

# Distribution and Diversity of Macrobenthos in Different Mangrove Ecosystems of Tamil Nadu Coast, India

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## Abstract

This paper deals with the spatial distribution and diversity of macrobenthos and their relationships between physico-chemical parameters of the water and sediment in different mangrove habitats of Tamil Nadu, India during different seasons of the year-2011. Among the different ecosystems of mangrove benthic faunal assemblages, macrofauna density, richness, evenness and Shannon-wiener index were the highest and the Simpson dominance index was medial at riverine mangrove community. However, the Pielou Evenness index of riverine mangrove community was slightly lower than other communities. The similarities among the macrobenthic communities at different sampling sites were determined using Bray-Curtis similarity coefficient and ordinations of non-metric multidimensional scaling (MDS). One hundred fifty six species were recorded in developing (102 polychaetes, 10 bivalves, 11 gastropods, 24 amphipods, 6 isopods and 3 cumacea), two hundred fifty two species were recorded in riverine (151 polychaetes, 12 bivalves, 16 gastropods, 53 amphipods, 16 isopods and 4 cumacea) and one hundred sixty three species were recorded in island mangrove ecosystem (105 polychaetes, 10 bivalves, 16 gastropods, 21 amphipods, 9 isopods and 2 cumacea). Among the three ecosystems, a total of 292 benthic macrofauna consisting of 188 species of polychaetes, 12 species of bivalves, 17 species of gastropods, 55 species of amphipods, 16 species of isopods and 4 species of cumacea were recorded. However, there were obvious differences among the community structures in the three mangrove habitats. This result implied that the different mangrove ecosystem had different effects on the macrofauna communities and shed light on the macrofauna adaptation capability to specific habitats.

**Keywords:** Mangrove ecosystem; Biodiversity; Macro fauna; Physico-chemical; Seasonal variation

## Introduction

Plants ecosystems are a habitat for a wide variety of species, some occurring in high densities and provide food and shelter for a large number of commercially valuable finfish and shellfishes. They are productive habitats and support coastal fisheries [1]. The mangrove forests are extremely important coastal resources, which are vital for socio-economic development of the region. As a detritus-based ecosystem, leaf litter from the mangroves provides the basis for adjacent aquatic and terrestrial food webs. It also serves as breeding, feeding, and nursery grounds for most of the commercially important finfish and shellfishes, on which thousands of coastal people depend for their livelihood. It is considered to have physical, chemical, and biological processes which promote the adaptation of inhabiting organisms to tolerate greater amplitude of environmental characters both morphologically and physiologically. Krom MD and Berner RA [2] have reported that the decomposition of organic matter consists of nutrients such as nitrogen and phosphorus, which play a vital role in the establishment of healthy mangroves. However, sediment where the animals inhabit often acts as buffer either as a source or sink of nutrients especially phosphorus by adsorption and desorption reactions [2,3]. Hence, the sediment plays a crucial role on benthic faunal diversity in the mangrove ecosystem. Benthic organisms constitute an important component that influences the productivity of the habitat to a greater extent. Benthos helps in the recycling of nutrients, which in turn promotes primary productivity. A detailed and complete knowledge of the bottom fauna is not only important for the determination of productivity [4] but is also helpful in understanding the diversity of the habitat. Macrofauna are the most widely studied benthic organisms which are retained on 0.5 mm sieve. They reside beneath the sediment surface in burrows and tubes. Thus, seemingly, the bottom of the mangrove substratum habitats forms and a wide array of macrobenthic organisms of various size and taxonomic

categories. Indian mangrove ecosystems are known to have a total of 3,985 biological species that include 919 floral species and 3,066 faunal species. Of the biological species, the faunal species occupy about 77%, and the floral species 23%. Thus, the faunal species component is about three times greater than the floral component of the mangrove ecosystem [5,6]. Of these, polychaetes, molluscs, and crustaceans are found to be the major macrobenthic organisms in mangrove environment. Most of the macrobenthos assist in the breakdown of particulate organic material by exposing them to microbes and their waste materials contain rich nutrients forming the food for other consumers. Thus, the macrobenthos plays a major ecological role in the mangrove ecosystem [7]. Mangroves are inhabited by a variety of macrobenthic invertebrates, such as brachyuran crabs, hermit crabs, gastropods, bivalves, barnacles, sponges, tunicates, polychaetes, and sipunculids. The mangrove invertebrates often exhibit marked zonation patterns and colonize a variety of specific micro-environments [8-10]. While some species dwell on the sediment.

## Materials and Methods

Station I (Developing mangrove ecosystem) is located at 11°29'N

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79°46'E. This is one of the best-studied estuaries in India comparable to the world conditions. It is highly productive and rich in floral and faunal resources. This located estuary remains open with the Bay of Bengal as it is a "true estuary" without complete closure of the mouth. Along the course of this estuary, in an area of 10 ha, a mangrove forest was developed by Dr. K. Kathiresan and his team, CAS in Marine Biology, Parangipettai since the year-1991 onwards. It is grown near the shore of Vellar estuary and is very good in supporting biodiversity of many species. Hence, this site was selected as a developing mangrove ecosystem.

Station II (Riverine mangrove ecosystem) is located at 10°20'N 79°32'E and it is situated 400 km south of Chennai which lies on the southern part of Cauvery delta region along the south east coast of the Peninsular India. *Avicennia marina* is the dominant mangrove species in Muthupettai and accounts for nearly 95% of the vegetative cover. In Muthupettai mangrove harbours, 112 species of insects 14 species of crustaceans, 18 species of molluscs, 73 species of finfishes, 10 species of herpeto fauna and 13 species of mammals [11,12].

Station III (Island mangrove ecosystem) consists of three different islands of Gulf of Mannar, namely Kurusadai, Poomarchan, and Manauli. It is located between 9°14'N 79°12'E and 9°12'N 79°7'E, along the south east coast of India. These islands are well known for their mangrove species composition and have lagoon pools and open mud flats (Figure 1).

### Water sampling and analysis of physico-chemical parameters

Four seasonal collections were made from January 2011 to December 2011. Samples were collected from each station (four seasons×three stations×six replicates). Rainfall data were collected from the metrological department office at CAS in Marine Biology, Annamalai University. Muthupettai for station I and Parangipettai for station II and Pamban for station III. Water samples were collected in pre-cleaned polypropylene containers, just below the water surface separately from the sampling sites. After collection, all the samples were cooled and then brought to the laboratory in an insulated thermocool box. Soon after returning to the laboratory, the water samples were filtered through a Whatman GF/C filter paper for nutrient analysis. Water temperature was measured using a mercury centigrade thermometer with 0.5°C accuracy. The pH of samples was measured

by using a calibrated pH pen (Phep; Hanna instruments Mauritius Ltd., Portugal) with an accuracy of  $\pm 0.1$ . The pH in the solution was measured using a pH meter, calibrated with standard buffer solution prior to use. The salinity of samples was measured by using a hand refractometer (Atago, Japan). Water samples were transferred carefully to BOD bottles. The modified Winkler's method described by Strickland JDH and Parsons TR [13] was adopted for the estimation of dissolved oxygen fixed. The nitrate, nitrite, inorganic phosphate, and reactive silicate content of water samples were analyzed by the method of Strickland JDH [13].

### Sediment sampling and analysis of physico-chemical parameters

Pterson's grab (0.256 m<sup>2</sup>) was used to collect sediment samples. The soil temperature was measured using a standard centigrade thermometer by directly inserting in the sediment. The soil pH was determined by adopting the method of Jackson ML [14]. Water was added to air-dried samples in the ratio of 1:1 and stirred in a mechanical shaker for an hour, and pH was measured in this solution. A known amount of sediment samples was moisturized with double distilled water up to the moisture saturation of the sediment. Then double the volume of saturation level of water was added, mechanically shaken for 15 min, and the water with salt was filtered through a Whatman No. 1 filter paper and the salinity was measured using a hand refractometer. Soil samples were brought to the laboratory in clean polythene bags, air dried, and stored for further analysis. The percentage composition of sand, silt, and clay in the sediment samples were determined by the sieving method of Krumbein WC [15].

