Chapter IV

Mussel associated natural faunal assemblages

Introduction

The functioning of ecosystems depends on the composition, richness and abundance of different species it supports and the ways in which organisms interact with one another through space and time (Chapin III *et al.*, 2000). According to Datta *et al.*, (2010), 42 species were recorded on Bandstand shore (Bandra), Mumbai, India. The distribution and abundance of organisms are influenced by both positive and negative associations among each other (Wright *et al.*, 2006). Habitat structure has a key role in affecting patterns of assemblages of organisms and the interactions among them. The mussel beds provide a favorable habitat for a wide range of associated organisms that find shelter and food between the mussels (Seed and Suchanek, 1992). Many associated species are more abundant in mussel beds than in surrounding habitats such as sand or mud bottoms or bare rock surfaces. Species richness and diversity of the associated fauna increase with age and size of mussel patches (Tsuchiya and Nishihira, 1986), and decrease with increasing tidal elevation (Hertlein, 1997).

Mussel beds are known to harbor a variety of animals in interstitial spaces or on surfaces provided by mussels and algae growing on their shells (Kocatas, 1978); Chintiroglou *et al.*, 2004). Associated species comprise highly mobile as well as more sedentary organisms. Mobile species roam in the complex matrix of the mussels searching for prey or detritus retained in interstitial spaces. Sedentary species attach self-constructed tubes between the mussels feeding primarily on allochthonous materials that is continuously imported in to the mussel bed (Thiel and Ullrich, 2002).
Mussel beds are complex entities that provide refuge and suitable habitat for an array of associated organisms (Tsuchiya and Nishihira, 1986). The associated fauna, as well as the mussels themselves, form a rich food source for many predators, such as crabs, starfish, and birds (Hertzler, 1995). Habitat structure has a key role in affecting patterns of assemblages of organisms and the interactions among them (Beck, 2000). Ecological engineers such as mussels (Thiel and Ullrich, 2002) occupy an ecosystem for long periods of time change it and create conditions that facilitate the existence of the other species (Borthagaray and Carranza, 2007).

Mussel beds retain the receding sea water and organic materials thus increasing moisture content and food availability for resident organisms (Gutierrez et al., 2003a). This means that mussel beds control nutrient flow to associated organisms (Hasting et al., 2007). Individual mussel patches remain in place for sufficiently long time to allow associated fauna to grow and reproduce within the dense interwoven network of byssal threads and mussels. Thus, in mussel beds increase the diversity of habitat characteristics available to other organisms.

Beds of mussels contain diverse assemblages of fauna and flora from different phyla (Svane and Setyobudianti, 1996). The distribution and abundances of species inhabiting mussels can vary according to height on the shore (Lintas and Seed, 1994), season (Peake and Quinn, 1993) and/or species of mussel (Iwasaki, 1995). This suggests that mussel aggregations in sedimentary environments may not invariably be diversity hot spots within the ecosystems in which they are found. The specific modes in which mussels provide hard substratum and shelter, stabilize, accrete and modify sediments and occupy space can have facilitatory on some as well as inhibitory effects on other species. Depending on the coastal system and its species assemblage, these effects may result in either enhanced or decreased diversity within mussel beds. Independently of the richness of associated communities, mussel aggregations may
provide habitat to species that are otherwise absent or rare in soft bottom habitats (Commito and Dankers, 2001). Despite their ubiquity and tremendous ecological and economic importance, little is known about macrofaunal diversity relationships in bottom mussel beds in Indian coasts, particularly along the Kanyakumari coast. Investigation on the species abundance and composition of the faunal assemblages of mussel mixed aggregations of *Perna indica*, *Perna viridis* and Intermediate *Perna sp.* were carried out and presented along Enayam, Colachel and Kadiyapattanam coast.
4.2 Materials and methods

4.2.1 Study area

The studies were carried out at three locations viz., Enayam, Colachel and Kadiyapttanam. These locations had moderately exposed rocky shores containing beds of intertidal mixed mussels, *Perna indica*, *Perna viridis* and Intermediate *Perna sp.* of different sizes in a single layer, although the average mussel size at three locations could be considered as similar (Plate 4.1).

Plate 4.1 Mussel settlement areas along (a) Enayam (b) Colachel and (c) Kadiyapttanam
These sites comprised of similar networks of bare rock, barnacle covered rock, patches of mussels and epilithic and epibiotic strands of macroalgae. Enayam (8°13 '29"N 77°11'6"E) is a flat intertidal rocky reef made up of mixed sand stones, shales and limestones (Plate 4.1a). Colachel (8°10 'N 77°15'E) is a sheltered cove of sandy mud with rapid tidal currents but little wind exposure (Plate 4.1b). Kadiypattanam (8°07' 57" N 77°19' 27" E) is a headland (Plate 4.1c), on an outcrop that contains many deep crevices and is made up of meta-sediments and rocks. The mussels *Perna indica, Perna viridis* and Intermediate *Perna sp.* are common inhabitants of intertidal hard bottoms along the coasts of Enayam, Colachel and Kadiyapttanam. Samples of these mussels and the associated fauna were collected during January to December 2011, from the three sites along the South Indian coast of Kanyakumari.

4.2.2 Experimental procedures

The experiment was initiated on 10th January 2011. At each location, six patches of mussels (100 cm$^2$), comprising mostly of large mussels (>2 cm length) were taken from the mid shore. The vast majority of mussels in patches of larger mussels were visibly larger than those in patches in of smaller mussels. Patches of larger mussels occasionally contained some small mussels and these were removed so that these patches only contained mussels of >2 cm length. The mussel patches were removed intact and brought to the laboratory, where they were rinsed with seawater and all associated fauna were removed carefully and sorted.

Many of the invertebrates that live amongst mussel beds were mobile. From each site, mussel formed a circle were carefully scraped from the rock with the entire associated fauna and samples were preserved in 5% formalin. In the laboratory, the samples were washed over a 500µm sieve. The entire material retained on the sieve was sorted for mussels and associated

Taxa were identified according to the Zoological survey of India (http://www.or/wiki/zoological_survey-of-India; Marine species identification portal key nature; OBIS- Indo-Pacific Molluscan database, Rosenberg and Gofas, 2012, Siphonaria assessed through: World register of Marine species at http://www.marinespecies.org/aphia.php?p=taxdetails&id; Robert and Robert, 1982 and Collin et al., 2005. Doubtful organisms were identified using the European Register of Marine Species (http://www.smed.org) and Hayward & Ryland (1995).

