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Seasonal Variation of Environmental Factors Influencing Benthic Macrofaunal Diversity in Parangipettai and Cuddalore Coast (Southeast coast of India)

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Abstract An attempt was made with the diversity and seasonal variations of macrobenthic fauna and associated environmental factors influencing the benthic community in the inshore waters of southern Indian coast. Four seasonal collections were made from January – 2013 to December – 2013, such as, post-monsoon, summer, pre-monsoon and monsoon in the inshore waters of Parangipettai and Cuddalore coastal region of Southeast, India. Atmospheric temperature 28 – 34.5°C, water temperature 27.5 – 34°C, salinity 27 – 34psu and pH 7.6 – 8.2 were recorded maximum at summer season and minimum at monsoon season. Dissolved oxygen rangers between 4.03 and 6.16 mg/l^{-1} were maximum at monsoon season and minimum at summer season. Altogether, 24 infaunal samples (Peterson grab 0.256 m^2) were collected which revealed the occurrence of 86 species representing five diverse groups. Polychaetes were the dominant group (56%), followed by Amphipods (12%), Gastropods and Isopods (9%) and Bivalves (8%). Diversity (H'log2) ranged between 4.030 (Cuddalore, monsoon) and 4.304 (Parangipettai, postmonsoon). K- Dominance curve drawn paralleled the trend of diversity indices. Cluster and MDS showed the similarity infaunal composition between stations and seasons. Some polychaetes were abundant more than other species i.e.g., *Arabella mutans, Capitella capitata, Cossura coasta, Lumbrineris sp.* and *Pisionidens indica* they are indicating that the particular area polluted with industrial waste.
Keywords Physico-chemical variation; Macrofauna; Sediment characteristic; Heavy metal

Introduction

Benthic macrofauna are those organisms that live on or inside the bottom of a water body (Idowu and Ugwumba, 2005). Macrobenthic invertebrates are useful bio-indicators (Basset et al., 2004) providing a more accurate understanding of changing aquatic conditions than chemical and microbiological data, which at least give short-term fluctuations (Ikomi et al., 2005). The most popular biological method in assessment of freshwater bodies receiving domestic and industrial wastewaters is the use of benthic macro-invertebrates (Odiete, 1999). Their composition, abundance and distribution can be influenced by water quality (Haslam, 1990; APHA, AWWA and WPCF, 1998; Odiete, 1999). They all stated that variations in the distribution of macrobenthic organisms could be as a result of differences in the local environmental conditions.

Limited benthic studies have been conducted in the tropics compared to higher latitudes, and the theory relating to the community structure is based largely on the studies from temperate regions (Alongi, 1990). Studies on benthos along the shelf region of northwestern India are limited to the studies of Neyman (1969), who studied the benthos of the shelves in the northern part of the Indian Ocean. Other works in the northwest coast of India include those of (Joydas and Damodaran, 2001; Joydas, 2002). In addition, Parulekar et al., (1982) studied the benthos of the Indian seas. However, no work has been done to elucidate the community structure of the shelf waters and the relationship between the benthos and environmental properties, except that of Varshney et al., (1988), who studied the macro-benthos of very-near-shore off Versova, West coast of India. Sourav et al., (2009) reported the environmental parameters and benthic fauna diversity in East coast of India.

An important feature of the Bay of Bengal is the influence of the southwest and northeast monsoons that bring about a complete reversal of the surface current pattern, either clock-wise or counter-clock-wise depending on the direction of the wind (Varkey et al., 1996; Madhupratap et al., 2003). The objective of this research was to characterise benthic communities (based on species abundance data) and link them to a suite of environmental factors (e.g. surface seawater temperature, salinity, dissolved oxygen and heavy-metal) measured synchronously at two predetermined locations in the inshore waters of the Bay of Bengal.

1 Materials and Methods

Four seasonal collections were made (January 2013 to December 2013), and altogether, 24 samples were taken from 2 stations (duplicate samples were collected from each station—4 seasons × 2 stations × 2) belonging to two transects, namely Cuddalore (Station 1) (11^o 42’ N and 79^o 47’ E) besides a station near State Industrial Promotion Council of Tamilnadu (SIPCOT) industrial cluster and Parangipettai (Station 2) (Lat.11°29’N and 79°46’E) – (Figure 1). Grab hauls were obtained according to standard protocols of Holme and McIntyre (1984). The environmental parameters such as temperature, salinity, dissolved oxygen and pH were analysed following the methods of (Stickland and Parsons, 1972).