### Macrofauna sampling and identification

The samplings covered all the tidal levels and were done by using a line transect method. Pterson's grab (0.256 m<sup>2</sup>) was used for unit sampling. Six replicates for each station were maintained. Soon after retrieval, samples were gently sieved through a 0.5-mm sieve. The organisms retained by the sieve were preserved in 5% formalin and brought to the laboratory for further identification. The sorted organisms were first segregated into different groups and then identified to specific, genetic or other higher levels to the greatest extent possible with the help of standard taxonomic references viz. Polychaeta [16,17] and Mollusca [18]. The organisms were counted under a stereoscopic microscope, and abundance was expressed as individuals per square meter. In the present study, the qualitative and quantitative assessments of benthic macrofauna were noted only to polychaetes, bivalves, and gastropods (molluscs), and isopods and amphipods (crustaceans).

### Data analysis

Macrofauna taxa collected from the beds were identified and listed. Pearson correlation coefficient was employed for the better understanding of relationship between the concentration of various nutrients, sediment composition, and pH by using statistical package (SPSS-11.5). Their settlement was analyzed using several indices: univariate measures such as Margalef's species richness (d), Shannon-Wiener diversity (H' log) and Pielou's evenness (J'), graphical tools like k-dominance curve and multivariate tool such as Bray-Curtis similarity after suitable transformation of sample abundance data, classification (hierarchical agglomerative clustering using group-average linking), and ordination (multidimensional scaling, MDS) were used for treating the data and were calculated using of computer software of PRIMER (Plymouth Routines In Multivariate Ecological Research ver. 6).

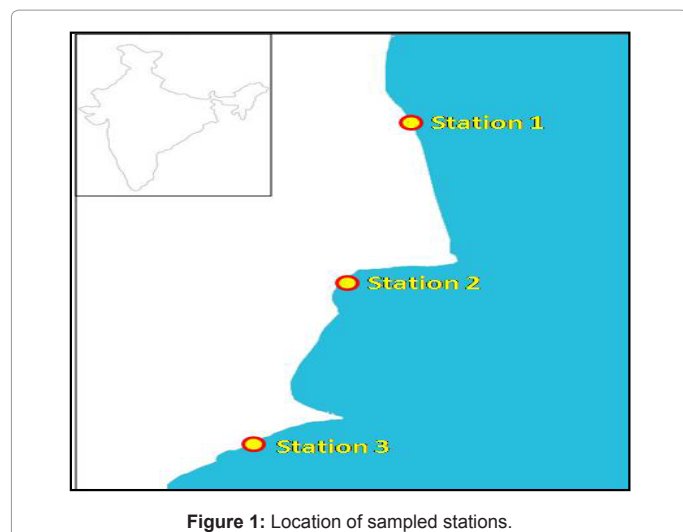


Figure 1: Location of sampled stations.

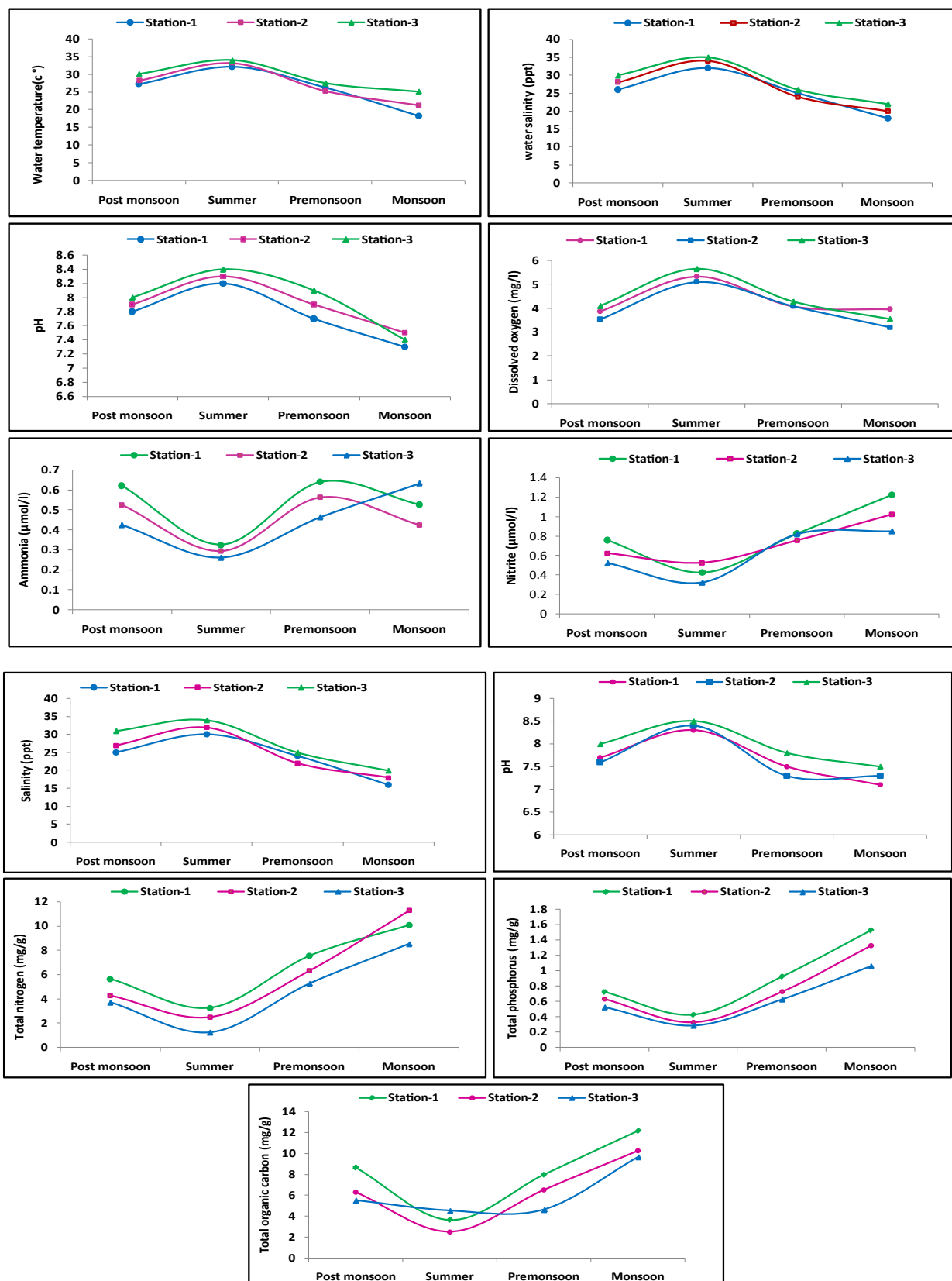


Figure 2: Seasonal variations of physico-chemical parameters in water and sediment samples.

## Results

### Environmental parameters

The physical parameters of water and sediment were similar in all stations (I, II & III) throughout the experimental period, indicating the well-mixed nature of this ecosystem. The value of rainfall ranged from 17.37 to 4,400 mm in all stations. Temperature, salinity, and pH of both water and sediments ranged from 18.2°C to 30.1°C and 20.1°C to 35.1°C, 18 to 35 ppt and 16 to 34 ppt, and 7.3 to 8.4 and 7.1 to 8.5 respectively. The values of dissolved oxygen ranged from 3.22 to 5.65 mg/l. Nutrients in water such as ammonia, nitrite, nitrate, total nitrogen inorganic phosphate, total phosphorus and reactive silicate ranged from 0.263 to 0.654 µmol/l, 0.326 to 1.226 µmol/l, 1.263 and 5.563 µmol/l, 3.25 to 15.637 µmol/l, 0.128 to 0.622 µmol/l, 0.285 to 1.526 µmol/l and 6.248 to 24.526 µmol/l respectively. In sediments nutrients such as nitrogen, phosphorus, and total organic carbon were recorded, and these are varied from 1.263 to 11.258 µg/g, 2.517 to 12.132 µg/g, and 2.517 to 12.132 µg/g respectively (Figure 2). The sediment texture in terms of sand, clay, and silt (%) were 1.18-69.87, 2.64-26.82, and 8.94-95.48 in all the three stations (Figure 2).