Following the identifications and counting the biomass was determined for each group of mussels and the major taxa of the associated fauna. Based on a sample mussel of >2 cm body length the individual biomass was calculated for all other mussels >2 cm. For the associated fauna an individual-based average biomass was determined and used to calculate the biomass of the respective species in each sample as per the method of Sukhotin et al., (2008); Connor and Crowe, (2007). Faunal assemblages were collected randomly from those available. In all cases, up to 2.5 cm from the edge of each patch was not sampled to avoid any potential edge-effects on the biota (Saunders et al., 1991; Bell et al., 2001).

**4.2.3 Statistical analyses**

The macrofaunal assemblage variables included abundance and species richness. ANOVA was employed to examine for statistical differences between sampling sites. Since in most cases, the variances were not homogeneous, a two factor ANOVA was used. Only studies in which samples had a minimum surface area of 50cm$^2$ were considered for inclusion in this comparison. The abundance values reported for individual taxa were averaged and transferred to a value of individuals per 100cm$^2$ in order to allow for direct comparison between different
studies. The studies on the fauna associated with bottom mussel beds considered in all cases the entire fauna down to the bare rock surface. All the environmental and macrofaunal assemblage variables and the abundances of the dominant individual species were analyzed for differences across scales with a two way ANOVA.
4.3 Results
4.3. Faunal assemblage of mussels

During the initial period of observation in January 2011, the density of mussels was higher than that of faunal assemblages at the mid- and low-tidal level on the patches. The taxa identified in the cores of mussels in all the three locations (Enayam, Colachel and Kadiyapttanam) (Plate 4.1 a, b and c) and the levels of taxonomic resolution noted are given in Table 4.1. The null hypothesis about that abundance and composition of assemblages and similarities between the three types of habitat on each coast was tested using two-way ANOVA and the results are presented in this chapter.

Plate 4.2 Mussel associated organisms (a) brittle star *Ophiocoma* sp. (b) *Neries* sp. (c) sponge *Callyspongia* sp. (d) mollusca *Fissurella nubecula* in mussels
4.3.2 Species richness, diversity and patterns of associated taxa

A total of 1244 individuals of 27 species belonging to 5 Phylum were found in the assemblages of which Phylum Mollusca had the highest number of species (12) followed by, Arthropoda 6, Annelida 4, Echinodermata 4 and Porifera 1. The Enayam coast showed maximum biomass (38.9%) value of mussels followed by Colachel coast (31.5%) and Kadiyapattanam (29.5%). However numbers of taxa was lower in the Enayam coast (14 taxa) followed by 18 taxa in Kadiyapattanam coast whereas the highest (22) numbers of taxa were recorded in Colachel between the period of January and December 2011 (Table 4.1).

Table 4.1

List of species collected from the different mussel species from study sites

<table>
<thead>
<tr>
<th>Phylum</th>
<th>Species</th>
<th>Enayam</th>
<th>Colachel</th>
<th>Kadiyapattanam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porifera</td>
<td><em>Callyspongia</em> sp.</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td></td>
<td><em>Arenicola</em> sp.</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Annelida</td>
<td><em>Harmothoe</em> sp.</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td><em>Neries</em> sp.</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td><em>Syllidia</em> sp.</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Arthropoda</td>
<td><em>Ampelisca brevocornis</em> (Costa, 1853)</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td><em>Balanus amphitrite</em> (Drawin, 1854)</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td><em>Balanus</em> sp.</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td><em>Carcinus</em> sp.</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td></td>
<td><em>Corophium archerusicum</em> (Costa, 1851)</td>
<td>+</td>
<td>+</td>
<td>-</td>
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<tr>
<td></td>
<td><em>Corophium</em> sp.</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td><em>Crassostrea</em> sp. (spat)</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Species</td>
<td>Code 1</td>
<td>Code 2</td>
<td>Code 3</td>
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<tr>
<td>Crepida sp.</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
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<tr>
<td>Donax variabilis (Say, 1822)</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
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<tr>
<td>Fissurella natalensis (Krauss, 1848)</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td></td>
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<tr>
<td>Fissurella volcano (Bruguiere, 1789)</td>
<td>-</td>
<td>-</td>
<td>+</td>
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<tr>
<td>Mysella sp.</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Neopilina sp.</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Mollusca Patella vulgata (Linnaeus, 1758)</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td></td>
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<tr>
<td>Petricola sp.</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Siphonaria javanica (Lamark, 1819)</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Siphonaria laciniosa (Linnaeus, 1758)</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Siphonaria normalis (Gould, 1846)</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td></td>
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<tr>
<td>Amphipholis sp.</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td></td>
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<tr>
<td>Axiognathus sp.</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Echinodermata Ophiocoma sp.</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Styela sp.</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

### 4.3.3 Species richness, diversity and associated taxa in Enayam coast

Faunal assemblages of Enayam coast accounted for 38.9% of the total individuals (1186 individual mussels) with higher average abundance of Phylum Mollusca (157 organisms), Arthropoda (133 organisms) followed by Annelida (87 organisms), Echinodermata (58 organisms) and Porifera (49 organisms). In this coast, Phylum Annelida had maximum numbers of organisms while the Phylum Porifera had the minimum (Fig. 4.1).
Fig. 4.1 Abundance of different Phylum at Enayam coast associated with mussels

The abundant species in this coast included *Neries* sp.(87 individuals), *Carcinus* sp.(57 individuals), *Callyspongia* sp. (49) *Balanus amphitrite*, Drawin, 1854(40), *Crassostrea* sp. (40) *Amphipolys* sp. (35) along with *Donax variabilis*, Say, 1822(34) even as lower abundance of *Coropium* sp.(17 individuals), *Corophium archerusicum* (Costa, 1851)(19) and *Patella vulgata*, Linnaeus, 1758(19) and *Petricola pholadiformis*, Lamark, 1818(20) (Fig. 4.2).