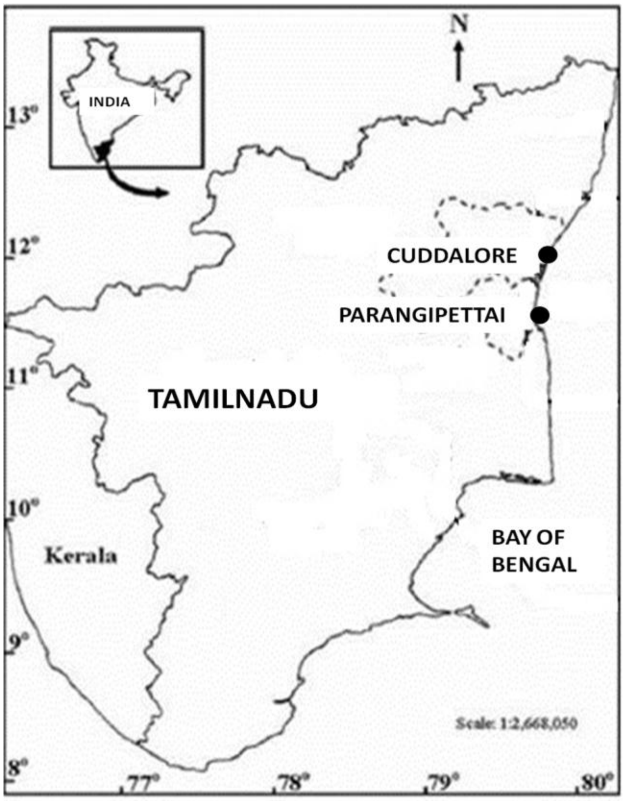

Figure 1 The map showing the study area

Van veen grab (0.1 m^2) was used for unit sampling and the subtidal benthic samples were collected monthly from each station. Hand operated grab hauls used for collect the sediment samples for physic-chemical and biological parameters. Collected sediment samples were transferred into pre-labeled polythene bags for subsequent determination of the sediment particle sizes. The remaining benthic samples were washed through a sieve of 0.5mm x 0.5mm mesh size to collect the benthos. The washed sediment with macrobenthos were poured into a wide mouth labeled plastic container and preserved with 10% formaldehyde solution to which Rose Bengal (dye) had been added. The Rose Bengal dye at strength of 0.5% selectivity colored all the living organisms in the sample (Claudiu et al., 1979; Zabbey, 2002; Idowu and Ugwumba, 2005). The preserved samples were later taken to the laboratory for further analysis.

All taxa were first segregated into different groups and then identified to specific, generic or other higher levels to the greatest extent possible with the help of standard taxonomic references. Fauvel, 1953 and Day, (1967) for Polychaeta, for Mollusca: Subba Rao et al., (1991). The organisms were counted under a stereoscopic microscope (Motic *B3 series*, and 40×magnification) and abundance was expressed as individuals per square meter. Sediment samples were subjected to pipette analysis according to the standard method (Krumbein and Pettijohn, 1938).

The data were analysed by various statistical methods namely univariate measures such as Margalef’s species richness *(d)*, Shannon–Wiener diversity (*H*’ log2) and Pielou’s evenness (*J*’); graphical tools like *k*-dominance curve and Ellipse plots and multivariate tools 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 with help of PRIMER 6.1.

2 Result and Discussion

The environmental physical characteristics recorded at all the stations, the atmospheric temperature varied from 28 ^oC to 34.5 ^oC (Fig. 2). The minimum value was recorded in station 2 during the monsoon season and the maximum values were recorded in both the stations 1 and 2 during summer season. The surface water temperature varied between 27.5 °C to 34 °C (Figure 2). Minimum were recorded in both the stations 1 and 2 during monsoon season. Whereas, the maximum value was recorded at station 2 during summer season. Higher surface water temperature recorded during summer season might be possibly due to influenced by intensity of solar radiation, evaporation, freshwater influx and cooling and mix up with ebb and flow from adjoining neritic waters (Ajithkumar et al., 2006; Saravanakumar et al., 2008). The lower value of surface water temperature recorded during monsoon season might be possibly due to strong land sea breeze and precipitation (Ashok Prabu et al., 2008; Rajkumar et al., 2009).