### Species composition of macrofauna

A total of 292 macrobenthic faunal species represented by six diverse groups were encountered, of which polychaetes, gastropods, bivalves, amphipods, isopods and cumacea were the most important groups. Polychaetes are dominated in the macrobenthic fauna (188 species) and contributed numerically up to 64.38% of the population. Bivalves consist of 12 species and contribute to 4.11% of the total fauna production. Gastropods consist of 17 species and contribute to 5.82% of the total fauna production. Amphipods consist of 55 species and contribute to 18.83% of the total fauna production. Isopods consist of 16 species and contribute to 5.47% of the total fauna production. Also,

cumaceans include 4 species and contribute to 1.37% of the total faunal production (Figure 3).

The 252 species (151 polychaetes, 12 bivalves, 16 gastropods, 53 amphipods, 16 isopods and 4 cumaceans) were recorded in station I, and the percentage composition was calculated and shown in Figure 4. The 156 species (102 polychaetes, 10 bivalves, 11 gastropods, 24 amphipods, 6 isopods and 3 cumaceans) and 163 species (105 polychaetes, 10 bivalves, 16 gastropods, 21 amphipods, 9 isopods and 2 cumaceans) were recorded in stations II and III respectively. The percentage composition was calculated for both stations and presented in Figures 5 and 6. The species belonging to all groups are presented in Table 1. Bivalves and crustaceans were dominant in faunal biomass. The highest number of species was recorded in station II than in others. The benthic macrofaunal density (ind/m<sup>2</sup>) was calculated and ranged from 156 to 217, from 84 to 171, and from 99 to 171 in stations I, II, and III, respectively. The highest benthic macrofaunal density was recorded in the early summer season at station I.

Classification analyses (using Bray-Curtis similarity) followed by an ordination through MDS on benthos abundance data (No/0.256 m<sup>2</sup>) independently for fauna (293 species) were undertaken. The 12 investigation stations (four seasons×three stations) have been divided into three groups: S1Pm, S2Sm, S3PrM, S4Mn; S5Pm, S6Sm, S7PrM, S8Mn; and S9Pm, S10Sm, S11PrM, S12Mn corresponding to Muthupettai (station I), Parangipettai (station II), and the Gulf of Mannar (station III). Figures 7 and 8 display results of MDS ordination and hierarchical clustering, respectively, on species abundance data representing the three stations during four seasons (post-monsoon, summer, pre-monsoon, and monsoon). Cluster analysis showed that the macrofauna communities at each of the mangrove communities were relatively most similar (Figure 9). The 2D stress value (0.11) indicated that the results are credible. The station I and III communities, which are very similar in the result of the cluster analysis, were clearly separated.

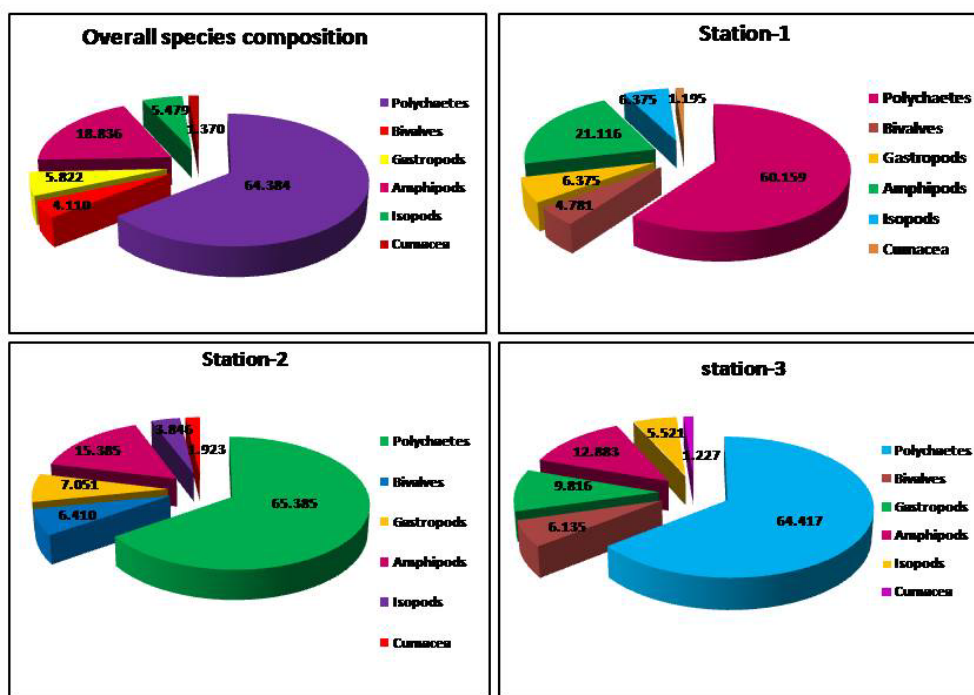


Figure 3: Percentage composition of macrobenthos in different stations.

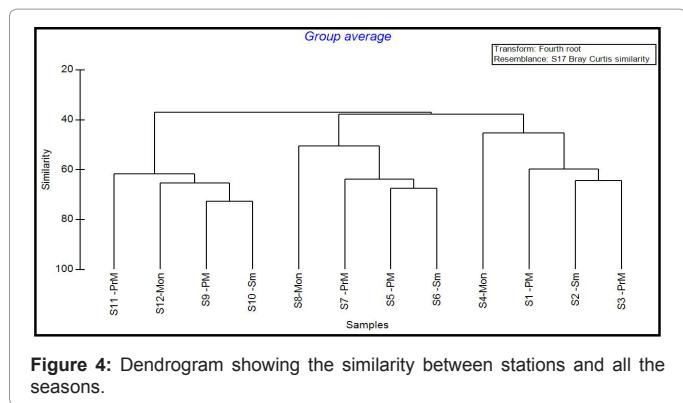


Figure 4: Dendrogram showing the similarity between stations and all the seasons.

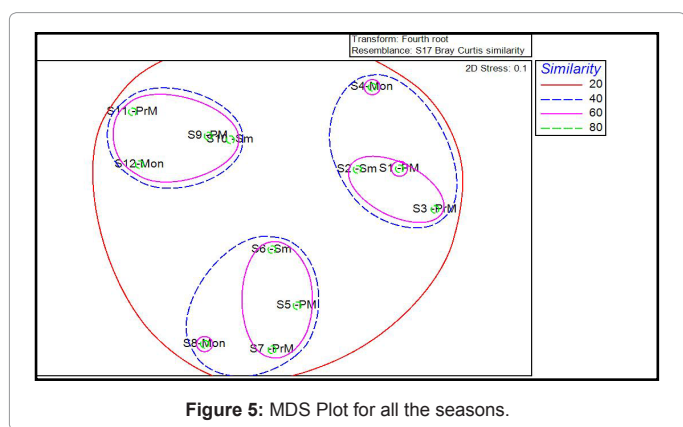


Figure 5: MDS Plot for all the seasons.

In comparison, among the three sampling stations, station II communities were the shortest, implying that the structure of macrofauna communities at this community was the most similar (Figure 9).

From the resulting dendrogram (Figure 4), it is possible to classify the results according to stations and also for seasons. Station III is separated from the others. In the MDS plot (Figure 4), it is found that all season samples are separated conforming to the dendrogram. The benthic faunal density (N) (Figure 5A) varied from 84 (station II, monsoon) to 217 (station I, summer). The Shannon-Wiener index (H) (Figure 5B) ranges between 4.311(station II, monsoon) and 5.167 (station I, summer). The evenness component (J') (Figure 5D) varied from 0.998 (station III, summer) to 0.999 (station I, monsoon). It is low during the post-monsoon and summer season and gradually increases during the monsoon seasons. The richness component (D) (Figure 5C) ranged between 16.69 (station II, monsoon) to 32.70 (station I, summer).

