eg. Chiromantes species) utilize the burrows of other species such as Neosarmatium meinerti to escape from predators (Gillikin, 2004).

Species richness of mangrove crabs was found to vary with plant species richness prevailing in the area. Both these parameters were directly correlated to each other (Figure 6). In Kunhimangalam seven crab species were observed from Sk 6 with eight mangrove tree species. But in Sk 1 and Sk 2 with A. officinalis and E. agallocha recorded only three species of crabs. Study area wise comparison also showed a positive correlation. Highest crab diversity (10 species) was observed from Kunhimangalam with 10 mangrove species. While Mangalavanam with 5 mangrove species showed the presence of only 4 species brachyuran crabs (Figure 6). This points to the probability that mangrove plant species richness is an indicator of brachyuran
diversity in mangrove ecosystem. Similar observations were recorded from Australia (Lee, 1998 and Davie, 2002), Malaysia (Ashton et al., 2003) and Hong Kong (Lee and Leung, 1993).

Soil texture changes rapidly with mangrove vegetation become established and the burrowing crustaceans are an important element in the process that leads to the soil becoming suitable for other species to colonize (Berry, 1972). This process may provide a variety of micro-climates within mangrove ecosystems, which facilitate diverse crab fauna to occupy the mangrove habitats, an aspect that has to be seriously considered in mangrove forest management. Unfortunately, only a few mangrove species are being used for afforestation and restoration projects in India, among which Rhizophora sp. and Avicennia marina are the most commonly used ones (Kathiresan et al., 2000). Tan and Ng (1994) suggested that the maintenance of high crab species diversity is fundamental to the health of the mangroves. So the present management strategy with dominance of Rhizophora sp./Avicennia marina may not be suitable for the development of a healthy ecosystem. This study underlines that high mangrove species diversity provides habitat heterogeneity and hence may support more diverse crab fauna.

Brachyuran crabs exhibit distinct zonation in all the study areas. Some were confined to landward area (Sesarmops intermedius), sandy beaches (Uca annulipes and U. triangularis), along creeks and water ways (Metapograpus messor) or in muddy areas (Parasesarma plicatum). This zonation is found related to their food habit. Sesarmops intermedius preferred freshly fallen senescent leaves of Exocoecaria agallocha (Nayar, 2011) as their major food was available only in landward area. In contrast, P. plicatum preferred decomposed leaves, which are available in the marshy areas only. Uca annulipes and U. triangularis were seen only in sandy soil with high organic content. Moreover, they preferred warmer sediments and always made burrows in areas with enough sunlight. All other crab species in the study areas were found to avoid direct sunlight. It appears that that the density and distribution of crabs depend
largely on the availability of food (plant distribution) and physical conditions prevailing in the area.

A distinct zonation of mangrove crabs has been reported from Kenyan mangrove (Dahdouh-Guebas et al., 2002). Here, *Neosarmatium meinerti* and *Sesarma ortmanni* is seen the landward area of *Avicennia marina* zone. *Neosarmatium smithii*, *S. guttatum* and *S. leptosome* are restricted to the *Rhizophora mucronata* zone and *Metapograpsus thukuhar* and *S. elongatum* to the seaward *A. marina* and *Sonneratia alba* zone. Koch et al. (2005) while studying the spatial distribution and population dynamics of four species of fiddler crabs in North Brazil mangrove found that *Uca rapax* was restricted to the high intertidal forest, while *U. maracoani* was mostly restricted to the sunny mud banks of larger creeks in the mid and low intertidal zones.

The average crab density in Kunhimangalam was 9.83 m\(^{-2}\) and that of Mangalavanam was 5.43 m\(^{-2}\) and Puthuvypu 5.77 m\(^{-2}\). *Sesarmops intermedius* and *Parasesarma plicatum*, the two dominant crabs together contributed 99% of the adult crabs in Puthuvypu, 83% in Kunhimangalam and 96% in Mangalavanam. Population densities of brachyuran fauna ranged from 29-71 m\(^{-2}\) in Pondicherry mangroves (Satheeshkumar, 2012). Frusher et al. (1994) recorded Grapsid density of 0-2 m\(^{-2}\) from mangroves at Murray River of Northeast Australia. McIvor and smith, 1995 recorded Xanthid crab density of 0.3-4 m\(^{-2}\) at Rookery Bay, USA. A high density of Ocypoid crab, *Uca annulipes*, 10-175 m\(^{-2}\), was recorded from East Africa by Skov et al. (2002). He observed *Neosarmatium meinerti* from in East Africa at density of 5 m\(^{-2}\).