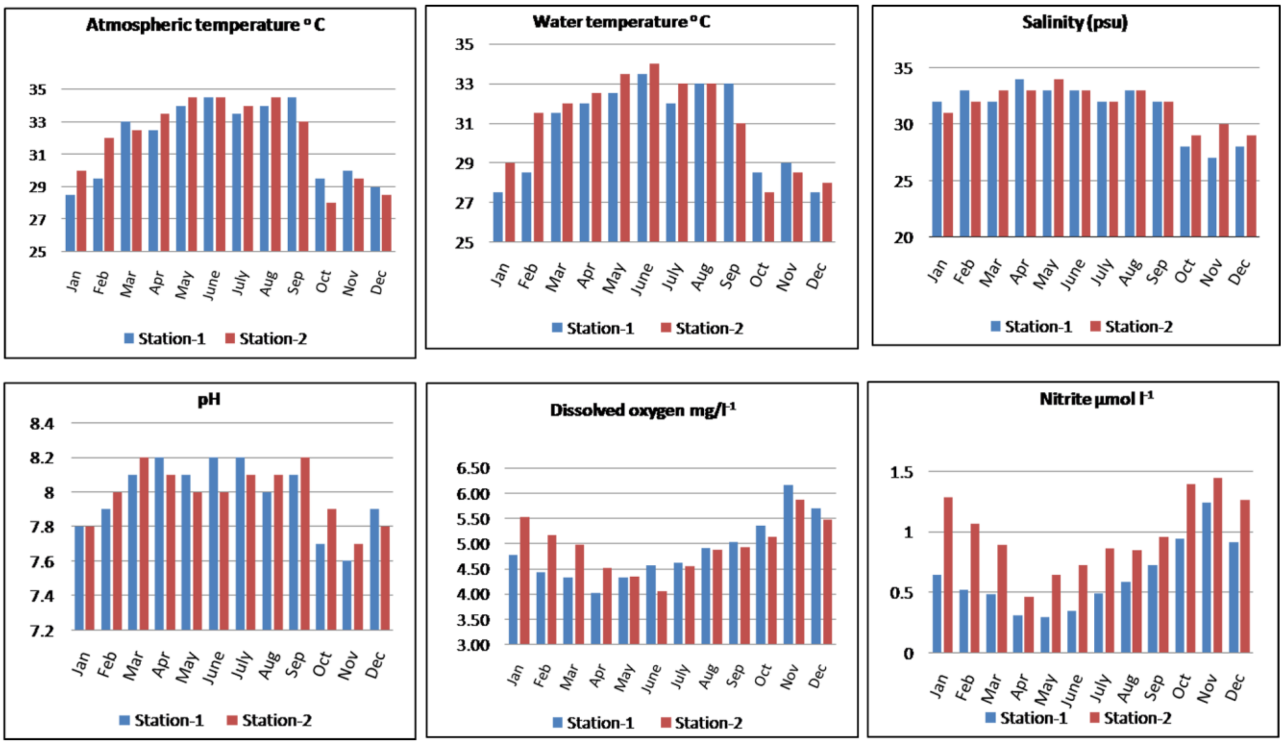

Figure 2 Water quality parameters Temperature, salinity, pH, Dissolved oxygen and nitrite present in the study period

The minimum value of salinity recorded was 27 psu and the maximum was 34 psu (Figure 2). The minimum salinity recorded in station 1. The maximum was recorded in station 2. Salinity was maximum value recorded during summer season and the minimum values reported in monsoon season. The salinity acts as a limiting factor in the distribution of living organisms, and its variation caused by dilution and evaporation influences the fauna most likely in the intertidal zone (Gibson, 1982). In the present study, salinity at all the sites was high during summer and low during the monsoon season. Higher values in summer could be attributed to faster evaporation in the study area. Thus, the variation of salinity at study sites is probably due to freshwater runoff and rain (Sridhar et al., 2006; Asha and Diwakar, 2007).

The dissolved oxygen varied from 4.03 to 6.16 mg/l^{-1} (Figure 2). The minimum level of dissolved oxygen recorded at station 1 during summer and the maximum was recorded at station 1 during monsoon. The 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, which could be mainly due to reduced agitation and turbulence of the coastal water. Das et al., 1997 and Saravanakumar et al., 2007 have attributed seasonal variations in dissolved oxygen mainly to the freshwater influx and ferriginous impact of sediments. It is well known that the temperature and salinity affect the dissolution of oxygen (Vijayakumar et al., 2000).

The pH varied from 7.6 to 8.2 and the pH level increased from the minimum values recorded during the monsoon season at station 1 to reach the maximum during pre-monsoon (Figure 2). Hydrogen ion concentration (pH) in surface waters remained alkaline at all sites throughout the study period, with the maximum value during summer season and the minimum during monsoon. Generally, fluctuations in pH values during different seasons of the year are attributed to factors like removal of CO_2 by photosynthesis through bicarbonate degradation, dilution of seawater by freshwater influx, reduction of salinity and temperature, and decomposition of organic matter (Rajasegar, 2003).

Nutrients are considered as one of the most important parameters in the marine environment influencing growth, reproduction and metabolic activities of biotic components. In the same way, environmental parameters are key factors in the decomposition process of organic matter (Sangiorgio et al., 2008). Distribution of nutrients is mainly based on season, tidal conditions and freshwater flow from land. The environmental chemical characteristics of the surface sea water maximum during monsoon and the minimum in the summer. The nitrite values ranged between 0.293 and 1.447 μmol l^{-1} (Figure 2). The nitrate values ranged between 2.736 and 10.26 μmol l^{-1} (Figure 3). The ammonia values ranged between 0.048 and 0.254 μmol l^{-1} (Figure 3). The total nitrogen values ranged between 11.024 and 12.368 μmol l^{-1} (Figure 3). In the present study highest values of nitrate and total nitrogen during monsoon season could be mainly due to the organic materials received from the catchment area during ebb tide (Ashok Prabu et al., 2008). Another possible way of nitrate input could be through oxidation of ammonia form of nitrogen to nitrite formation (Rajasegar, 2003). The recorded low values during non-monsoon period may be due to its utilization by phytoplankton as evidenced by high photosynthetic activity and the dominance of neritic seawater having a negligible amount of nitrate (Rajaram et al., 2005; Bragadeeswaran et al., 2007).