Multiple k-dominance plots facilitate the discrimination of benthos according to species-relative contribution to standard stock. The k-dominance curves obtained for different stations show higher diversity except S8Sm. The stations S2Sm and S1PM show maximum diversity as the curves for all three stations are lying lower than others whereas the curve of the S12M is lying in the top and has a stiff elevation indicating the lowest diversity (Figure 6).

The k-dominance plot is plotted according to station (Figure 7); it shows the plot for pooled data, i.e., it shows a perfect S curve indicating the high diversity of macrofauna in station I without disturbance, when the curves were drawn separately for the three stations among the seasons. The k-dominance plot is also plotted for all the seasons, and the curve drawn inputting all the stations and all the seasons are

S. No	Species	St-1	St-2	St-3
I	<b>Polychaetes</b>			
1	<i>Abarenicola gilchristi</i>	*	*	*
2	<i>Gattyana deludens</i>	*	-	-
3	<i>Nephtys bucera</i>	*	-	*
4	<i>Nereis abbreviata</i>	*	*	*
5	<i>Nereis diversicolor</i>	*	*	*
6	<i>Nereis jacksoni</i>	*	*	*
7	<i>Onuphis eremite</i>	*	*	*
8	<i>Scolecopsis squamata</i>	*	-	-
9	<i>Abarenicola gilchristi</i>	*	*	*
10	<i>Amphiteis gunneri</i>	-	-	*
11	<i>Amphinome rostrata</i>	*	-	-
12	<i>Ancistrosyllis constricta</i>	*	*	*
13	<i>Ancistrosyllis groenlandica</i>	*	*	-
14	<i>Ancistrosyllis parva</i>	*	*	*
15	<i>Arabella iricolor</i>	*	*	-
16	<i>Arenicola loveni</i>	*	-	-
17	<i>Armandia lanceolata</i>	-	-	*
18	<i>Armandia longicaudata</i>	*	*	*
19	<i>Axiiothella obockenisis</i>	*	*	-
20	<i>Bhawania goodei</i>	*	-	-
21	<i>Branchiocapitella singularis</i>	*	-	-
22	<i>Capitella capitata</i>	-	*	*
23	<i>Ceratonereis costae</i>	*	*	*
24	<i>Ceratonereis keiskama</i>	*	-	-
25	<i>Ceratonereis mirabilis</i>	*	*	-
26	<i>Chaetozone setosa</i>	*	-	-
27	<i>Chloelia flava</i>	-	*	*
28	<i>Chloelia parva</i>	*	-	*
29	<i>Chone collaris</i>	*	*	*
30	<i>Chone filicaudata</i>	*	*	*
31	<i>Cirratulus chrysoderma</i>	*	*	*
32	<i>Cirratulus concinnus</i>	*	*	*
33	<i>Cirratulus gilchristi</i>	-	*	*
34	<i>Cirriformia tentaculata</i>	*	*	*
35	<i>Cossura delta</i>	*	*	*
36	<i>Dasychone cingulata</i>	*	-	-
37	<i>Dendronereis aestuarina</i>	*	-	-
38	<i>Dendronereis arborifera</i>	*	-	*
39	<i>Diopatra cuprea</i>	*	*	*
40	<i>Diopatra neapolitana</i>	*	-	-
41	<i>Disoma orissae</i>	*	-	*
42	<i>Dorvillea incertus</i>	*	*	*
43	<i>Dorvillea neglecta</i>	*	-	*
44	<i>Enice pennata</i>	-	*	*
45	<i>Enice tentaculata</i>	*	*	*
46	<i>Epidiopatra huperiana</i>	-	*	*
47	<i>Eteone ornata</i>	-	-	-
48	<i>Eteone ornata</i>	*	-	*
49	<i>Eteone siphodonta</i>	-	*	-
50	<i>Euchone rosea</i>	*	-	-
51	<i>Euclymene annandalei</i>	*	*	-
52	<i>Eulalia macroceros</i>	*	-	*
53	<i>Eulalia sanguinea</i>	-	*	-
54	<i>Eunice australis</i>	*	-	-
55	<i>Eunice indica</i>	-	*	*
56	<i>Eunice tubifex</i>	*	-	*
57	<i>Euphrosine capensis</i>	-	*	-
58	<i>Eurythoe complanata</i>	*	*	-
59	<i>Exogone clavator</i>	*	*	*

