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Distribution and Diversity of Macrofoulers in the Coastal Areas of Port Blair, Andaman and Nicobar Islands

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ABSTRACT: Flora and fauna of rocky coastal habitats are versatile in adapting to the prevalent tidal fluctuations. The current study was undertaken to evaluate the diversity of fouling and associated species around the Port Blair coastal areas of Andaman and Nicobar Islands. Except TSS, the hydrographical parameters (temperature, salinity, pH and dissolved oxygen) did not significantly vary among the 5 selected stations. Fifty one species of macrofoulers were recorded belonging to macroalgae (8 species), porifera (1 species), cnidaria (9 species), bryozoa (3 species), polychaete (5 species), crustacea (6 species), mollusca (15 species), echinoderm (2 species), and tunicate (2 species). The species *Balanus amphitrite*, *Tetraclita squamosa* and *Saccostrea cucullata* were dominant in all the stations. The maximum macrofoulers density was observed at Chatham (95 ± 0.81 individuals/m^2) and the minimum (30 ± 4.49 individuals/m^2) at Minnie Bay. Cluster analysis and principal component analysis indicated that arthropds and molluscs are predominant in the fouling community.

Key words: Macrofoulers, Biofouling, Diversity, Distribution, A & N Islands

INTRODUCTION

Attachment is a way of life for many organisms in the marine environment. However, when such organisms colonise structures of interest to man, it is referred to as 'biofouling'. The sequence of biofouling includes a primary microfouling phase, followed by the secondary macrofouling assemblage. The key macrofouling organisms include algae, ascidians, barnacles, bryozoans, hydroids, mussels, and serpulids (Salta et al., 2009). Macrofouling can be categorised as 'soft fouling' or 'hard fouling' depending on the nature of the attached organisms. Soft fouling comprises macroalgae and invertebrates such as soft corals, sponges, anemones, tunicates and hydroids, while hard foulers are invertebrates such as barnacles, mussels and tubeworms. Although a lot of research has been carried out on biofouling organisms, most of the studies were focused on developing control strategies (Dehmordi *et al.*, 2011). However, the fouling organisms are an intergral part of intertidal rocky ecosystems and their diversity and abundance plays an important role in determining the overall health of the coastal ecosystem.

The Andaman and Nicobar (A & N) archipelago is one of the mega biodiversity hotspots of India with high endemism. The archipelago consists of 572 islands, located in the Bay of Bengal, lying between 6°45'-13°45' N and 92°12'-93°57' E in the Indo-Burmese microplate junction. The islands spread over a distance of 1120 km with a coast line of about 1962 km, are a typical example of a tropical ecosystem with high humidity (82%) and an annual rainfall of 300 cm. The temperature in the islands ranged between 22 and 32°C. The islands have 106 protected areas which include 96 wildlife sanctuaries, 9 national parks, 1 biosphere reserve and 2 marine national parks (Jeyabaskaran, 1999). The tropical wet evergreen forest is seen throughout the islands on higher altitudes and the moist deciduous forests are found on the slopes. Though these islands are submerged mountain peaks, many of the coastal areas are rocky and provide good habitat for numerous sedentary marine organisms.

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The present study was undertaken to explore the distribution and diversity of macrofoulers along the coastal areas of Port Blair, South Andaman, A & N Islands, India. Macrofoulers being a prominent community in rocky coasts, the influence of environmental parameters on the prevailing species was also explored.

MATERIALS & METHODS

Minnie Bay (11°38'38.89" N ; 92°42'26.85" E), Chatham (11°40'59.49" N ; 92°43'26.59" E), Phoenix Bay (11°40'33.83" N; 92°43'51.59" E), Science centre (11°39'15.76" N ; 92°45'25.96" E) and Corbyn's Cove (11°38'28.65" N ; 92°44'48.93" E) around Port Blair were the five areas selected for the study (Fig. 1) during the post-monsoon period of November 2012.

Rocky areas as well as man-made surfaces were evaluated and the marine macrofoulers were counted by quadrate method (100 cm x 100 cm, 3 replicates). The fouling organisms were collected and preserved in formalin (5%) for identification. The collected organisms were identified based on the keys and species recorded by Tikader et al. (1985, 1986), Dance (1992), Fernando (2006) and Franklin and Laladhas (2014). The water quality parameters such as pH, salinity, dissolved oxygen (DO), temperature and total suspended solids (TSS) were analysed. The pH was determined by digital pH probe (Cyberscan PCD 5500), salinity by refractometer, dissolved oxygen (DO) by Winkler's method (Parsons *et al.*, 1984) and temperature by mercury thermometer.