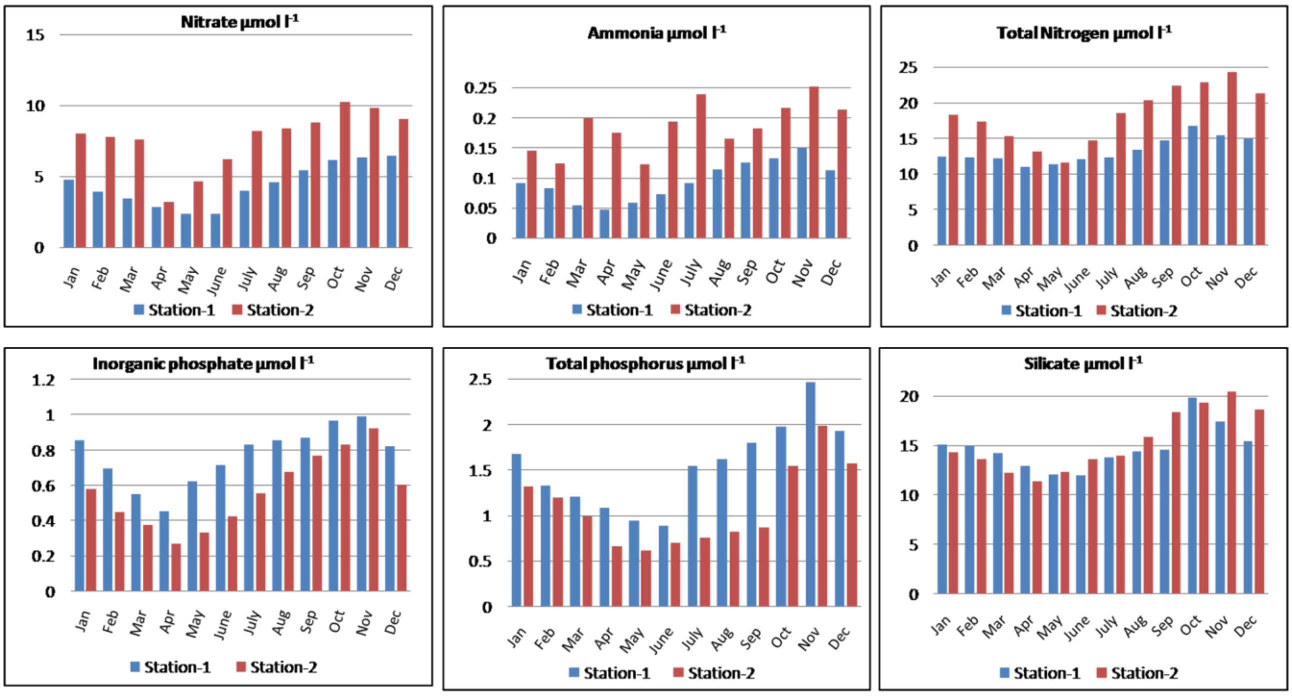

Figure 3 Water quality parameters Nitrate, Ammonia, Total nitrogen, Inorganic phosphate Total phosphorus and silicate present in the study period

The inorganic phosphate values ranged between 0.268 and 0.989 μmol l^{-1} (Figure 3). The total phosphorus values ranged between 0.617 and 2.466 μmol l^{-1} (Figure 3). Present study maximum level of inorganic phosphate and total phosphorus were recorded during monsoon season and the minimum values were noticed in summer period. High concentration of inorganic phosphate observed during monsoon season high is possibly due to intrusion of upwelling seawater, which increased the level of phosphate (Nair et al., 1984). Further, regeneration and release of total phosphorus from bottom mud into the water column by turbulence and mixing also contributed to the higher values during monsoon (Chandran and Ramamoorthy, 1984).

The silicate values ranged between 11.35 and 20.47 μmol l^{-1} (Figure 3). The silicate content was higher than that of the other nutrients and the recorded high monsoon values could be due to large influx of freshwater derived from land drainage carrying silicate leached out from rocks and also from the bottom sediment (Rajasegar, 2003). The observed low summer values could be attributed to uptake of silicates by phytoplankton for their biological activity (Ashok Prabu et al., 2008; Saravanakumar et al., 2008).

The sediment temperature was ranged between 27 °C and 34 °C (Figure 4). The maximum sediment temperature value was recorded at station 2 and the minimum was recorded in station 2. All stations showed a similar trend with similar seasonal variations. The physico-chemical factors of sediments is a key on quality assessment of sediments in costal environment, in this concern the present study analyzed the physic-chemical characterization of sediments in three different stations of costal. Oceans large thermal inertia causes temperature variation due to absorption of solar energy and subsequent release to the atmosphere (Varadhachari et al., 1987). Similar trend recorded due to freshwater flow (Varadhachari et al., 1987). The sediment salinity was ranged between 26 psu and 35 psu (Figure 4). The maximum and the minimum values were recorded in station 2. The sediment pH was ranged between 7.7 and 8.2 (Figure 4). The maximum recorded in station 2 and the minimum was recorded in station 1. These physical parameters of the sediment characteristics were maximum value during summer and the minimum during monsoon. Total organic carbon of the sediment was ranged between 0.435 and 3.795 mgC/g soil (Figure 4). The minimum TOC recorded during pre-monsoon period at station 2 and the maximum was recorded during monsoon at station 1. The distribution of total organic carbon closely followed the distribution of sediment fine nature and clay content and high rate sedimentation (Raghunath and Sreedhara Murthy, 1996).