60	<i>Exogone verugera</i>	-	*	*
61	<i>Fabriciolla mossambica</i>	*	*	*
62	<i>Gattyana deludens</i>	-	*	-
63	<i>Glycera africana</i>	*	*	-
64	<i>Glycera alba</i>	-	*	*
65	<i>Glycera longipinnis</i>	*	-	-
66	<i>Glycera onicornis</i>	*	*	*
67	<i>Glycinde capensis</i>	*	*	*
68	<i>Glycinde oligodon</i>	*	*	-
69	<i>Goniada emerita</i>	-	-	*
70	<i>Goniada goniada</i>	*	*	*
71	<i>Goniadella gracilis</i>	*	-	-
72	<i>Goniadopsis maskallensis</i>	-	-	*
73	<i>Harmothoe africana</i>	*	-	*
74	<i>Hesione interexta</i>	-	*	-
75	<i>Heteromastus similis</i>	*	-	-
76	<i>Hololepidella maculata</i>	-	-	*
77	<i>Hydroides albiceps</i>	*	*	-
78	<i>Hydroides heteroceros</i>	-	*	-
79	<i>Hydroides homoceros</i>	*	-	*
80	<i>Isolda pulchella</i>	-	*	*
81	<i>Lanice socialis</i>	*	-	-
82	<i>Laonice cirrata</i>	*	*	-
83	<i>Laonome indica</i>	-	-	*
84	<i>Leanira hystricis</i>	*	-	-
85	<i>Leocrates claparedii</i>	-	*	*
86	<i>Lepidonotus tenuisetosus</i>	*	*	-
87	<i>Loimia medusa</i>	-	-	*
88	<i>Lopadorhynchus henseni</i>	*	-	-
89	<i>Lopadorhynchus nationalis</i>	*	-	*
90	<i>Lumbriconereis impatiens</i>	-	*	-
91	<i>Lumbriconereis latreilli</i>	*	-	*
92	<i>Lumbriconereis polydesma</i>	*	*	-
93	<i>Lumbriconereis heteropoda</i>	-	-	*
94	<i>Lumbriconereis latreilli</i>	*	-	*
95	<i>Lumbriconereis pseudobifilaris</i>	-	*	*
96	<i>Lumbriconereis simplex</i>	-	-	*
97	<i>Lumbrineris brevicirra</i>	*	*	*
98	<i>Lumbrineris magalhaensis</i>	*	*	*
99	<i>Magelona cincta</i>	*	-	*
100	<i>Magelona papillicornis</i>	*	-	*
101	<i>Malacoceros indicus</i>	*	-	-
102	<i>Maldane sarsi</i>	*	-	*
103	<i>Marphysa gravelyi</i>	*	*	*
104	<i>Mercierella enigmatica</i>	*	*	-
105	<i>Mesochaetopterus mesochaetopterus</i>	*	-	-
106	<i>Nephtys capensis</i>	*	*	*
107	<i>Nephtys polybranchia</i>	*	*	*
108	<i>Nephtys sphaerocirrata</i>	*	*	*
109	<i>Nereis granulata</i>	*	*	*
110	<i>Nereis virens</i>	*	*	*
111	<i>Notocirrus brevicirrus</i>	*	-	*
112	<i>Notomastus aberans</i>	*	*	*
113	<i>Notomastus fauveli</i>	*	*	*
114	<i>Notomastus giganteus</i>	*	-	*
115	<i>Onuphis eremita</i>	*	-	*
116	<i>Onuphis geophiliformis</i>	*	*	*
117	<i>Onuphis holobranchiata</i>	*	*	-
118	<i>Ophelia africana</i>	*	-	*
119	<i>Ophelia capensis</i>	*	*	-
120	<i>Orbinia angrapequensis</i>	*	*	-
121	<i>Oriopsis eimeri</i>	-	*	*
122	<i>Oriopsis neglecta</i>	*	-	-
123	<i>Owenia fusiformis</i>	*	*	*
124	<i>Paralacydonia weberi</i>	*	-	-
125	<i>Pectinaria crassa</i>	*	-	-
126	<i>Pectinaria crassa</i>	*	-	-
127	<i>Pelagobia longicirrata</i>	*	-	-
128	<i>Pelagobia longicirrata</i>	*	*	-
129	<i>Perinereis cultrifera</i>	*	*	*
130	<i>Phyllodoce longipes</i>	-	*	*
131	<i>Phyllodoce madeirensis</i>	*	-	-
132	<i>Phyllodoce malmgreni</i>	*	-	-
133	<i>Phyllodoce tenuiss</i>	-	*	*
134	<i>Phyllodoce tubicola</i>	*	-	*
135	<i>Pisione africana</i>	*	*	-
136	<i>Pisionidens indica</i>	*	-	*
137	<i>Pista quadrilobata</i>	*	*	-
138	<i>Pista typha</i>	*	-	*
139	<i>Platynereis calodonta</i>	*	-	-
140	<i>Poecilochaetus serpens</i>	*	*	-
141	<i>Polycirrus plumosus</i>	-	*	*
142	<i>Polycirrus tribullata</i>	*	-	-
143	<i>Polydora ciliata</i>	*	*	*
144	<i>Polydora hophura</i>	*	*	*
145	<i>Polydra ciliata</i>	*	*	*
146	<i>Pomatoceros triqueter</i>	*	-	*
147	<i>Pomatoleios kraussii</i>	*	*	-
148	<i>Prionospio cirrifera</i>	*	-	*
149	<i>Prionospio cirrobranchiata</i>	*	*	*
150	<i>Prionospio malmgreni</i>	*	*	-
151	<i>Prionospio pinnata</i>	*	*	*
152	<i>Prionospio polybranchiata</i>	*	-	*
153	<i>Prionospio saldanha</i>	*	*	*
154	<i>Protodorvillea egena</i>	-	-	*
155	<i>Pseudonereis variegata</i>	*	*	-
156	<i>Pseudopolydora kempii</i>	-	*	-
157	<i>Rhodine gracilior</i>	*	-	-
158	<i>Sabellaria cementarium</i>	*	*	-
159	<i>Sabellaria intoshi</i>	*	-	-
160	<i>Sabellaria spinnulosa</i>	-	-	*
161	<i>Scolecopsis squamata</i>	*	*	*
162	<i>Scolopella capensis</i>	*	*	-
163	<i>Scolopella capensis</i>	*	-	*
164	<i>Scoloplos marsupialis</i>	*	-	*
165	<i>Serpula vermicularis</i>	*	-	*
166	<i>Sigalion squamatum</i>	-	-	-
167	<i>Sphaerosyllis erinaceu</i>	*	-	-
168	<i>Spio filicomis</i>	*	-	*
169	<i>Spiochaetopterus costarum</i>	*	*	*
170	<i>Spirobranchus teraceros</i>	-	-	-
171	<i>Spirorbis foraminosus</i>	*	*	-
172	<i>Sternaspis scutata</i>	*	-	*
173	<i>Sthenelais boa</i>	*	*	-
174	<i>Sthenelais japonica</i>	-	-	-
175	<i>Stylarioides stylarioides</i>	*	-	-
176	<i>Syllidia armata</i>	*	*	-
177	<i>Syllis benguellana</i>	*	-	*
178	<i>Syllis gracilis</i>	*	*	*
179	<i>Syllis longicirrata</i>	*	*	*
180	<i>Syllis trifalcata</i>	*	*	-

181	<i>Terebella pterochaeta</i>	*	-	-
182	<i>Terebellides stroemi</i>	*	*	-
183	<i>Thelepus setosus</i>	*	-	-
184	<i>Tlonereis fauveli</i>	*	-	-
185	<i>Tomopteris helgolandica</i>	*	*	-
186	<i>Travislopsis lobifera</i>	*	*	-
187	<i>Typhloscolex muelleri</i>	*	-	-
188	<i>Vanadis formosa</i>	*	-	-
<b>II</b>	<b>Bivalves</b>			
189	<i>Anadara granosa</i>	*	*	*
190	<i>Anadara rhombea</i>	*	*	*
191	<i>Cardium setosum</i>	*	*	*
192	<i>Donax scortum</i>	*	*	*
193	<i>Donax cuneatus</i>	*	*	*
194	<i>Donax spinosus</i>	*	*	*
195	<i>Meretrix meretrix</i>	*	-	*
196	<i>Modiolus metcalfei</i>	*	*	*
197	<i>Perna viridis</i>	*	-	*
198	<i>Pinndata fucata</i>	*	*	*
199	<i>Placenta placenta</i>	*	*	-
200	<i>Paphia malabarica</i>	*	*	-
<b>III</b>	<b>Gastropods</b>			
201	<i>Bullia vitata</i>	*	*	*
202	<i>Cerithedia cingulata</i>	*	*	*
203	<i>Cerithedia obtusa</i>	*	*	*
204	<i>Epitonium scalare</i>	*	*	-
205	<i>Littorina scabra</i>	*	*	*
206	<i>Nassarius variegatus</i>	*	*	*
207	<i>Natica tigerina</i>	*	-	*
208	<i>Oliva nebulosa</i>	*	-	*
209	<i>Turritella attenuata</i>	*	*	*
210	<i>Turritella albenuata</i>	*	-	*
211	<i>Turritella acqutangula</i>	*	-	*
212	<i>Umbonium vestiarium</i>	*	*	*
213	<i>Telescopium telescopium</i>	*	*	*
214	<i>Murex tribulex</i>	*	*	*
215	<i>Nassa jacksoniana</i>	*	-	*
216	<i>Nassarius scabra</i>	*	*	*
217	<i>Oliva nebulosa</i>	-	-	*
<b>IV</b>	<b>Amphipods</b>			
218	<i>Ampelisca scabripes</i>	*	*	-
219	<i>Ampithoe rubricata</i>	*	*	-
220	<i>Ampithoerubricata</i>	*	*	*
221	<i>Ampithogammaroides</i>	*	*	*
222	<i>Atylus falcatus</i>	-	*	-
223	<i>Caprella mendax</i>	*	*	*
224	<i>Cerapus crassicornis</i>	*	-	*
225	<i>Cheiriphotis megacheles</i>	*	-	-
226	<i>Corophium triaenonyx</i>	*	*	-
227	<i>Cymadusa pathyi</i>	*	-	-
228	<i>Erichthonius brasiliensis</i>	*	-	-
229	<i>Eriopisa abhilashi</i>	*	-	-
230	<i>Eriopisa chilensis</i>	*	-	-
231	<i>Gammaropsis esturinus</i>	*	*	*
232	<i>Gammaropsis maculata</i>	*	*	*
233	<i>Gammarus duebeni</i>	*	*	*
234	<i>Gammarus zaddachi</i>	*	*	*
235	<i>Gitanopsis bispinosa</i>	*	*	-
236	<i>Gitanopsis gouriaie</i>	*	-	-
237	<i>Grandidierella bispinosa</i>	*	*	*
238	<i>Grandidierella bonnieroides</i>	*	-	-
239	<i>Grandidierella gilesi</i>	*	-	*
240	<i>Grandidierella gravipes</i>	*	*	-
241	<i>Grandidierella macronyx</i>	*	*	*
242	<i>Grandidierella megnae</i>	*	-	-
243	<i>Harmellia incerta</i>	*	-	*
244	<i>Harpinia antennaria</i>	*	-	-
245	<i>Harpinia laevis</i>	*	-	-
246	<i>Harpinia Pectinata</i>	*	-	-
247	<i>Hornellia incerta</i>	*	-	-
248	<i>Hyale honoluluensis</i>	*	-	-
249	<i>Idunella chilensis</i>	*	-	-
250	<i>Ingolfiella putealis</i>	*	-	-
251	<i>Jassa falcata</i>	*	-	-
252	<i>Jassa marmorata</i>	-	-	-
253	<i>Maera othonides</i>	*	*	*
254	<i>Metaphoxus fultoni</i>	*	*	-
255	<i>Metaphoxus pectinatus</i>	*	*	-
256	<i>Microprotopus maculatus</i>	*	-	-
257	<i>Microprotopus cumbreansis</i>	*	-	-
258	<i>Natarajphotis manieni</i>	*	*	*
259	<i>Orchestia platenis</i>	*	*	-
260	<i>Paracalliope indica</i>	*	-	-
261	<i>Parhyale hawaiiensis</i>	*	-	-
262	<i>Parorchestia morini</i>	*	-	-
263	<i>Parorchestia notabilis</i>	*	-	-
264	<i>Photis digitata</i>	*	-	*
265	<i>Phoxocephalus holbolli</i>	*	*	*
266	<i>Podocercus brasiliensis</i>	*	-	*
267	<i>Pontharpinia rostrata</i>	*	*	*
268	<i>Quadrivisio bengalensis</i>	*	-	-
269	<i>Talorchestia martensii</i>	*	-	-
270	<i>Urothoe pulchella</i>	*	*	*
271	<i>Urothoe serrudactyla</i>	*	*	*
272	<i>Urothoe viswanathi</i>	*	-	*
<b>V</b>	<b>ISOPODS</b>			
273	<i>Angeliera phreaticola</i>	*	*	*
274	<i>Basserolis kimblae</i>	*	-	-
275	<i>Calabozoa pellucida</i>	*	-	-
276	<i>Eisothistos antarcticus</i>	*	*	*
277	<i>Haploniscus laticephalus</i>	*	-	-
278	<i>Jaeropsis beuroisi</i>	*	-	-
279	<i>Janaira gracilis</i>	*	-	-
280	<i>Microjaera anisopoda</i>	*	*	*
281	<i>Paragnathia formica</i>	*	*	*
282	<i>Sphaeroma serratum</i>	*	-	*
283	<i>Munna boeckii</i>	*	-	-
284	<i>Plurocope dasyura</i>	*	-	*
285	<i>Eurydice pulchra</i>	*	-	*
286	<i>Microjaera anisopoda</i>	*	*	-
287	<i>Cymodoce truncata</i>	*	-	*
288	<i>Anthura gracilis</i>	*	*	*
<b>VI</b>	<b>Cumacea</b>			
289	<i>Campylaspis minor</i>	*	*	-
290	<i>Nannastacus inflatus</i>	*	-	*
291	<i>Gynodiastylis lata</i>	*	*	*
292	<i>Picrocuma poecilata</i>	*	*	-
	<b>Total</b>	<b>251</b>	<b>156</b>	<b>163</b>