The TSS was estimated by filtration of 1L of sea water in dried and pre-weighed Millipore Glass Fibre prefilters. After filtration the papers were dried and the TSS was calculated based on the difference in initial and final weight and expressed in mg/l.

Cluster analysis (CA) and principal component analyses (PCA) were employed to assess the distribution and diversity of fouling community in the study area. The hierarchical agglomerative CA was performed on the normalized data set by means of the Ward's method, using squared Euclidean distances as a measure of similarity (Simeonov *et al.*, 2003; Boyacioglu, 2008 and Mendiguchia *et al.*, 2007). To analyse the correlation among the stations as well as biofoulers in the study sites, a principal component analysis was employed. In this method the original variables would be transformed into new; uncorrelated variables (axes) called the principal components, which are linear combinations of the original variables. The principal component (PC) can be expressed as

$$Z_{ij} = pc_{i1}x_{1j} + pc_{i2}x_{2j} + \cdots + pc_{im}x_{mj}$$

Where Z = component score, pc= component loading, x = measured value of the variable, i = component number, j = sample number and m = total number of variables (Singh *et al.*, 2005).

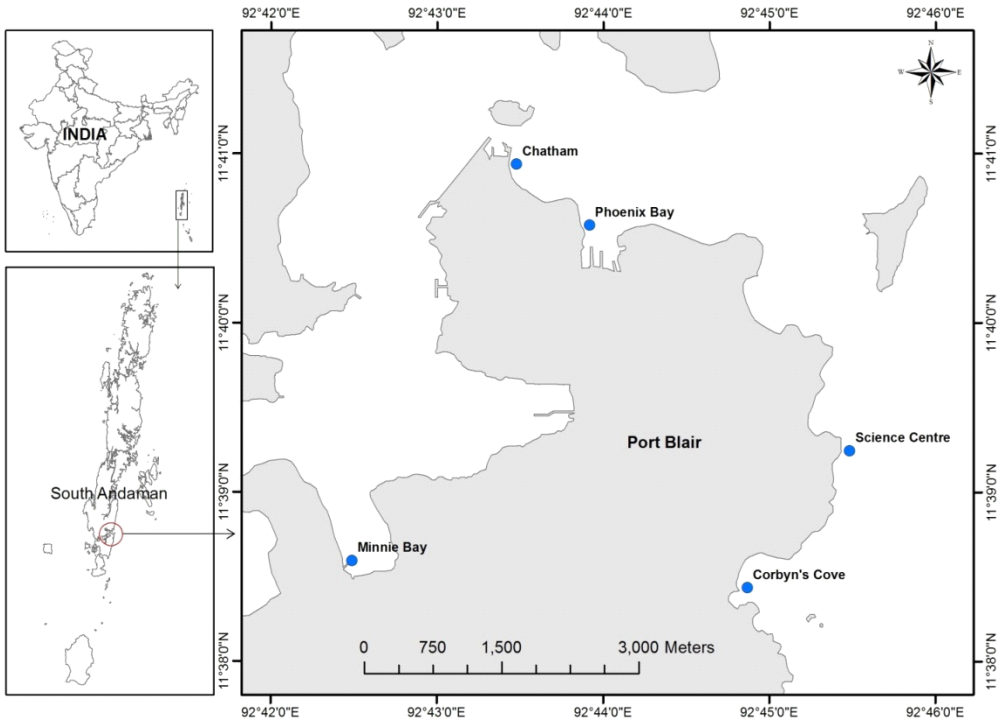

Fig. 1. Map showing the study stations: Minnie Bay, Chatham, Phoenix Bay, Science center and Corbyn's Cove