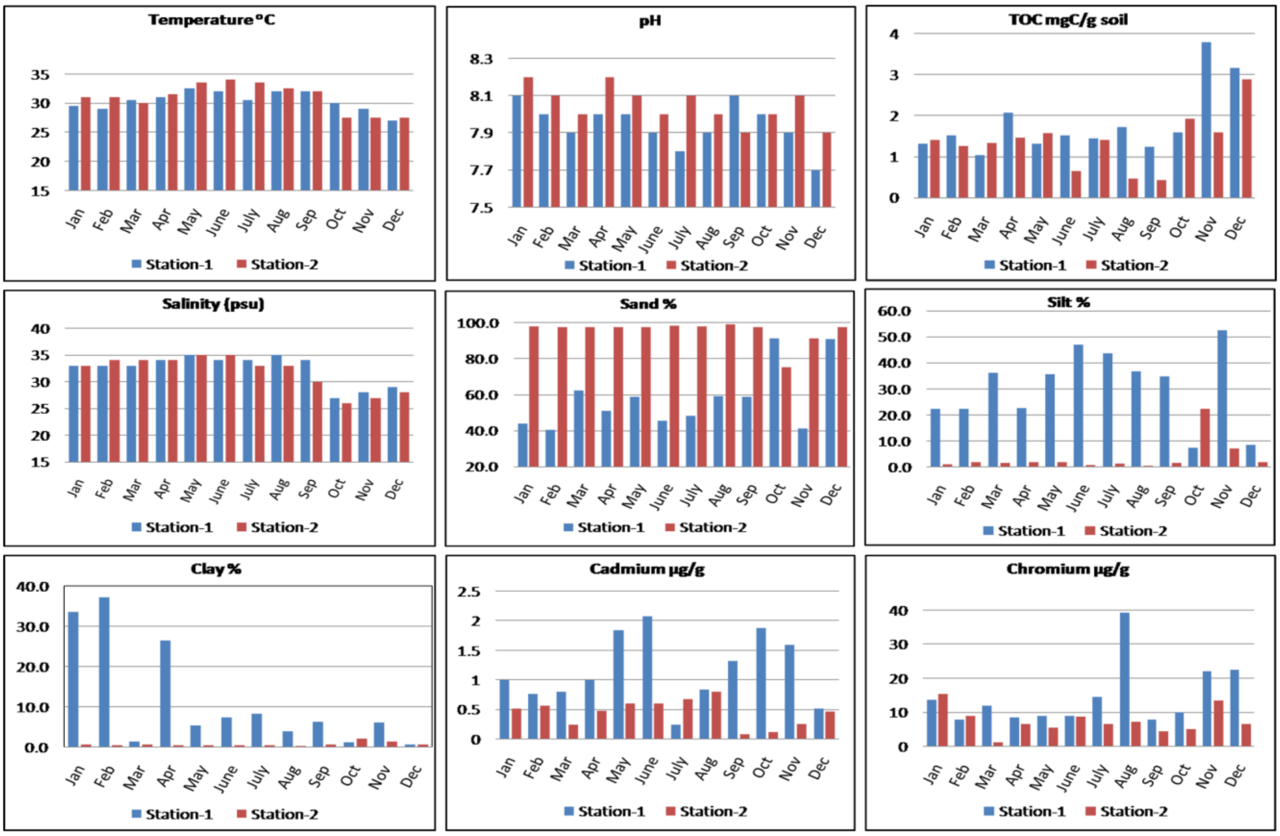

Figure 4 Sediment parameters Temperature, pH, TOC, Salinity Sand %,Silt%, Clay%, Cadmium and Chromium present in the study period

Percentage of sand particles varied from 40.410% to 99.178% (Figure 4). The maximum level of sand particles was present in station 2 and minimum sized particles are present in station 1. Percentage of silt particles varied from 0.459% to 52.441% (Figure 4). The maximum level of silt particles was present in station 1 and minimum sized particles are present in station 2. Percentage of clay particles varied from 0.363% to 37.312% (Figure 4). The maximum level of silt particles was present in station 1 and minimum sized particles are present in station 2. Sand, slit and clay was supported by following research articles (Badarudeen et al., 1996; Chanda et al., 1996).