Table 1: Species Recorded During the Study Period of January 2011 to December 2011.

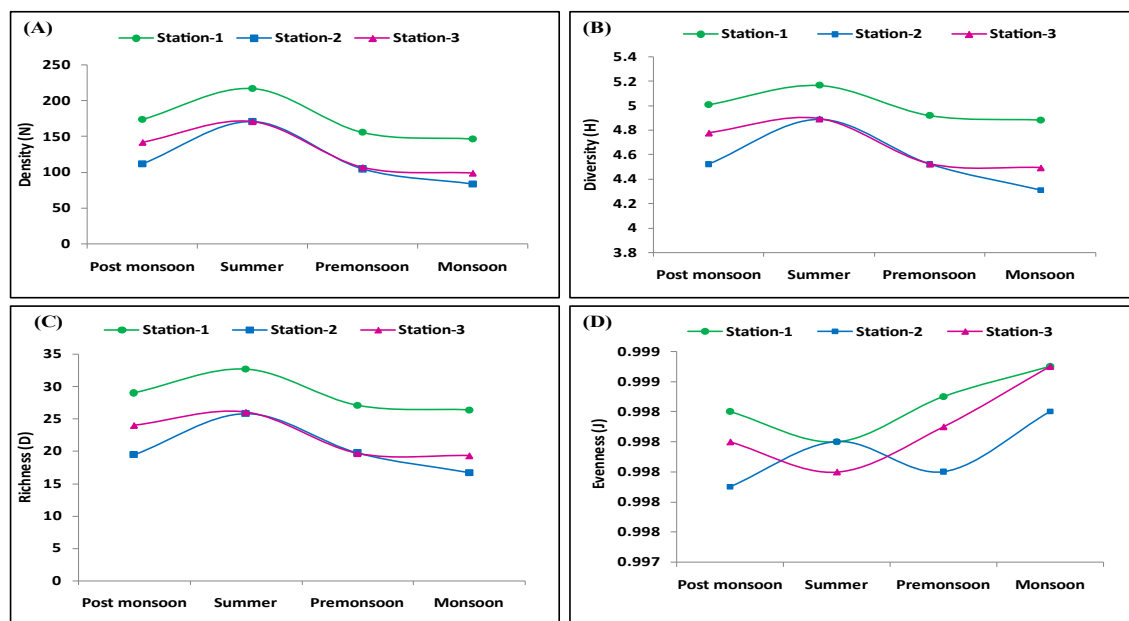


Figure 6: Univariate Measures for Macro-Benthic Macrofauna of Study Area (season-wise). A. Species density (N), B. Shannon Wiener diversity (H), C. Margalf richness (D), D. Pielou's evenness (J).

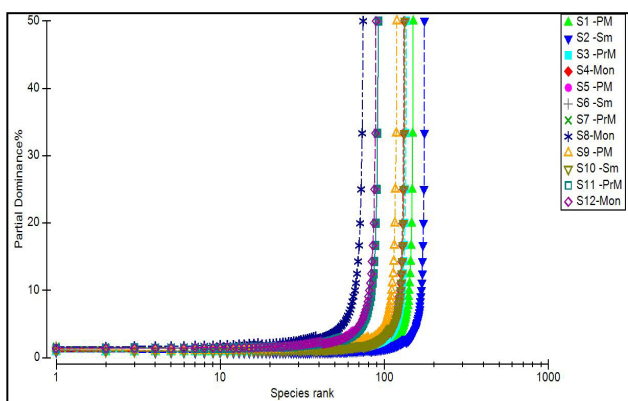


Figure 7: K-Dominance curves for all stations and seasons.

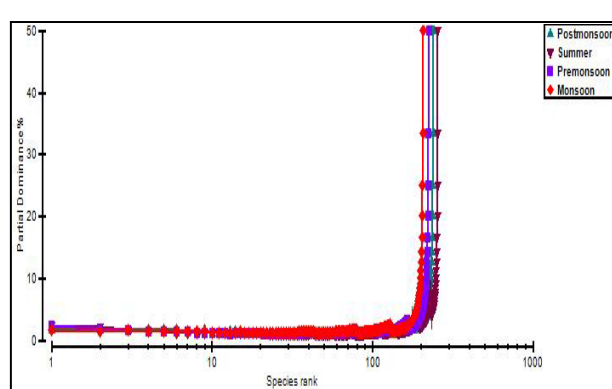


Figure 9: K-Dominance curves drawn for all the four seasons.