RESULTS & DISCUSSION

The biodiversity of an ecosystem is always influenced by its environmental and geographical factors and the A & N Islands are an unique ecosystem with rich marine diversity, especially the coastal areas. The rocky coasts found in the A & N Islands harbour a rich diversity of flora and fauna, most of which are fouling (sedentary) in nature. A lot of motile forms like crabs and amphipods are also found in concurrence with the fouling species. The biodiversity of biofoulers varies according to the environmental conditions (light, nutrients, temperature, salinity, flow rates) and geographical locations. Tropical and sub-tropical areas are subjected to minor variation of water temperature and level of lights and thus have been reported to face a high pressure of fouling due to the continuous reproduction period of macroalgae and invertebrates (Hellio, 2010). The present study showed no significant variation in the physiochemical parameters of the selected stations around Port Blair. The physiochemical parameters such as water temperature, salinity, pH, DO and TSS ranged between 29.0 and 29.7°C, 32.19 and 32.80 PSU, 8.12 and 8.19, 6.10 and 6.75 mg/l and 25.65 and 28.7 mg/l, respectively, in the five stations (Table 1).

Except TSS, which showed minor variation, all other parameters exhibited a similar trend in the different study sites.

A total of 51 species were recorded (Table 2) during the current study, pertaining to the heterogeneous group of macrofoulers, including macroalgae (8 species), porifera (1 species), cnidarians (9 species), bryozoans (3 species), polychaetes (5 species), crustaceans (6 species), molluscans (15 species), echinoderms (2 species) and tunicates (2 species). The maximum species diversity was recorded at Science centre with 42 species and the minimum at Minnie bay with 15 species.

The maximum species density (95 ± 0.81 individuals/m2) was recorded in the Chatham and the minimum (30 ± 4.49 individuals/m^2) was in Minnie Bay (Fig. 2). The dominant species was *Balanus amphitrite* followed by *Tetraclita squamosa* and *Saccostrea cucullata*. These species also displayed similar pattern in other stations. The molluscs and arthropods were the major foulers in all the stations (Fig. 3).

The station, Minnie Bay with low species density (30 ± 4.49 individuals/m^2) and relatively high TSS (28.7 mg/l) in water, indicates that the water quality influences the fouling assemblage of a given site. Similarly, it was observed that the muddy shore nature of Minnie Bay is not supporting the succession of diversity of macrofoulers. The stations Chatham and Science centre were abundant in fouling dwellers due to the rocky coast. The relatively low TSS content could also have supported the settlers. Chatham had the highest species density (95 ± 0.81 individuals/m^2) while Science centre had the highest species diversity (total 42 species). The high species density in Chatham was due to the high incidence of gastropods on this extensively rocky site, while the rich diversity in Science centre can be attributed to the occurrence of varied species of anthozoans and bryozoans in this area (Table 2). The presence of dominant species such as *Balanus amphitrite*, *Tetraclita squamosa* and *Saccostrea cucullata* in all the stations indicated the development of a climax community of hard foulers in the ecosystem. This observation is in accordance with earlier studies wherein barnacles have been reported to be the most important component of macrofouling assemblage (Nair, 1965; Satpathy, 1996; Sahu *et al.*, 2011).The CA dendrogram shows the group similarity between different stations (Fig. 4). It was observed that Phoenix Bay and Minnie Bay stations are one group and all the other stations are different from each other. The spatial similarity dendrogram grouped the biofoulers (Fig. 5) into two with significant difference between the clusters.

Arthropods and molluscs were grouped as one and the remaining organisms formed another group. Hierarchical agglomerative clustering is the most common

Table 1. Hydrographical parameters of selected sites of Port Blair, Andaman & Nicobar Islands

Hydrographical parameters	STATIONS				
	Minnie Bay	Chatham	Phoenix Bay	Science Centre	Corbyn's Cove
Temperature (°C)	29.50	29.10	29.20	29.00	29.70
Salinity (PSU)	32.19	32.50	32.20	32.80	32.40
pH	8.17	8.19	8.12	8.13	8.18
DO (mg/l)	6.10	6.72	6.74	6.75	6.25
TSS (mg/l)	28.7	25.65	26.12	25.82	27.50