The concentration heavy metal found to be due to the meager metal rich fresh water influx. The sediment heavy metal values were recorded as follow as. The cadmium levels were ranged between 0.08 µg/g and 2.08 µg/g (Figure 4). The maximum value was found in station 2 during pre-monsoon and the minimum was recorded in station 1 during summer. The chromium levels were ranged between 1.12 µg/g and 39.32 µg/g (Figure 4). The maximum value was found in station 1 during pre-monsoon and the minimum was recorded in station 2 during post monsoon. The copper levels were ranged between 4.84 µg/g and 60.72 µg/g (Figure 5). The maximum value was found in station 1 during summer and the minimum was recorded in station 2 during monsoon. The elements Cr, Cu and Cd displays quite similar pattern of distribution, these elements are used as markers of metal industries (Kumar et al., 2001; Loska et al., 2004). Which are probably controlled by sedimentary features such as organic matter and grain size (Harbison, 1984). The Cr and Cu in the industry and domestic waste affected areas suggesting that iron and steel industries and sewages contribute equally to the contamination in the study area (El Nemr et al., 2006). Cadmium enrichment is independent of the accumulation rates of terrigenous detritus input (Calvert and Pedersen, 1993). These elements are known as markers of paint industries (Lin et al., 2002) many are present in the study area.

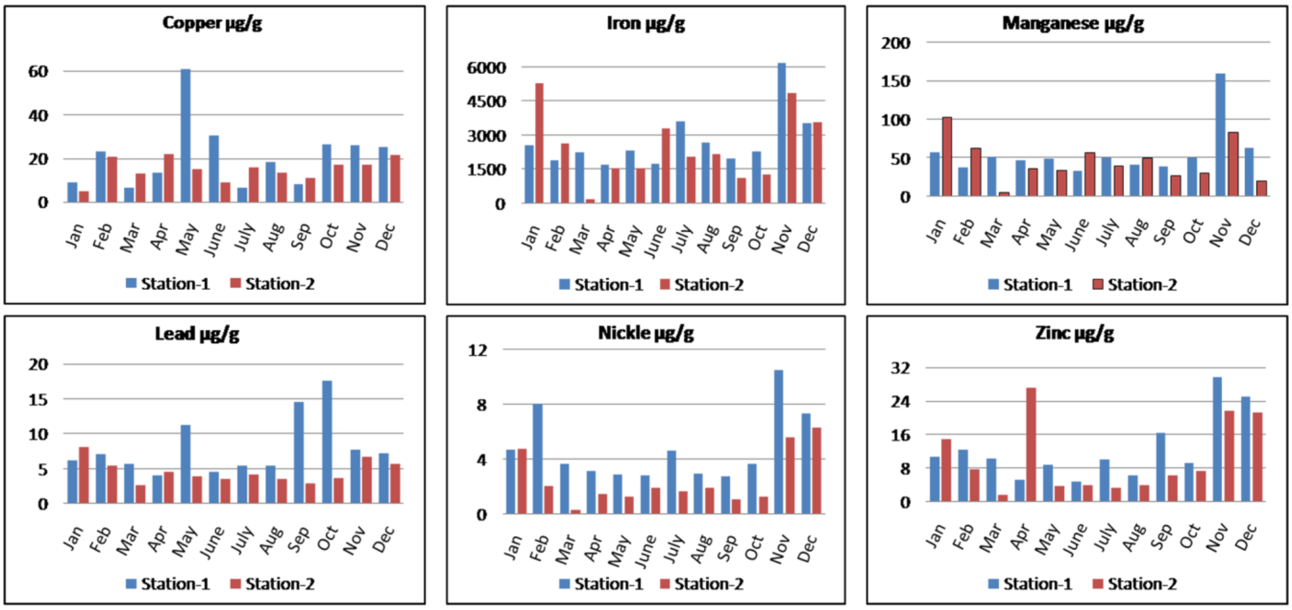

Figure 5 Sediment parameters Copper, Iron, Manganese, Lead Nickle and Zinc present in the study period

The Iron levels were ranged between 172.16 µg/g and 6200 µg/g (Figure 5). The maximum value was found in station 1 during monsoon and the minimum was recorded in station 2 during post monsoon. It seems likely that the Fe enrichment results in the reduction of Fe in the sediment during the oxidation of organic matter (Francois, 1988). The manganese levels were ranged between 4.12 µg/g and 158.84 µg/g (Figure 5). The maximum value was found in station 1 during monsoon and the minimum was recorded in station 2 during post monsoon. The iron and manganese can be converted to complex hydroxy compounds that may eventually precipitate (Riley and Chester, 1971). It is well established that iron and manganese oxides are excellent scavengers for trace metals (Tessier et al., 1979). This would lead the co-precipitation of other metals in the water column and so increase the concentration of many metals in sediments.

The nickel levels were ranged between 0.32 µg/g and 10.48 µg/g (Figure 5). It was maximum found in station 1 during monsoon and the minimum was recorded in station 2 during postmonsoon. The lead levels were ranged between 2.68 µg/g and 17.56 µg/g (Figure 5). It was maximum found in station 1during monsoon and the minimum was recorded in station 2 during post monsoon. The zinc levels were ranged between 1.6 µg/g and 29.72 µg/g (Figure 5). It was maximum found in station 1 during monsoon and the minimum was recorded in station 2 during postmonsoon. This similar observation reported in the Pichavaram mangrove (Glory Dally, 1984) and in the Kodiakkarai coastal area (Pragatheeswaran et al., 1986).