Fig. 4.2 Abundance of different species associated with mussels at Enayam coast
The seasonal and size variation of mussel assemblages at Enayam coast was high (109 organisms) in December and was noted among 7.1±0.68 cm length group of mussels followed by 92 organisms in November, 73 in October and 54 in September among the mussels, of 6.4±0.10 to 5.5±0.33 cm. Lower number of organisms (10) was recorded during June, 11 organisms in July and 12 in May from mussels with the length of 3.65±0.35, 4.4±0.47 and 2.75±0.18 cm. The trend is represented in Fig. 4.3.

Fig.4.3 Trend of faunal abundance in Enayam coast with different shell sized mussels

In this coast, only one Porifera species, *Callyspongia* sp. (49 individuals) in which highest number of 11 individuals was noted at December followed by 9 in November and 8 in October with the mussel size ranged from 7.1±0.68 to 6.2±0.4cm and very low level of individual (1) was observed from May to August with the mussel size from 2.75±0.18 to 4.6±0.22cm (Fig.4.4 & 4.5a).

In Phylum Annelida, *Neries sp.* was the abundant (87 individuals) species, wherein 18 individuals observed on December, 15 in November, 14 in October and 10 individuals in September, the length of mussel were 7.1±0.68 to 6.2±0.4cm. but minimum number of *Neries*
sp. (2) was observed from May to July at this point of time the mussel length were $2.75\pm0.18$ to $4.4\pm0.47$cm (Fig.4.4 & 4.5b)

In Arthropoda, highest average abundant species *Carcinus* sp. Linnaeus, 1758 (57), where 10 individuals noted on November and December in which the mussel attained length ranging between $6.4\pm0.10$ and $7.1\pm0.68$cm while minimum number (1) of this species noted on May to July, the mussel length ranged from $2.75\pm0.18$ to $4.4\pm0.47$ cm respectively. Whilst the minimum number of species observed among this Phylum was *Coropium* sp. (17) in which, the maximum 6 individuals observed on December followed by 2 in November, October and September at that time mussel length ranged between $7.1\pm 0.68$ and $5.5\pm 0.33$ cm. No individual of this species was observed between June and August, when the mussel size was $3.65\pm 0.35$ and $4.6\pm0.22$cm (Fig. 4.4 & 4.5c).

In Mollusca, spats of *Crassostrea* sp. was the highest abundance species (40 individuals) followed by 11 in December, 10 in November and 6 in October, in which the mussel length was $7.1\pm0.68$ to $6.2\pm0.4$cm. In addition, low numbers (19) of *Petella vulgata* (Lamark, 1818) was observed, hence the maximum number (4) was recorded on November and December within the mussel length were $6.4\pm0.10$ and $7.1\pm0.68$cm but lowest number (1) of individuals noted on July and August with the mussel length $4.4\pm 0.47$ and $4.6\pm0.22$cm respectively. But from March to June, these species were completely missing in this station (Fig. 4.4 & 4.5 d).

In Echiodermata, *Amphipolis sp.* was the highest (35) assemblage species followed by 9 individuals in December, 8 in November and 6 in October by which time the mussel length ranged from $7.1\pm0.68$ to $6.2\pm0.4$cm. However 23 number of *Styela* sp. was observed, the highest number (6) of these species observed on December month where the length of the mussels were $7.1\pm0.68$cm but a minimum number of single individual was noted on January to March and
August, when the mussel length ranged between $6.4 \pm 0.14$ and $2.38 \pm 0.34$ cm and $4.6 \pm 0.22$ cm. However, *Styela* sp. was completely absent in June and July when length of the mussels were $3.65 \pm 0.35$ and $4.4 \pm 0.47$ cm respectively (Fig. 4.4 & 4.5e).

![Graph showing species abundance from January to December 2011](image)

**Fig. 4.4** Species abundance along Enayam coast from January to December 2011

![Graphs showing mussel length vs number of individuals for different phyla](image)

(a) Mussel length vs Number of individuals of Phylum Porifera  
(b) Mussel length vs Number of individuals of Phylum Annelida
In the Enayam coast, maximum number of single Porifera (11) were observed in December followed by November (9) and October (8) in which the mussel length ranged from $7.1\pm0.68$ to $6.2\pm0.4$cm although a minimum (1) individuals belong to this Phylum were noted on May to August within the length size of $2.75\pm0.18$ to $4.6\pm0.22$cm. In Phylum Annelida, the highest abundance number (18) of species was recorded in December, 15 in November, 14 in October and 10 in September, the mussel lengths were $7.1\pm0.68$, $6.4\pm0.10$, $6.2\pm0.4$ and
The minimum number (2) of these groups organisms recorded between the period of May and July, the length of mussels was 2.75±0.18 and 4.4±0.47 cm. In phylum Arthropoda, maximum number of faunal assemblage (31) was recorded on December followed by 23 in November, 18 in October and 16 in September; the mussel length ranged from 7.1±0.68 to 5.5±0.33 cm but very low number (3) were observed on June and July, the mussel length was 3.65±0.35 and 4.4±0.47 cm. In phylum Mollusca, maximum number (34) of organisms were observed in December, 32 in November, 16 in October and 10 in September, the mussel length ranged from 7.1±0.68 to 5.5±0.33 cm, the minimum 3 organisms were observed belonging to this phylum in June and July; the mussel length being 3.65±0.35 and 4.4±0.47 cm respectively. In Phylum Echinodermata, the maximum of 15 individuals were observed in December, 13 in November and 10 in October, the mussel length ranged from 7.1±0.68 to 6.2±0.4 cm. Minimum number of single individuals were noted in April and May, the mussel length being 2.71±0.36 and 2.75±0.18 cm. However, in June and July, this phylum was missing in this coast (Fig.4.5 f and 4.6).
Two-way ANOVA analysis showed a significant effect (F=44.81; df= 11; M.S=108.46; P ≥ 0.01; Fcrit= 1.843) of mussel assemblages with influence seasons (January to December) as well as, significant effect (F= 44.8; d.f=11; M.S=108.76; P≥0.01; Fcrit= 1.840) of mussel assemblages with various size of mussels (2.0 to 7.0cm).

4.3.4 Species richness, diversity and patterns of associated taxa in Colachel coast

The Colachel mussel site was characterized by a very patchy distribution of the mussel and the faunal assemblage accounted for 31.5% of the total individuals (1130) mussels. The most dominant Phyla in the area were Annelida (121) individuals, Mollusca (110), Arthropoda (93), Echinodermata (37) and Porifera (31 individuals). Phylum Annelida had maximum number of organisms at this station and phylum Porifera was minimum at this coast (Fig. 4.7).