Table 2. Macrofoulers of Port Blair, Andaman & Nicobar Islands

Sl. No		BIOFOULERS	Minnie Bay	Chatham	Phoenix Bay	Science Centre	Corbyn 's Cove
	MACROALGAE						
	PHAEOPHYCEAE						
	Family	**DICTYOTACEAE**					
1		*Dictyota dichotoma* (Hudson)		+	+	+	+
2		*Padina pavonica* (Linnaeus)			+		+
3		*Padina tetrastromatica* Hauck.			+	+	+
	Family	**SARGASSACEA**					
4		*Sargassum duplicatum* J.Agardh			+		+
5		*Sargassum cinereum* J.Agardh				+	
6		*Sargassum ilicifolium* (Turner) C. Agardh 1820		+	+	+	+
	RHODOPHYCEAE						
	Family	**GALAXAURACEAE**					
7		*Actinotrichia fargilis* (Forsskal) Boergesen				+	+
	Family	**RHZOPHYLLIDACEAE**					
8		*Portieria hornemannii* (Lyngbye) P. Silva					+
	PHYLUM	**PORIFERA**					
	Class	**Demospongiae**					
9		*Haliclona cribricutis* (Dendy, 1922)				+	
	PHYLUM	**CNIDARIA**					
	Class	**Hydrozoa**					
10		*Clytia noliformis* (McCrady, 1859)		+		+	
11		*Obelia longissima* (Pallas, 1766)	+	+	+	+	+
	Class	**Anthozoa**					
12		*Metridium* sp.		+	+	+	+
13		*Hydratinia* sp.		+		+	
14		*Porites lobata* Dana, 1846				+	
15		*Porites* sp.				+	
16		*Favites abdita* (Ellis & Solander, 1786)				+	
17		*Favia sp.*				+	
18		*Sarcophyton trocheliophorum Von Marenzeller, 1886*				+	

Table 2. Macrofoulers of Port Blair, Andaman & Nicobar Islands

	PHYLUM	**ANNELIDA**					
	Class	**Polychaeta**					
19		*Chaetopterus variopedatus* Renier, 1804	+	+			
20		*Syllid* sp.		+		+	
21		*Tomopteris* sp.	+	+	+	+	+
22		*Eunice* sp.				+	
23		*Nereis* sp.		+			
	PHYLUM	**ARTHROPODA**					
	Class	**Crustacea**					
24		*Balanus amphitrite* Darwin, 1854	+	+	+	+	+
25		*Balanus reticulatus* Utinomi, 1967	+	+		+	+
26		*Tetraclita squamosa* (Gmelin, 1790)	+	+	+	+	+
27		*Dardanus deformis* (H. Milne Edwards, 1836)	+	+	+	+	+
28		*Dardanus* sp.	+	+	+	+	+
29		*Dotilla* sp.		+		+	
	PHYLUM	**MOLLUSCS**					
	Class	**Gastropoda**					
30		*Littorina scabra* (Linnaeus, 1758)	+	+	+	+	+
31		*Nerita polita* Linnaeus, 1758		+		+	
32		*Nerita albicilla* Linnaeus, 1758		+	+	+	
33		*Nerita chamaeleon* Linnaeus, 1758		+		+	
34		*Nerita sp.*	+	+	+	+	+
35		*Nerita costata* Gmelin, 1791		+	+	+	+
36		*Natica didyma* (Roding, 1798)					+
37		*Natica sp.*		+	+	+	+
38		*Cellana radiata (Born, 1778)*	+	+	+	+	+
39		*Patella saccharina* Linnaeus, 1758.				+	
40		*Latirus belcheri*. (Reeve, L.A., 1847)	+				
41		*Latirus* sp.				+	
42		*Umbonium vestiarium* (L.)	+	+		+	
	Class	**Bivalvia**					
43		*Pinctada radiata* (Leach, 1814)	+				
44		*Saccostrea cucullata* (Born, 1778)	+	+	+	+	+
	PHYLUM	**ECTOPROCTA (BRYOZOA)**					
45		*Membranipora Sp.*		+		+	
46		*Bugula neritina* (Linnaeus, 1758)		+	+	+	
47		*Bugula stolonifera* Ryland, 1960				+	
	PHYLUM	**ECHINODERMATA**					
48		*Ophiocoma scolopendrina* (Lamarck, 1816)				+	
49		*Ophiocoma* sp.				+	
	PHYLUM	**CHORDATA**					
	SUBPHYLUM	**TUNICATA**					
	Class	**Ascidiacea**					
50		*Lissoclinum fragile* (Van Name, 1902)		+		+	
51		*Didemnum* sp.					