In total, 86 macro-benthic infaunal species represented by five diverse groups were encountered, of which polychaetes, bivalves, gastropods, amphipod and isopods were the most important groups. Polychaetes dominated the infauna (49 species) and contributed numerically up to 56% of the population. Bivalves were consisting of 7 species and contributed 8% of total infauna production. Gastropods were consisted of 8 species and contributed 9%, amphipods were 10 species and contributed 12%, Isopods were 8 species 9% and the other families of the infauna were 4 species and contributed 5% of the total population (Table 1). Species composition of the benthic macro-fauna in the present observation showed numerical dominance in the order of polychaetes, molluscs (bivalves and gastropods), crustaceans and others, as was observed earlier by Kumar, (2001).

Table 1 Species checklist for Cuddalore and Parangipettai

S.No	Polychaetes	St1-POM	St1-SUM	St1-PRM	St1-MON	St2-POM	St2-SUM	St2-PRM	St2-MON
1	*Arabella mutans*	*	*	*	*	-	-	-	-
2	*Armandia intermedia*	*	*	*	*	*	*	*	*
3	*Armandia longicaudata*	*	*	*	*	*	*	*	*
4	*Boccardia polybranchia*	*	*	*	*	*	-	*	*
5	*Capitella capitata*	*	*	*-	*	*	*	*	*
6	*Chone collaris*	*	*	*	*	*	*	*	*
7	*Cirratulus africanus*	*	*	*	*	*	*	-	*
8	*Cirratulus chrysoderma*	-	-	*	-	-	-	-	*
9	*Cirratulus concinnus*	-	-	-	-	*	-	*	-
10	*Cirratulus filiformis*	*	*	*	*	-	-	-	-
11	*Cirriformia* sp.	-	-	-	-	*	*	-	-
12	*Cossura coasta*	*	*	*	*	*	*	*	*
13	*Dorvillea gardineri*	-	-	-	-	*	*	*	*
14	*Drilonereis monroi*	*	*	*	*	*	*	*	*
15	*Epidiopatra gilchristi*	*	*	*	*	*	*	*	*
16	*Eulalia bilineata*	*	*	*	*	*	*	*	-
17	*Eunice indica*	*	*	*	*	*	*	*	*
18	*Exogone clavator*	*	*	*	*	*	-	-	*
19	*Fabricia filamentosa*	*	*	*	-	-	-	-	-
20	*Glycera alba*	*	*	*	*	*	*	*	*
21	*Glycinde capensis*	-	-	-	-	*	-	*	-
22	*Goniada emerita*	*	*	*	*	*	-	*	*
23	*Goniadides falcigera*	*	*	*	*	*	*	*	*
24	*Hesione* sp.	*	*	*	*	*	*	*	*
25	*Hesionura laubieri*	*	*	*	*	*	*	-	*
26	*Jaeropsis beuroisi*	*	*	*	*	**	*	*	*
27	*Leanira hystricis*	*	*	*	-	-	-	-	-
28	*Lumbrinereis aberrans*	-	-	-	-	*	*	*	-
29	*Lumbrineris sp*	*	*	*	*-	-	-	-	-
30	*Maldane sarsi*	-	-	-	-	*	-	*	*
31	*Nephtys dibranchis*	*	*	*	*	*	*	*	*
32	*Nephtys sphaerocirrata*	*	*	*	*	*	*	*	*
33	*Nereis capensis*	-	-	-	-	*	*	*	*
34	*Notocirrus australis*	*-	*	*	*	*	*	*-	*