Fig.4.7 Faunal assemblages in Colachel coast

The most frequent species of the mussel samples of this coast were Neries sp., (50 individuals) of the total biomass in mussel samples, followed by Arenicola sp. (37 individuals), Callyspongia sp., (31), Balanus sp., 1854 (29) Neopilina sp., (29) and Crassostrea (25) at the
same time as minimum frequent species were *Styela sp.* (2) followed by *Amphipolis sp.* (5), *Axiognathus sp.* (6), *Crepidula sp.* (7) and *Coropium archerusicum* (Costa, 1851) (8) (Fig. 4.8).

**Fig. 4.8** Species abundances in Colachel coast

In Colachel coast, the seasonal and size variation of mussel affected faunal assemblages and high number of organisms (90) was noted in December along with mussels in the range of 7.1±0.12 cm, 73 organisms in November with mussel size of 6.78±0.57 cm and 62 organisms in October with 6.03±0.87 cm size mussels. Low numbers of 7 organisms were noted in June among of 4.08±0.35 cm mussels (Fig. 4.9).
In Colachel coast, only one species *Callyspongia* sp. (31) among Phylum Porifera was recorded with highest number of 9 individuals at December in 7.17±0.12cm size of mussels followed by 6 at November in 6.78±0.57cm mussels. Whilst lowest amount of single individual noted on March, April and August in mussel sizes were 2.59±0.74, 3.35±0.81 and 4.99±0.59cm but no individual was noted between May and July in mussel length was 3.59±0.63, 4.08±0.35 and 4.63±0.29cm (Fig.4.10 & 4.11a).

In Annelida, *Neries* sp. species was highly abundance (50) in this coast, in which 12 individual in December, 10 in November, 9 in October and 8 in September were observed and the mussel length size of this period were 7.1±0.12, 6.78±0.57 and 5.55±0.08cm respectively, at the same time as single number of this species was observed in between March and August, their mussel length was 2.59±0.74, 3.35±0.81, 3.59±0.63, 4.08±0.35, 4.63±0.29 and 4.99±0.59cm correspondingly. Followed by 37 individual of *Arenicola* sp. was observed. From this, 9 in
December, in November and October and their mussel length were 7.1±0.12, 6.78±0.57 and 5.55±0.08cm and single individual of this species observed from February to August the length of mussel were 6.38±0.11, 2.59±0.74, 3.35±0.81, 3.59±0.63, 4.08±0.35, 4.63±0.29 and 4.99±0.59cm respectively. In this Annelida, Syllidia sp. were observed in very low numbers(13), wherein a maximum of 2 individuals were recorded in January and between September and December period the length of the mussels were 6.67±0.15, 5.55±0.08, 6.03±0.87, 6.78±0.57 and 7.17±0.12cm. Unfortunately no individual of this species was noted from April to July months, the mussel length of this period was 3.35±0.81, 3.59±0.63, 4.08±0.35 and 4.63±0.29cm respectively (Fig.4.10 & 4.11 (b).

In Arthropoda, highest average abundance of the species Balanus Amphitrite, Darwin, 1854, (29 individuals) were recorded 7 in December, 6 in November and 4 in October during which the mussel length was 7.17±0.12, 6.78±0.57 and 6.03±0.87cm. No individual was noted in March when the mussel length was 2.59±0.74cm. In this Phylum, Coropium archerusicum, Costa,1851 (8 individual) was the minimum number of species (Fig.4.8), wherein maximum 2 individual of this species noted on September and October, just then the mussel length of this period were 5.55±0.08 and 6.03±0.87cm. Interestingly this species was completely absent between February and July, then the mussel measurement of this period were 6.38±0.11, 2.59±0.74, 3.35±0.81, 3.59±0.63, 4.08±0.35 and 4.63±0.29cm respectively (Fig. 4.10 & 4.11(c).

Among phylum Mollusca, Neopilina sp. (29 individuals) was most abundant species distributed in the coast of Colachel. During this study period high number (7 individuals) of this species were observed in December followed by 5 in November and 4 in October (Fig.4.7) wherein the length of the mussels were 7.17±0.12, 6.78±0.57 and 6.03±0.87c.m (Fig.8 (d), although the minimum number (1) of this taxa was noted in between March and August (Fig.4.7)
in which the mussel length were 2.59±0.74, 3.35±0.81, 3.59±0.63, 4.08±0.35, 4.63±0.29 and 4.99±0.59 cm respectively (Fig.4.8 (d). *Mysella sp.* was the very lowest number (5) of taxa noted among this phylum. In this phylum, maximum numbers of 2 individuals were observed in December with mussel size 7.17±0.12cm except no individuals of this species was noted between January and August (Fig. 4.10 & 4.11(d).

In Phylum Echinodermata, *Ophiocoma* sp. has the highest number (24), the maximum numbers of this species (7) were recorded on December followed by 6 individuals on November. In which the mussel length were 7.17±0.12, 6.78±0.57 and 6.03±0.87cm. Whilst the minimum number of this species (1) was observed in January, February, March and August, their length size of mussels were 6.67±0.15, 6.38±0.11, 2.59±0.74 and 4.99±0.59cm correspondingly. Unfortunately this species was entirely missing from April to July. Among this Phylum Mollusca, *Styela* sp. (2 individual) has the lowest number of species observed, here 1 individual in November and another single individual in December with shell size of 6.78±0.57 and 7.17±0.12cm (Fig.4.10 & 4.11(e).