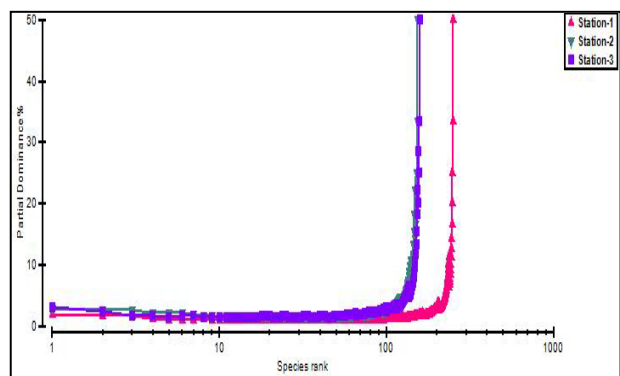


Figure 8: K-Dominance curves for all stations.

shown (Figure 8). The curve representing during the monsoon season lies at the top indicating lower diversity and curve represented during the summer season at the bottom indicating a higher diversity. Other two seasons fall in between these two seasons; the S shape of the graph is clear evidence that there is no disturbance to these resources.

## Discussion

One of the main goals of benthic ecology has been to understand the mechanisms regulating relationships between physico-chemical parameter and organisms [19-22]. The present study shows that the macrofaunal communities of three mangrove ecosystems exhibit distinct variations. It is characterized by temporal and spatial changes in its population and distribution pattern seems to be fully governed by the physico-chemical and hydrobiological characteristics of the environment. Intertidal fauna at the study area have to cope with harsh environmental conditions marked by high salinity, increased



evaporation, wide seasonal temperature fluctuations, and different degrees of tidal amplitudes. These unique physico-chemical factors exert a strong influence on faunal assemblages, which are withstanding the situation. Owing to the heterogeneous nature of estuarine water, the relatively stationary benthic animals on the bottom have to endure a wide range of environmental changes when the circulation carries different kinds of water over the site or borrow [23]. Mangroves also possess some positive advantages of benthic animals, compared to the open coast. Estuaries are relatively sheltered against wind waves and ocean swell; most estuaries are also rich in food provided by river input, input from mangroves, and high primary production [24,25].

This study has shown that there is difference in macrobenthic fauna at different mangrove types like developing, riverine, and island mangroves. The structure of benthic macrofauna communities is characterized by a low abundance and a very low diversity. Richer communities have been found in station I. The macrobenthic faunal density ranges from 84 to 217 ind/m<sup>2</sup> in all the stations. This density is higher than the macrobenthic faunal densities as reported by Parulekar AH [26] for Zuari estuary (50 to 1,437 ind/m<sup>2</sup>), by Parulekar AH and Ansari ZA [27] for Andaman seas (80 to 998 ind/m<sup>2</sup>), and comparable with that of Harikantra SN et al. [28] who record the density range of macrobenthos from 50 to 3,715 ind/m<sup>2</sup> in the shelf region along the west coast of India. However, this value is lower than the reported density of 1,253 to 5,723 ind/m<sup>2</sup> in northwestern Arabian Sea shelf by Parulekar AH [26] in northern sea. The difference in the benthic macrofaunal densities of different aquatic systems could be attributed mainly to variations in salinity, substratum and sediment organic carbon level, currents, and predation.

The species composition of benthic macrofauna in the present observation shows the dominance of polychaete followed by molluscs and crustaceans. Similar preponderance of polychaetes has been observed earlier by Sankar G [29] in Muthupet lagoon, Sunil Kumar [30] in Cochin backwaters, Prabha Devi L [31] in Coleroon estuary, and Ansari ZA et al. [32] in Mandovi estuary. Athalye RP and Gokhale KS [33] reported the dominance of polychaetes followed gastropods, bivalves, and hermit crabs in the Thane creek, Mumbai. The benthic population density shows seasonal variation in such a way that the maximum is recorded in summer and the minimum during monsoon at all the stations. The dominance of polychaetes might be due to firm substrate provided by roots and dense canopy of the mangroves which also provide protection against desiccation [34]. They have more opportunistic bearing potential ability to colonize in stressed environments [4]. The aforementioned adaptable nature of polychaetes may be a plausible reason for their dominance in the species composition

and their abundance in the present investigation. In the present study, mollusks form the second dominant group followed by polychaetes. The dominance of gastropods and bivalves are also observed by Kathiresan K et al. [35] in Vellar estuary on the southeast coast of India. They report that high tolerance to different environmental situation and various estuarine conditions reveal its higher abundance. In the present study, crustaceans form the third group after polychaetes and molluscs. The present observation shows numerical dominance in the decreasing order as polychaetes, mollusks (bivalves and gastropods), and crustaceans, as observed earlier by Mohammed SZ and Kumar RS [36,37] in other mangrove environs of India. Irrespective of mangrove types, the mangroves show the same order of polychaetes, molluscs, and crustaceans. From this, it is evident that polychaetes form the dominant group of macrobenthos in mangroves.

Environmental factors such as temperature, sediment composition, and inundation are the main factors influencing the distribution of faunal communities in tropical mangroves. Salinity is one of the important key factors which determine the composition of biological component in the marine environment. The fluctuations in salinity affect the biological characteristics of the environment. The present study did not show characteristic relationship between salinity and macrofaunal distribution; however, soil salinity showed significant negative correlation with species evenness ( $r=-0.999$ ;  $p<0.05$ ) at station I (Table 2) and ( $r=-0.960$ ;  $p<0.05$ ) at station III (Table 3). This means that the fluctuation of salinity in riverine and island mangroves have profound influence on the species evenness. Reid GK [38] remarks that the momentary salinity may be regarded as a function of the quantity and quality of inflowing and out flowing waters, rainfall, and evaporations since these factors may vary with seasons (in some instants rather drastically).

In the present investigation, dissolved oxygen was high during the monsoon season at all sites, which might be due to the cumulative effect of higher wind velocity coupled with heavy rainfall and the resultant freshwater mixing. Relatively lower values were observed during summer; this may be due to the increased surface water temperature which reduces the dissolution of O<sub>2</sub> in the coastal waters. It is well known that temperature and salinity affect the dissolution of oxygen [39]. Hydrogen ion concentration (pH) in surface waters remained alkaline at all sites throughout the study period with the maximum value during summer seasons and the minimum during the monsoon. However, the present study did not find a characteristic relationship between pH, salinity, and temperature and macrobenthic fauna, confirming that the fauna of independent mangrove system requires specific environmental characters.

	ST	SSA	SPH	STN	STP	STOC	Sand	Silt	Clay	Density	Diversity	Richness	Evenness
ST	1												
SSA	0.986091	1											
SPH	0.991117	0.96058	1										
STN	-0.99501	-0.97095	-0.98555	1									
STP	-0.985	-0.99344	-0.9533	0.980507	1								
STOC	-0.96459	-0.96499	-0.96937	0.935008	0.933743	1							
Sand	-0.77014	-0.86224	-0.68744	0.740486	0.858074	0.755322	1						
Silt	0.799819	0.882087	0.717767	-0.77786	-0.88583	-0.76537	-0.99642	1					
Clay	-0.82504	-0.89623	-0.74431	0.811411	0.908346	0.770039	0.984813	-0.99597	1				
Density	0.940327	0.875838	0.975454	-0.94351	-0.86945	-0.91682	-0.51077	0.548353	-0.58393	1			
Diversity	0.946937	0.881975	0.976773	-0.95518	-0.88256	-0.90725	-0.52424	0.565644	-0.60513	0.997993	1		
Richness	0.940199	0.872801	0.973116	-0.94806	-0.87202	-0.90377	-0.50697	0.548085	-0.58741	0.998796	0.999715	1	
Evenness	-0.99956	-0.98092	-0.99279	0.997003	0.981719	0.959627	0.753535	-0.7853	0.812843	-0.94748	-0.9547	-0.94825	1

Table 2: Simple correlation coefficient (R) between macrofaunal and physico-chemical parameters at station I.