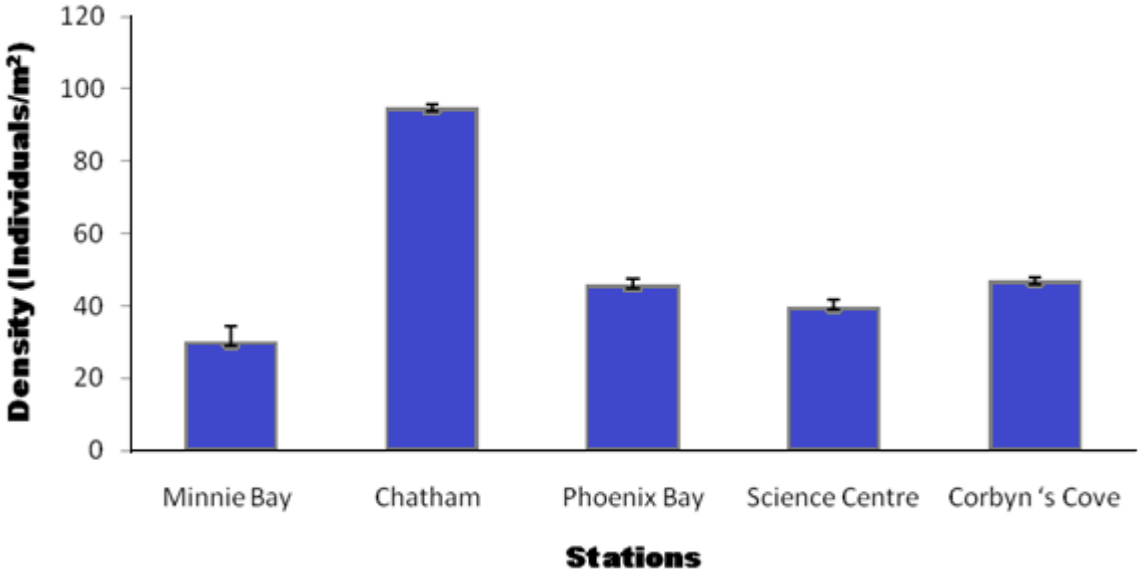

Fig. 2. Macrofoulers density in the coastal regions areas around Port Blair

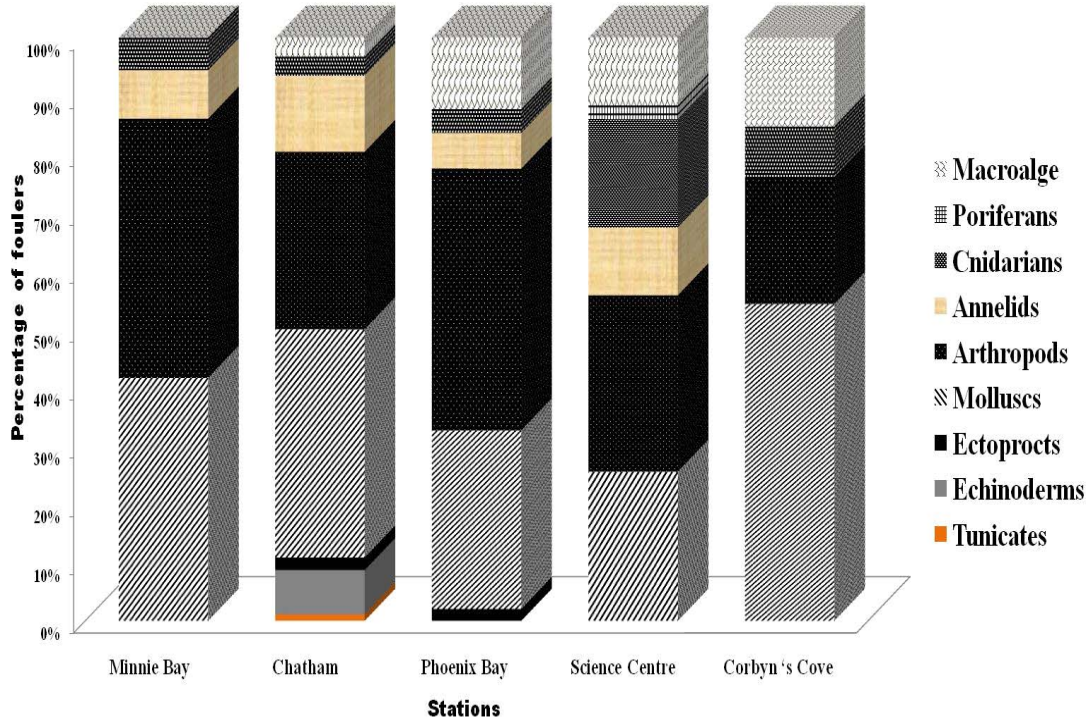

Fig. 3. Percentage of macrofoulers of different study sites around Port Bair

approach and provides intuitive similarity relationships between any one sample and the entire data set (Iscen *et al.*, 2008). The dendrogram, thus confirms the relative dominance of arthropods and molluscs in the macrofouling community. The dendrogram also provides a visual summary of clustering processes, presenting a picture of the groups and their proximity, with a dramatic reduction in the dimensionality of the original data.

Due to the complexity of the relationships between the stations and biofoulers, it was difficult to draw clear conclusions directly. However, principal component analysis could extract the latent information and explain the structure of the data on biofouling commu-