It has been found that crab density registered in a given area should be interpreted very carefully. Crab density does not fluctuate significantly over a period of one year. Many of them will be semi-dormant during pre-monsoon season and remain inside their burrows and their absence outside the burrows may be mistaken as low crab density during this period. Hence, the highest crab density recorded for a crab species in an area at any time of an year is to be considered as the actual density of the crab. Low crab density recorded during the pre-monsoon and initial two months of post-monsoon
seasons can be attributed to their low activity in unfavorable environmental conditions under which they prefer to remain inside the burrows.

Burrows are the primary indicators in mangrove ecosystems to denote the presence of crabs (Nayar, 2011). There is a tendency to equate burrow density with crab density. But the present study showed that this cannot readily be applied to multispecies density assessment. It may be noted that the burrow density of *Parasesarma plicatum* was always less than the actual density, which is due to the filling of burrows by sand particles by tidal waves at frequent intervals. In contrast *Sesarmops intermedius* burrow density was 3 times more than that of the actual crab density as more than three openings are the ramifications of a single main burrow. In Kunhimangalam the density of *S. intermedius* was 10.56 m$^{-2}$ in Sk 1 and 8.89 m$^{-2}$ in Sk 2. The burrow density in site1 was 23.78 m$^{-2}$ and that of Sk 2 was 25.89 m$^{-2}$. It could be seen that actual crab density is nearly three times less than the burrow density. This pattern was observed in Puthuvypu and Mangalavanam. For *S. intermedius* an accurate density is possible by counting their burrows, which is not applicable for *Parasesarma plicatum* as most of their burrows are temporary. So year round visual counting of crab is the reliable method for studying its density and burrow count if adopted, the burrowing ecology of crabs has to be taken in to account.

Ashton *et al.* (2003) found a clear relation between crab abundance and environmental variables like topographical height, water pH and water salinity. In the present study among the abiotic factors, salinity and rainfall were the major factors influencing the temporal variation in crab density. Salinity at all the study sites was high during pre-monsoon (summer) and low during the monsoon season. Higher values in summer could be attributed to faster evaporation in the study area. Thus, the variation of salinity at study sites is probably due to freshwater runoff and rain. Gibson (1982) opined that salinity acts as a limiting factor in the distribution of living organisms, and its variation caused by dilution and evaporation influences the fauna most likely in the intertidal zone. Maximum rainfall was observed in July and August in
the study area. High rainfall results in lowering of salinity in mangroves. A negative correlation was observed between salinity and *Parasesarma plicatum* density. This is true in the case of *Sesarmops intermedius* also (Figure 25, 26).

Topography of the soil also is found to influence zonation among brachyurans. In Kunhimangalam *Sesarmops intermedius* showed high density at Sk 1 and Sk 2 (10.56 and 8.89 crabs m\(^{-2}\) respectively), sites having hard muddy substratum because of low water availability. *Sesarmops intermedius* registered less (1.33, 0.22, 0.22) density at Sk 3, Sk 4 and Sk 5 where plant species diversity is high. These sites are with marshy substratum. *Sesarmops intermedius* and *Parasesarma plicatum* showed moderate density at Sk 6. This site possesses a mixture of hard muddy and marshy substrata. Similarly, *P. plicatum* registered high (13.33, 10.67 crabs m\(^{-2}\) respectively) density at sites 4 and 5 with marshy substratum. But its density was less at Sk 1 and Sk 2 (1.78 and 1.22 crabs m\(^{-2}\)) with hard muddy substratum. The role of topography in controlling the abundance and distribution in mangrove forest has been reported by Macintosh (1984), Chakraborthy and Choudhury (1992), Ashton *et al.* (2003) and Gillikin and Schubart (2004). According to Ravichandran (2001), combination of factors like topography, tide, sediment texture, nutrient abundance, root-mat density, food source, environmental variables and physiological adaptations are responsible for brachyuran abundance and distribution.

### 4.5. Summary

Ten brachyuran crab species were recorded from the study areas, which forms 38.46% of the mangrove crabs so far recorded from Kerala state. Eight species recorded from the study sites are found to be herbivorous with occasional carnivory. Kunhimangalam mangroves revealed highest brachyuran abundance and species richness followed by Puthuvypu and Mangalavanam. *Sesarmops intermedius* and *Parasesarma plicatum* are the abundant crab species in all the study areas. Crab species richness was found directly proportional to mangrove plant species richness. Crabs
showed spatial and temporal variation in their abundance, showing a peak activity in monsoon and initial months of post monsoon. Salinity and rainfall are the major abiotic factors responsible for this. They exhibited distinct zonation in all the study areas; most of them preferred low intertidal area. Topography of the soil is found to influence zonation of crabs. Among the crabs *S. intermedius* is found to predate intensively on mangrove propagules and seedlings.