![Fig.4.10 Species abundance during various months](image)
(a) Mussel length vs Number of individuals of Phylum Porifera
(b) Mussel length vs Number of individuals of Phylum Annelida

(c) Mussel length vs Number of individuals of Phylum Arthropoda
(d) Mussel length vs Number of individuals of Phylum Mollusca

(e) Mussel length vs Number of individuals of Phylum Echinodermata
(f) Mussel length vs Number of individuals of 5 Phylum
Fig. 4.11 Species abundance among the different size group of mussels

Porifera samples with a maximum numbers observed were: December (9), November (6) and October (5), the length of the mussels was $7.17\pm0.12$, $6.78\pm0.57$ and $6.03\pm0.87$. Very low number, each single individual was noted during March, April and August, the mussel length were $2.59\pm0.74$, $3.35\pm0.81$ and $4.99\pm0.59\text{cm}$ but Porifera organisms fully vanished from May to July, the mussel length were $3.59\pm0.63$ to $4.63\pm0.29\text{cm}$ respectively. In Annelida (121 individuals), the maximum number of organisms (28) noted during December, 23 in November and 21 in October, when the mussel length were ranged from $7.17\pm0.12$, $6.78\pm0.57$, $6.03\pm0.87$ and $6.67\pm0.15\text{cm}$ as well as minimum numbers (3) were noted on May to July, then the length of the mussels were $3.59\pm0.63$ to $4.63\pm0.29\text{cm}$. But the Phylum Arthropoda (93 individuals), in which higher number of 18 individuals observed on December, 17 in November and 14 in October and 12 in September then the length of the mussels were ranged from $7.17\pm0.12$ to $5.55\pm0.08\text{cm}$ respectively but least single individual was noted on July, where the length of the mussel was $4.63\pm0.29\text{cm}$. In Mollusca (110 individuals), the greatest number of organisms (23) was screened on December and 18 on November at this time the length of the mussels were $7.17\pm0.12$ and $6.78\pm0.57\text{cm}$ although the minimum numbers of 2 individuals were noted on July, the mussel length was $4.63\pm0.29\text{cm}$. In Echinodermata (37 individuals), the highest number of 12 individuals noted on December, 9 on November and 6 on October, then the mussel length were $7.17\pm0.12$ to $6.03\pm0.87\text{cm}$. However, lowest number of single individual was noted on February, March and August, the length of the mussels were $6.38\pm0.11$, $2.59\pm0.74\text{cm}$ and $4.99\pm0.59\text{cm}$. But not even one species of Phylum Echinodermata was observed among from April to July, in which the mussel lengths were $3.35\pm0.81$ to $4.63\pm0.29\text{cm}$. Fig. 4.11(f) and 4.12.
Fig. 4.12 Abundance of different Phyla in different months in Colachel coast

Two-way ANOVA analysis showed a significant effect ($F=36.21; \text{d.f}= 11; \text{M.S}=40.092; P \geq 0.01; F_{\text{crit}}= 1.82$) of mussel assemblages with various season (January to December), significant effect ($F= 37.5; \text{d.f}= 11, \text{M.S}=41.42; P \geq 0.01; F_{\text{crit}}= 1.819$) of mussel assemblages with various size of mussels (2 to 7cm).

4.3.5 Species richness, diversity and patterns of associated taxa in Kadiyapattanam coast

In Kadiyapattanam coast, the mussel and the faunal assemblage accounted for 29.5% of the total individuals (1145 indi. mussels). The highest number of phyla in this station were Mollusca (166 organisms) followed by Annelida (56 organisms), Arthropoda (76), Echinodermata (43) and Porifera (27 individuals). From this result revealed that the Phylum Mollusca reached the highest abundance of this coast and Porifera was lowest position of this station (Fig.13).
Fig. 4.13 Faunal assemblages of Kadiyapattanam coast from January to December, 2011

The major taxa were represented on the samples of the mussel included *Neries* sp. (56 individuals), followed by *Ophiocoma* sp. (43), *Crassostrea* sp. (30), *Balanus* sp. (27), *Balanus amphitrite* (25) and *Donax variabilis* (Say, 1822) (25) along with least numbers of species were *Siphonaria normalis* (Gould, 1846) (6) followed by *Mysella* sp. (6), *Corophium* sp. (11), *Petricola* sp. (12), Fig. 4.14.
In Kadiyapattanam coast, the size of mussels and seasonal variations affected faunal assemblages. Higher assemblages was noted (77 organisms) in December when mussel size was (7.6±0.81 cm) along with 66 organisms in November with mussel size of 6.8±0.76cm and 53 organisms in October with 5.69 ±0.32cm size even if minimum numbers of 9 organisms were screened in July and their length of mussels were 4.29±0.21cm subsequently10 numbers of organisms in May and June, 14 in April and 16 in March but these organisms occupied mussels length were 3.35±0.20, 3.93±0.39, 2.71±0.48 and 2.38±0.15cm o 4.63±0.29cm respectively (Fig.4.15).
During the study period of this station, unique taxa *Callyspongia* sp. (27 individuals) was identified among the Phylum Porifera. In which the highest number of 8 individuals at December in 7.6 ±0.81cm size of mussels followed by 7 in November with 6. 8±0.76cm mussels. Even as lowest amount of single individual noted on February when mussel size was 6.32±0.27 but no individual was noted between March and July by which time the mussel size was 2.38±0.15, 2.71±048, 3.35±0.20, 3.93±0.39, 4.29±0.21cm respectively as could be noted from Fig.4.16 & 4.17(a).

A total of *Nerites* sp. (56) was the highest abundance species infested belong the phylum Annelida., here the maximum number (12) of these group individuals observed on December after that 10 individuals in November, 9 individuals in October and 8 in September, then the length of mussels were 7.6±0.81, 6.8±0.76, 5.69±0.32 and 5.24±0.30 cm apart from single
individuals recorded on between May and July, their mussel length were 3.35±0.20, 3.93±0.39 and 4.29±0.21cm correspondingly (Fig. 4.16 & 4.17 (b).

The present study, larger numbers of Balanus sp. (27) established prevalence. Among Phylum Arthropoda, maximum 6 individuals were observed on November and 5 on December in that case the length of the mussels were 6.8±0.76 and 7.6±0.81cm but very low number (1) of these noted from March to June and August, the length of the mussels were 2.38±0.15, 2.71±0.48, 3.35±0.20, 3.93±0.39 and 4.40±0.13cm correspondingly interestingly no individual of this taxa was observed on July, the mussel length was 4.29±0.21cm. But Coropium sp.(11) was the very low number of individuals recorded, the maximum numbers of 2 individual of this species were noted on January, September, October and November during that period the mussel length were 6.5±0.33, 5.24±0.30, 5.69±0.32 and 6.8±0.76 cm yet minimum number (1) of this species was observed on February, August and December, the length of the mussels were 6.32±0.274.40±0.13 and 7.6±0.81 cm even no individual of this species was noted between March and July (Fig. 4.16 & 4.17 (c).