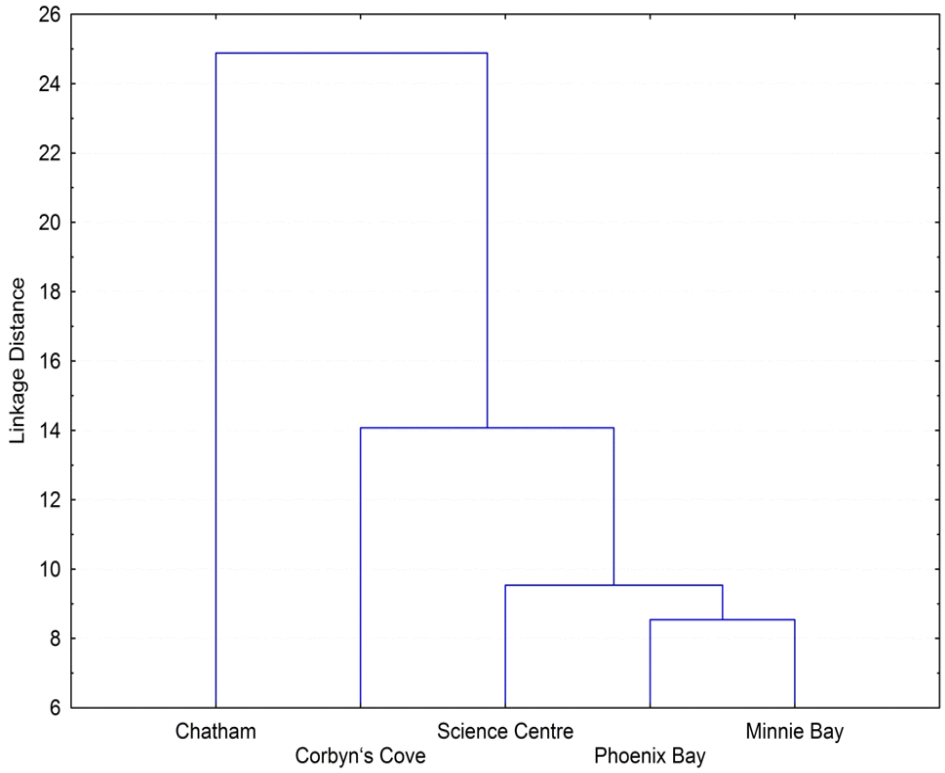

Fig. 4. Cluster analysis dendrogram showing similarities between five stations

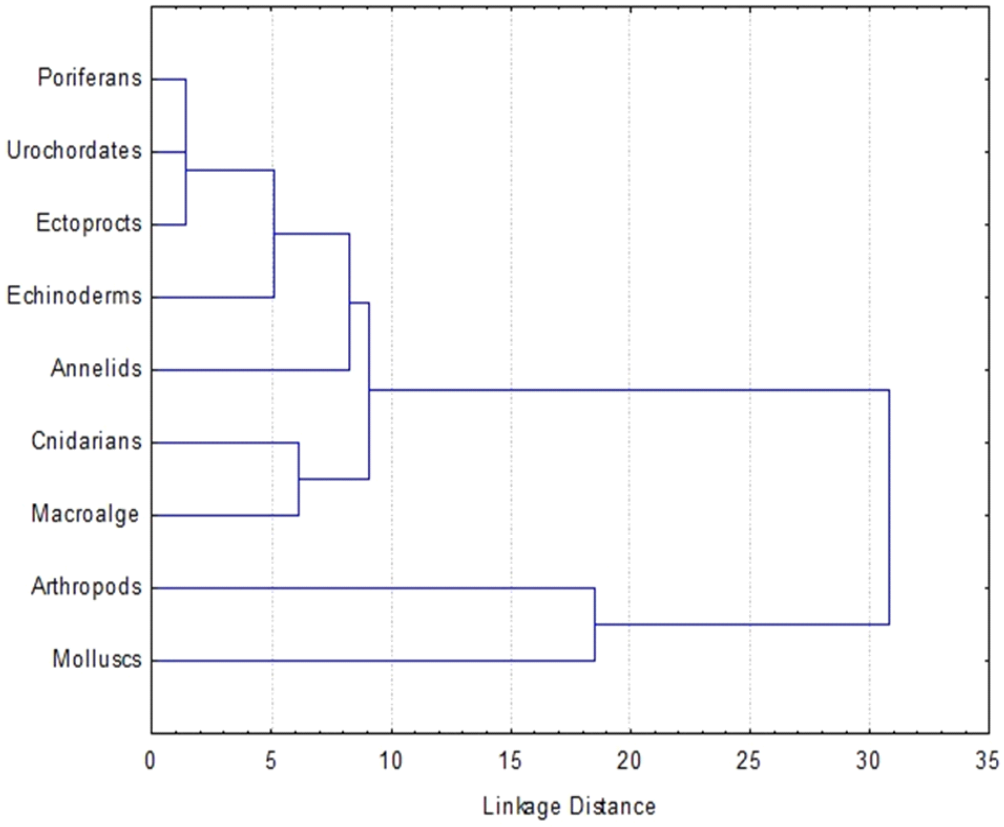

Fig. 5. Cluster analysis dendrogram showing various groups of biofoulers around Port Blair