	ST	SSA	SPH	STN	STP	STOC	Sand	Silt	Clay	Density	Diversity	Richness	Evenness
ST	1												
SSA	0.867871	1											
SPH	0.930644	0.913275	1										
STN	-0.79303	-0.9515	-0.76116	1									
STP	-0.84562	-0.93824	-0.77308	0.990798	1								
STOC	-0.9414	-0.95002	-0.87191	0.950075	0.975984	1							
Sand	-0.99612	-0.86326	-0.90031	0.815045	0.871225	0.955119	1						
Silt	0.838626	0.800743	0.967909	-0.58521	-0.59109	-0.72117	-0.78889	1					
Clay	0.448426	0.286066	0.11425	-0.50688	-0.58958	-0.54493	-0.52365	-0.11045	1				
Density	0.983487	0.935874	0.97216	-0.84591	-0.8751	-0.95531	-0.97287	0.887245	0.343411	1			
Diversity	0.985594	0.933212	0.931586	-0.88376	-0.91955	-0.98285	-0.98698	0.81616	0.464778	0.990661	1		
Richness	0.9946	0.913559	0.940589	-0.84912	-0.89028	-0.968	-0.99243	0.83739	0.444172	0.993375	0.997568	1	
Evenness	-0.04257	-0.36494	0.043396	0.608955	0.562666	0.37067	0.106685	0.260725	-0.53398	-0.09677	-0.19314	-0.12586	1

Table 3: Simple correlation coefficient (R) between macrofaunal and physico-chemical parameters at station II.

	ST	SSA	SPH	STN	STP	STOC	Sand	Silt	Clay	Density	Diversity	Richness	Evenness
ST	1												
SSA	0.820628	1											
SPH	0.955647	0.952424	1										
STN	-0.88275	-0.98094	-0.97719	1									
STP	-0.84942	-0.96033	-0.95008	0.992338	1								
STOC	-0.6327	-0.7759	-0.74357	0.847665	0.906718	1							
Sand	-0.92639	-0.9451	-0.97847	0.936259	0.886342	0.609879	1						
Silt	0.880526	0.45549	0.704752	-0.57842	-0.55291	-0.39693	-0.6493	1					
Clay	0.738683	0.957966	0.884171	-0.89031	-0.84038	-0.57064	-0.93638	0.341052	1				
Density	0.890673	0.96105	0.967448	-0.93775	-0.88778	-0.61132	-0.99606	0.579391	0.963771	1			
Diversity	0.827154	0.963641	0.934409	-0.91792	-0.86545	-0.58353	-0.97754	0.474882	0.989115	0.992222	1		
Richness	0.82776	0.957085	0.931135	-0.91005	-0.85497	-0.56534	-0.97809	0.479554	0.987637	0.99215	0.99971	1	
Evenness	-0.83512	-0.96094	-0.94285	0.9904	0.999639	0.911869	0.878709	-0.53079	-0.84115	-0.88224	-0.86254	-0.85163	1

Table 4: Simple correlation coefficient (R) between macrofaunal and physico-chemical parameters at station III.

Sediment texture plays an important role in the ecology of benthic invertebrates [40,41]. The pelagic larvae of macrobenthic organisms before finally settling down at the bottom have to cross many barriers, and each type of bottom deposit will attract a very limited and selected set of species [42]. A common concept in benthic animal-sediment relation is that the feeding type of the infauna is in one way correlated to the sediments [43]. Deposit or detritus feeders constitute an important and often dominating part of macrobenthic invertebrates [44]. Sediment character has been identified as one of the driving forces in determining the macrofaunal communities. At station I, species diversity is negatively correlated with sand ( $r=-0.986$ ) while in station II and III, positive correlation is obtained between density and silt ( $r=0.984$  and  $r=0.887$ ) at  $p<0.05$  level (Table 4).

This indicates that availability of silty soil sustains to macrofaunal diversity and density, while sand dominance will reduce the macrofaunal population. Clayey silt substrate is always known to support epifauna [45,46]. Food supply seldom acts as a limiting factor in the seasonal abundance of macrobenthos [47]. Organic nutrients enhance the growth of different types of algae that provide food resources for benthos [48]. In the present study, the higher density macrobenthos is observed during summer season. Higher organic matter gets deposited during the post-monsoon season in the mangrove areas. It would be converted into available organic carbon by various fungal and bacterial sources, which in turn increase the macrobenthic forms especially polychaetes [49]. High organic carbon induced abundance of macrofauna in Coleroon estuary [50]. This confirmed that the abundance of benthic fauna is highly related to organic carbon.

To find out a clear picture of species diversity and distribution, various univariate and multivariate analyses have been carried out and results are discussed. Individual species is a simple and useful measure of the biological system. The species individual diversity in the present study registered a wide fluctuation between 4.311 (monsoon) and 5.167 (summer) among stations and seasons. The lower species diversity was recorded during monsoon and higher diversity values during summer in the study area. This is in conformity with the earlier observations made in Vellar [51] and Coleroon estuaries [31]. Moreover, Pearson TH and Rosenberg R [52] proposed that the use of diversity indices is advantageous for the description of fauna at different stages in succession. In the present study, negative correlation is obtained between species richness and diversity at stations I ( $r=-0.999$ ), II ( $r=-0.997$ ) and III ( $r=-0.999$ ) at  $p<0.05$  level.

All the nutrients (TN, TP and TOC) are found enriched in the sediment during monsoon. These nutrients might have reached the benthic realm through food web during summer and pre-monsoon seasons. The species richness of benthic macrofauna was found maximum during the summer season (32.70). A similar observation was reported by Kumar RS [37] in Cochin backwaters. The low richness was recorded during monsoon (16.69) might be due to the high freshwater inflow with low saline conditions, which in turn affect the distribution of benthos, particularly the polychaetes. Maximum diversity and richness recorded during summer at the all sites might be due to stable and optimum environmental factor such as salinity, which plays an important role in faunal distribution and abundance. Shannon diversity was exceptionally high and it was in the range of 4.311-5.167. The minimum (4.311) and maximum (5.167) was recorded at station II

during the monsoon season and at station I during the summer season, respectively. Shannon diversity in the present study was considered to be good and the range recorded in the present study vouchsafes for the healthy nature of mangrove ecosystem. Similar seasonal pattern is evident from the view of Kundu et al. [53].

Species area plots used to show the cumulative number of different species observed as each new sample is added. The advantage of plotting this technique is to predict the total number of stations to be sampled for getting the maximum number of species in a station. The present study revealed that 12 times sampling during various seasons is enough to get all the species in the study areas. The dendrograms derived in the present study showed clustering of stations and gradual change in species composition from the island mangrove ecosystem towards riverine mangrove ecosystem. This means that a certain level of similarity prevails in faunal diversity in developing and island mangroves than in the riverine mangrove ecosystem. Derived multidimensional scaling (MDS) ordination reveals the same grouping of stations as in the cluster analysis. The stress values found in the MDS configuration is low (0.11), indicating good representation of the interrelationship between the macrofauna of each station. Benthic population density (N) is positively correlated with sediment temperature ( $r=0.940$ ), salinity ( $r=0.875$ ), Ph ( $r=0.975$ ), Silt ( $r=0.548$ ) in station I. In station II, benthic population density is positively correlated with sediment temperature ( $r=0.983$ ), salinity ( $r=0.935$ ), pH ( $r=0.972$ ) and silt ( $r=0.887$ ). In station III, sediment temperature ( $r=0.890$ ), sediment salinity ( $r=0.961$ ), pH ( $r=0.967$ ) and silt ( $r=0.579$ ) are positively correlated with benthic population at  $p<0.05$  level.

## Conclusion

Among the three ecosystems, riverine mangrove (station I) ecosystem is more pristine in nature than the developing and island mangrove ecosystems. Benthic macrofauna species assemblage is comparatively higher in station I than in stations II and III. Analysis of data undertaken with predictable like line Shannon diversity, Simpson richness, and recently introduced diversity indices such as taxonomic diversity index and total phylogenetic index clearly opined that healthy nature of the mangrove ecosystem. From the present study, it could be concluded that the hydrography, nutrients, and sediment texture are the major factors responsible for fluctuation in benthic macrofaunal assemblages in the study area.

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