The higher number of species Crassostrea sp.(30) were represented in the Phylum Mollusca, though 8 in December and 6 in November, the mussel length were 7.6±0.81 and 6.8±0.76 cm At the same time as single individuals occurred between March and August, here the length of mussels were 2.38±0.15 to 4.40±0.13cm. Even as Mysella sp. and Siphonaria normalis (Gould, 1846) were the smallest number (6) of species observed among this phylum. The single Mysella sp. was observed on January, April and August to December. But no individual was observed on other period. In contrast the maximum number Siphonaria normalis (Gould, 1846) of two individuals recorded on January, the mussel length was 6.5±0.33cm. But this species was completely absent from February to July and November (Fig. 4.16 & 4.17 d).
In Echinodermata only one species was *Ophiocoma* sp. (43) collected in this station. At this point the maximum number of 15 individuals recorded on December followed by November 11 and October 8, where the mussel length were 7.6±0.81, 6.8±0.76 and 5.69±0.32, but very low number (1) was noted between January and March, here the mussel length were 2.71±0.48 to 4.29±0.21 cm respectively. This species entirely missed from April to July (Fig. 4.16 & 4.17(e)).

![Species abundance in different months](image_url)

Fig. 4.16 Species abundance in different months
(a) Mussel length vs Number of individuals of Phylum Porifera  
(b) Mussel length vs Number of individuals of Phylum Annelida

(c) Mussel length vs Number of individuals of Phylum Arthropoda  
(d) Mussel length vs Number of individuals of Phylum Mollusca

(e) Mussel length vs number of individuals of Phylum Echinodermata  
(f) Mussel length vs Number of individuals of 5 Phylum

Fig.4.17 Faunal abundance in different size of mussels
In Kadiyapattanam coast, Porifera species (with a maximum numbers of 8) were observed in December followed by 7 during November when the length of the mussels was $7.6\pm0.81$ and $6.8\pm0.76$cm. But very low number of single individual observed in February, then length of the mussel was $6.32\pm0.27$cm. No Porifera was observed during March to July, when the mussel length was $2.38\pm0.15$ to $4.29\pm0.21$cm respectively. In Annelida, 56 individuals were noted, wherein the maximum number of 12 in December, 10 in November, 9 in October and 8 in September, the length of the mussels were ranged from $7.6\pm0.81$ to $5.24\pm0.30$cm and minimum number single species was noted between May to July, the mussel length was $3.35\pm0.20$cm $3.93\pm0.39$ to $4.29\pm0.24$cm. But 76 species was observed among the Phylum Arthropoda, in which higher number of 15 individuals observed on November 12 in December and 11 in October here the mussel length ranged from $6.8\pm0.76$, $7.6\pm0.81$ and $5.69\pm0.32$cm respectively other than minimum 2 individuals noted on April and June, in which the mussel length were $2.71\pm0.48$ and $3.93\pm0.39$cm. No individual was note on July. In Mollusca (166), the maximum number of organisms (30) was screened on December, 23 on November and 21 on October here the mussel length ranged from $7.6\pm0.81$ to $5.69\pm0.32$cm although the minimum number of 6 individual was noted on May, the mussel length was $3.35\pm0.20$cm. In Echinodermata (43), the highest number of 15 individuals noted on December and 11 on November then the length of mussels were $7.6\pm0.81$ and $6.8\pm0.76$cm But minimum number of single individual were noted between January and March, the mussel length ranged from $6.5\pm0.33$ to $2.38\pm0.15$cm. Interestingly no one species was observed among Echinodermata phylum from April to July, in which the mussel length were $2.71\pm0.48$ to $4.29\pm0.21$cm. Fig. 4.17(f) and 4.18.
Two way ANOVA analysis showed a significance \( F=18.7; \text{d.f.}=11; \text{M.S.}=43.58; P \geq 0.01;\text{F}_{\text{crit}} = 1.83 \) of mussel assemblages with that of various seasons (January to December) as well as, significant effects \( F= 19.9; \text{d.f.}=11, \text{M.S.}=45.32; P \geq 0.01;\text{F}_{\text{crit}} = 1.832 \) of mussel assemblages with various size of mussels (2 to 7cm).

Over the duration of the study period, totally 3465 mussels were collected from these three coasts, in which 1186 from Enayam, 1130 from Colachel and 1145 from Kadiyapattanam, the most abundant species (22 species, 392 individuals) found in mussel beds along the coast Colachel (Fig.4.7) followed by the organisms were numerically abundant (18 species, 368 individuals) in mussel beds formed in Kadiyapattanam coast (Fig.4.12). Species showed a reverse trend, with the lowest abundance at that Enayam coast (14 species) but interestingly, highest number of 484 individuals was noted in this station (Fig.4.2). Observations revealed that the major taxa were represented at all sampling sites, but some taxa only occurred. The mean abundance of species from each sample differed among months and with the zonation of the mussel species. Overall data showed that the maximum number of organisms found during September to December and January, February months, throughout the period mussel length was >5 cm that is the highest length of mussels hold large amount of species than the smaller ones.
4.4 Discussion

In many coastal habitats, complex three-dimensional microhabitats are formed by plants and invertebrates. Such habitats may be formed by the different species living in close proximity such as oyster reefs (Coen and Luckenbach, 2000), mussels beds (Seed and Suchanek 1992; Lintas and Seed, 1994) and macroalgae (Kelaher et al., 2001). A large number of small invertebrates and algae live in association with these biogenic structures, which provide shelter from physical stress (Kelaher et al., 2001) and food (Caine, 1987). Such small, cryptic species form a large proportion of local biodiversity, although there are relatively few quantitative studies of their distributions, abundances, habitat-requirements, etc., compared to those of the larger and more obvious fauna. The present study brought to light about a very large diversity of mobile as well as sessile invertebrates in clumps of *Perna indica*, *Perna viridis* and Intermediate *Perna* sp. mussels. Most studies of assemblages living in association with biogenic habitat have compared them to those living on bare rock or in intertidal sediments and found significant differences (e.g. Gunther, 1996; Thompson et al., 1996; Crooks, 1998; Turner et al., 1999; Olabarria and Chapman, 2001a; Atilla et al., 2003).