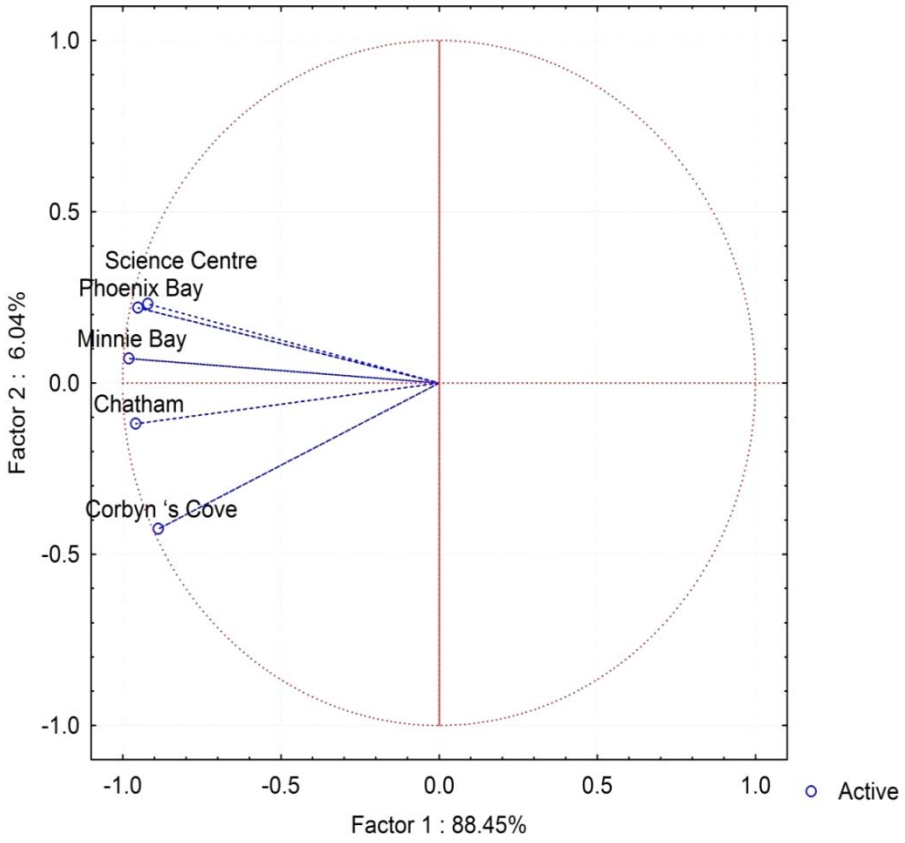

Fig. 6. The loading plot of five coastal sites Port Blair

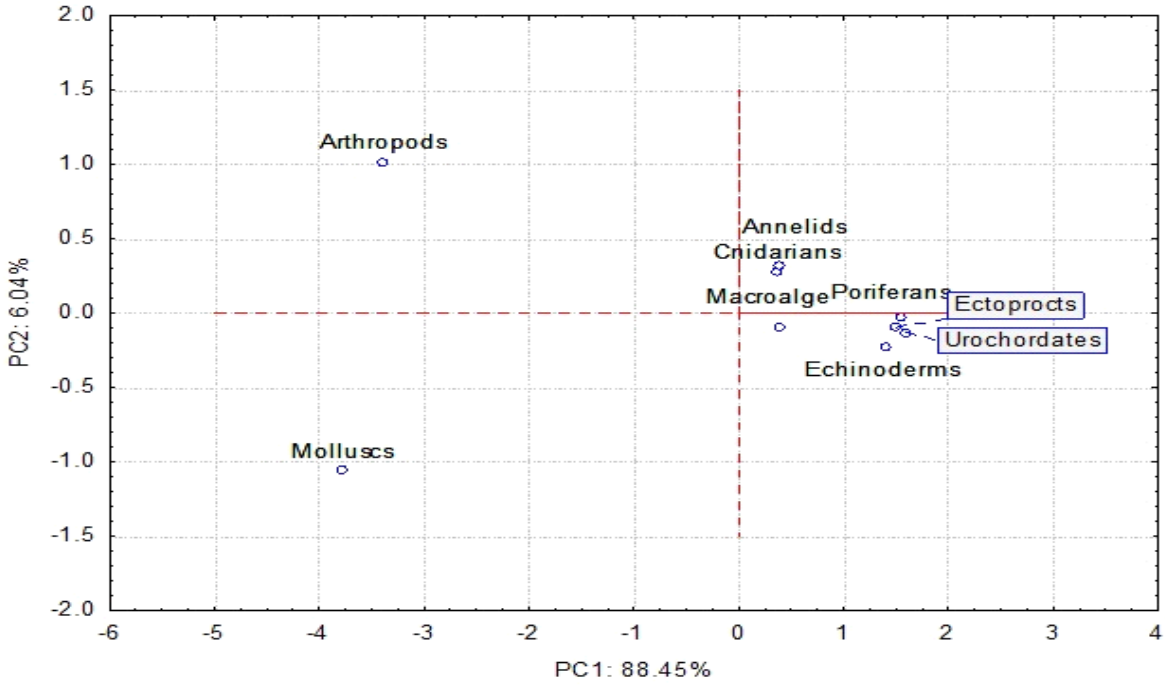

Fig. 7. The scores plot of various groups of biofoulers around the stations

nity in detail. Correlations among the stations as well as the group of biofoulers are represented in figs 6 &7.

The loadings and scores plots of first two PCs (Fig. 6 and Fig. 7) displayed grouping and relationship between the stations. The highest correlation coefficient was observed between Phoneix Bay and Science centre. The scores plot of the biofoulers present in the different study sites grouped the molluscs and arthropods into separate groups, while the annelids and cnidarians were positively correlating with each other. The separate grouping of arthropods and molluscs in the scores plot explains that both these groups independently dominated the fouling community in all the study sites. This is in accordance with the observation of *Balanus amphitrite* followed by *Tetraclita squamosa* and *Saccostrea cucullata* as the dominant species.

CONCLUSIONS

The present study revealed that the density and diversity of fouling organisms is site-specific. TSS was found to be a decisive factor influencing the density as well as diversity of the macrofoulers. The CA and PCA were found to be useful statistical tools to better correlate the studied stations and various groups of biofoulers. The distribution and diversity of the macrofouling organisms of Port Blair indicate that the coastal area of Port Blair is a healthy tropical marine ecosystem, supporting a rich and diverse macrobenthic community. Further long-term investigations on community-structure along with studies on seasonal physico-chemical variations have to be carried out to evaluate the possible changes and succession trends of fouling communities.

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