The assemblages varied within species and these differences in abundance were probably most important for distinguishing between habitats. Frequencies of occurrence were similar for shared (approx. 70%) taxa, but the identity and/or frequencies of occurrence of unique taxa also contributed to differences. Available multivariate analyses do not allow the relative contributions of taxonomic identity and frequency of occurrence among replicates to be distinguished (Clarke, 1993). For most of the taxa that contributed relatively, large proportions of the measures of dissimilarity between assemblages, there were more individuals in mussels. The considerable small-scale variability in marine assemblages is the norm (Morrisey et al., 1992; Underwood and
Chapman, 1998; Kelaher et al., 2001), including those living on seawalls (Chapman and Bulleri, 2003). Often very little of this variability is explainable by physical, environmental factors (Underwood and Chapman, 1998). This shift in dominance seems to be induced by climatic factors and supported by structural factors. For example oysters are assumed to offer more surfaces for settlement when they grow tightly packed in vertical position (Markert, 2006).

The importance of mussel size structure influencing the structure of assemblages associated with the mussel beds varied spatially and is, therefore, context-dependent. This suggests that the resulting change in the structure of assemblages was driven by the relative abundance of the most abundant taxa and was not representative of a major change in the overall structure of the assemblages. The difference between assemblages was due largely to a change in abundance and proportion of several of the taxa found amongst mussels of both size classes (e.g. Neries sp. and Callyspongia sp.). However, almost 30% of the taxa were found uniquely in either patches of small or larger mussels. Assemblages in patches of larger mussels were less even, illustrating a greater variability in the presence and abundance of species and suggesting that the taxa found amongst larger mussels may be more patchily distributed in general. Larger species such as Neries sp., Callyspongia sp., Balanus amphitrite, Crassostrea sp., Arenicola sp., Ophiocoma sp., and Carcinus sp., were found in greater abundances in patches of larger mussels.

The species may be restricted to patches of larger mussels by the sizes of the interstices between mussels. Patterns of distribution may also be linked to feeding preferences and the availability of resources, however, this is difficult to interpret as the feeding preference of many marine organisms such as isopods and amphipods are poorly understood and may be quite plastic (Ingolfsson et al., 2003). The present study also recorded that species in greater abundances in patches of larger mussels than the smaller mussels. The number and identity of taxa recorded in
this study are comparable to previous studies on Irish mussel beds (e.g. Briggs, 1982; Healy & McGrath, 1998).

Organisms that provide additional living space with ameliorated stress may be beneficial for the conservation of biodiversity (Norkko et al., 2006). However, the interaction between habitat-forming organisms and the inhabiting species is not always positive (Kelaher, 2003). Habitat complexity may have a positive effect on the diversity and abundance of species associated with mussels and algae (McKindsey and Bourget, 2001; Kelaher, 2003). But species richness decreases as habitat complexity increases as shown in algal mats (Kelaher, 2003). Mussels generally occupy and often dominate much of the primary space on rocky shores (Paine and Levin, 1981; Iwasaki, 1995). Because mussels are ubiquitous and form complex mats on rocky shores, sediment is easily trapped in the interstitial spaces of mussel beds (Tsuchiya, 2002; Gutierrez et al., 2003a). The physical structure of mussel beds differs from species to species and so the associated macrofauna may also differ (Iwasaki, 1995; Hammond, 2001). In this context, the overall results of this study were predictable and in agreement with the original hypotheses even if there was some degree of variability between the three sites, the intertidal rocky reef made up of mixed sandstones, shales and limestones of Enayam, sheltered cove of sandy mud with rapid tidal currents but little wind exposure of Colachel and a headland, on an outcrop that contains many deep crevices and is made up of meta-sediments and rocks Kadiypatanam coast data sets.

The factors that influence the physical structure of an engineered habitat become more challenging to assess because of the biological processes that also influence the associated organisms in biogenic habitats (Kelaher, 2003). Similar to mussel beds (Tsuchiya, 2002), the organisms associated with coralline turfs are mainly influenced by the physical structure of the
habitat (Kelaher, 2003). Kelaher (2003) found that biological processes are far less important than the physical characteristics in structuring communities in coralline turfs. Mussels are the most conspicuous feature on most intertidal rocky shore made up of mixed sandstones, shales and limestones of Enayam. The compactness of mussel beds can increase or decrease the abundance and diversity of species. Because mussel beds are so complex in their structure, they present an opportunity for habitat heterogeneity to be further explored and quantified as suggested by Tsuchiya (2002) though the details of the communities associated with mussel beds were analysed for a period of one year.

Mussel beds suspend different amounts of sediment because of their tidal positioning and they can support different species (Iwasaki, 1995). The byssal threads pack the live mussels tightly with shell remains of other Mollusca and other organic material, and the sediment is suspended in between the interstitial spaces of a mussel bed. The results of this study indicate that the large mussel and seasonal variation probably support the highest number of species because mussel beds from these three stations are more structurally complex.

Although high sediment content in mussel beds may lead to unfavourable anoxic conditions, mussel patches with sediment still have higher species richness than those without sediment (Norling and Kautsky, 2008). Species richness is not only increased by the habitat structure provided by mussels, but also mussel their functional characteristics of clearing the water by filter-feeding and providing food for associated organisms (Norling and Kautsky, 2008). Mussel beds are generally very productive habitats that support high levels of biodiversity (Tsuchiya, 2002). From this study, a total of 27 species were collected, most of which belonging to the phyla Mollusca followed by Arthropoda, Annelida, Echinodermata and Porifera. This
study tested how the community structure of the macro-invertebrates associated with mussel beds are affected by mussel length size and season (month).

Both biological and physical factors affect the community structure of the marine organisms associated with mussel beds (Hammond, 2001). Species abundance and composition differs from coast to coast because it is governed by a combination of environmental factors and biological interactions (Chintiroglou et al., 2004). For this study, different species were found abundantly at different tidal levels, but few were exclusive to a specific zone. *Neries* sp. and *Carcinus* sp. were most abundant on the Enayam coast, the *Neries* sp. and the species *Arenicola* on the Colachel coast, and the taxa *Neries* sp. and *Ophiocoma* sp., on the Kadiyapatanam coast. However, there were a few species that were found exclusively in specific location and months (Fig.4.3, 4.9 & 4.15). December 2011 samples had a wider representation of species contributing to the community abundance than other months (Fig. 4.3, 4.9 & 4.15). From the present study, it could be inferred that the distribution, composition and abundance of the fauna associated with mussels were strongly influenced by season.

The changing density of mussels may negatively affect the abundance of associated species and the types of species that occupy mussel beds (Beadman et al., 2004). Wright and Jones (2006) claimed that the consequences of the removal of a foundation species have not been explored. The biomass and abundance of associated fauna decreases when mussels are removed intertidally (Hammond, 2001). However, Thiel and Ullrich (2002) claimed that associated organisms were more abundant within mussel beds than surrounding substrata or habitats. The comparison of biodiversity between the adjacent rock substratum and in the mussel beds was not considered in this study. The presence of mussels on rocky shores does not necessarily mean that species biomass is increased (Thiel and Ullrich, 2002), but mussel beds do facilitate the existence
of some species (Hammond and Griffiths, 2004) while excluding others (Ragnarsson and Raffaelli, 1999). The introduction of *Mytilus* has not only extended the occurrence of mussel beds vertically, but it has subsequently increased the benign, habitable spaces for other organisms to survive on the high shore at Marcus Island on the west coast of South Africa (Robinson *et al*., 2007). Mussels on hard substrata cater for a distinct group of organisms that need to take refuge from wave action and predators on rocky shores (Thiel and Ullrich, 2002).

The results of the present observation also indicated that the effectiveness of mussels in providing this shelter changes, regardless of the structural and temporal component. This suggests that the seasonal variation may govern biodiversity patterns at the scales that were examined in this study, overcoming parameters like structural and temporal variability. Although the choices of three sites were appropriate for the hypothesis test in this study, the results cannot be extrapolated as general patterns of this coast. The creation of unique habitats by ecosystem is important because it affects the distribution and the diversity of the associated species (Norkko *et al*., 2006). The qualities that make a facilitator successful in providing liveable conditions for other organisms have not been explored in detail (Bruno and Bertness, 2001) and understanding these positive interactions is important for conservation planning because natural habitats are disappearing at an alarming rate (Norkko *et al*., 2006). Mussels have been broadly described, in most parts of the world, as facilitators and providers of habitat for organisms that seek refuge from harsh environmental factors (Suchanek, 1986; Prado and Castilla, 2006; Seed, 1996).

The functions of mussels in their communities are, mussels dominate space on rocky shores and alter the physical state and the appearances of the rock, creating structurally complex beds that directly interfere with trophic interactions, mussel beds create livable spaces that have reduced physical stress and therefore, increase species abundance and diversity. They
involuntarily trap organic material and food that sustains these associated organisms and their shells increase the potential surface settlement area for encrusting organism and another one function were, mussels filter food from the water column and serve to link the pelagic and benthic ecosystems (Schiel, 2004; Borthagaray and Carranza, 2007). The presence of intertidal mussels provides the opportunity for different communities to survive on the rocky shores because of the favourable and tolerable conditions that mussel beds provide, and the various habitat options they offer. Although habitat complexity often translates to a species rich assemblage, the relationship between habitat structure and species diversity is not always positive because species diversity eventually declines with increasing habitat complexity (Kelaher, 2003). One of the important observation is that the mussel beds which contained high amounts of sediment particularly as noted in the Colachal coast supported a higher number of species, as shown in other studies (e.g. Tsuchiya and Nishihira, 1986; Lintas and seed, 1994; Hammond, 2001).

The efficiency of habitat modifiers in providing less stressful living spaces for other organisms changes along environmental gradients such as the rocky intertidal shores (Kelaher, 2003; Mullan and Bertness, 2006). Furthermore, the quality of carpet-like biogenic habitats created by habitat-forming organisms is influenced by structural complexity, the functioning of the species in its community (Davenport et al., 1999; Kelaher, 2003) and other contributing environmental factors. Evidently, in this study the effectiveness of mussels in providing three stations were enhanced, and because of the underlying physical effects experienced along the vertical gradient of the rocky shores there are clear limitations in the ability of mussels to provide ideal habitats for intertidal macro-organisms. The significance of an ecosystem engineer changes along these stress gradients according to the “ecosystem functions of interest” (Mullan and
Bertness, 2006) because the needs of the associated organisms also change along this gradient. A facilitator that is able to cater to the needs of the associated organisms in different environmental circumstances is surely a good investment for conservation because it supports a diversity of species (Mullan and Bertness, 2006). A good example of such is the role of mussels on the intertidal rocky shores as observed in this study and many others. Mussel beds protect the associated organisms on the low shore from biological factors such as predation and competition, and they create less stressful habitats for high shore organisms that did not previously exist (Mullan and Bertness, 2006).

The high organic content of deposited sediments can be exploited by the deposit feeding annelids (Mayer et al., 1997) which may directly invert assimilated energy into new offspring. Svane and Setyobudianda (1996) suggested a direct relationship between the degree of organic enrichment and the number of deposit-feeding annelids in mussel beds, as was also found by Norkko and Bonsdorff (1996 b) and Thiel et al., (1998) under algal mats. Mussel beds supported wide diversity of different trophic groups that are favoured by the structural protection within the mussel matrix. Thus, mussel beds do not necessarily enhance biomass (or production) of associated fauna but they provide a habitat for particular species that otherwise could not exist in the respective environments. The present study also revealed high abundances of species in mussel beds.

The investigation also brought to light that the mussels provided ideal shelter both for parents and offspring of the species with direct development, most of which are large- sized macrofauna (2–7cm shell length). Species with direct development may rapidly build large populations in mussel beds, because they release their offspring directly within the mussel beds (and other biogenic habitats) that usually develop in areas with high food supply (Crooks and
Khim, 1999; Thiel et al., 2000). Females that incubate embryos or larvae within or on their bodies may find most favorable conditions for conquering reproduction in mussel beds. Their offspring, upon being released, may remain in the parental habitat. This “neighbourhood recruitment” may thus primarily be responsible for the high abundance of species with direct development compared to that of species that have to take a long detour via the water column.

Many have acknowledged the presence of positive associations in nature, not many studies have looked at how positive interactions affect species diversity as status by Hacker and Gaines, (1997). For future studies, it would be interesting to see how other parameters like the density of mussels affect species abundance and diversity, considering sediment content, mussel size and the relative sizes of the interstitial spaces in the mussel beds.