Continued Table 1

S.No	Polychaetes	St1-POM	St1-SUM	St1-PRM	St1-MON	St2-POM	St2-SUM	St2-PRM	St2-MON
35	*Notomastus aberans*	*	*	*	*	*	*	*	*
36	*Onuphis* sp.	*	*	*	*	*	*	*	*
37	*Ophelia* sp.	*	*	*	*	*	*	*	*
38	*Phyllocomus hiltoni*	-	-	-	-	*	*	*	-
39	*Pisione africana*	*	*	*	*	*	*	*	*
40	*Pisionidens indica*	*	*	*	*	*	*	*	*
41	*Polydora ciliata*	*	*	*	*	*	*	*	*
42	*Pontdora pelagica*	-	-	-	-	*	-	*	*
43	*Prionospio pinnata*	*	*	*	*	*	*	*	*
44	*Prionospio capensis*	*	*	*	*	*	*	*	*-
45	*Scololepis squamata*	*	*	*	*	*	*	*	*
46	*Scoloplella capensis*	*	*	*	*	*	-	-	*
47	*Scoloplos johnstonei*	*	-	*	-	*	-	-	-
48	*Syllis longocirrata*	*	*	*	*	*	*	*	*
49	*Terebellides* sp.	*	*	*	*	*	*	*	*
	Bivalves								
1	*Anadara granosa*	*	*	*	*	*	*	*	*
2	*Anadara rhombea*	-	-	-	-	*	*	*	*
3	*Cardium setosum*	*	*	*	*	*	*	-	*
4	*Donax cuneatus*	*	*	-	*	*	*	-	*
5	*Meretrix casta*	*	*	*	-	*	*	*	*
6	*Meretrix meretrix*	-	-	-	-	*	*	*	*
7	*Perna viridis*	*	*	*	*	-	-	-	-
	Gastropods								
1	*Bullia vitetta*	*	*	*	*	*	*	*	*
2	*Cerithedia cingulata*	-	-	-	-	*	*	*	*
3	*Littorina scabra*	*	*	*	*	*	*	*	*
4	*Nassarius* sp.	-	-	-	-	*	*	*	*
5	*Natica sp.*	*	*	-	*	*	*	*	*
6	*Oliva nebulosa*	*	*	*	*	*	*	-	*
7	*Turritella attenuata*	*	*	*	*	*	*	-	*
8	*Umbonium vestiarium*	*	*	*	*	*	*	*	*
	Amphipods								
1	*Ampithoe romondi*	*	*	*	*	*	*	*	*
2	*Ampithoe rubricata*	*	*	*	*	*	-	*	*
3	*Caprella mendax*	-	*	-	-	-	-	-	-
4	*Eisothistos* sp.	*	-	*	-	-	-	-	-
5	*Gammarus salinus*	-	*	*	*	*	*	-	*
6	*Grandidirerella sp.*	*	*	-	*	*	*	*	*
7	*Harpinia laevis*	*	*	-	-	*	*	-	*
8	*Microprotopus cumbrensis*	-	-	-	-	*	*	*	*
9	*Phaxocephalus holbolli*	-	-	-	-	*	*	*	*
10	*Urothoe* sp.	*	*	*	*	*	-	*	*
	Isopods								
1	*Angeliera phreaticola*	*	*	*	*	*	*	*	*
2	*Calabozoa pellucida*	-	-	-	-	*	-	*	*
3	*Cymodoce truncata*	*	*	*	*	-	-	-	-
4	*Eisothistos* sp.	-	-	-	-	*	*	*	*
5	*Jaeropsis beuroisi*	-	-	-	-	*	-	*	-
6	*Microcerberus* sp.	*	*	*	*	*	*	-	*
7	*Paragnathia formica*	*	-	*	-	*	*	*	*
8	*Sphaeroma serratum*	*	*	*	*	*	*	*	*
	Other species								
1	*Emerita asiatica*	*	*	*	*	*	-	*	*
2	Amphioxus	*	*	*	*	*	*	-	*
3	*Penaeid shrimp larvae*	-	-	-	-	*	*	*	*
4	Sipunculida	*	*	-	*	-	-	-	-

The species count was at the maximum (75) in station 2 during postmonsoon and minimum (58) in station 1 during monsoon. The maximum number of organisms was 119 animals/0.1 m^2 (station 2, postmonsoon) (Table 2), and the minimum was 74 animals/0.1 m^2 (station 1, premonsoon). It was apparently low due to the effect of heavy rainfall. Similar to this (Seshappa, 1953) reported a 'severe decline' in the shallow water macro-benthos during the southwest monsoon, and the decrease was attributed to lower salinity. The present observation coincides with the previous findings of Kumar and Antony, 1994; and Kumar, 2001. The Shannon–Wiener diversity H' (Table 2) ranged between 4.030 (station 1, monsoon) and 4.304 (station 2, postmonsoon). Species diversity is a simple and useful measure of a biological system. Sanders, (1968) and Redding and Cory, (1975) found a high level of agreement between species diversity and the nature of the environment and, hence, regarded the measure of species diversity as an ecologically powerful tool. Moreover, Pearson and Rosenberg, (1978) proposed that the use of diversity indices is advantageous for the description of faunas at different stages in the succession. Sanders, (1968) postulated that the species diversity is mainly controlled by the fluctuations in the environment that lead to less diversity. The pattern of lower species diversity during monsoon and higher diversity values in post-monsoon recorded in the study area is in conformity with the earlier observations made in Parangipettai and Pazhayar (Chandran, 1987; Devi, 1994). The evenness component (*J*') (Table 2) varied from 0.9924 (station 1, monsoon) to 0.9969 (station 2, postmonsoon). In the case of *H*' there was no great difference between stations. However, season-wise (Table 2), it showed differences. It was low during the monsoon season and gradually increased during the post-monsoon and summer seasons. The evenness component (*J*') (Table 2) showed a gradual decrease with the increase of stations, and season-wise (Table 2), it was lower during monsoon and higher during summer seasons. The species richness (Margalef's *d*) (Table 2) ranged between 12.97 (station 1, monsoon) and 15.48 (station 2, postmonsoon). Similar observation was reported by Kumar, (1995) in Cochin waters.

Table 2 Diversity indices in various stations of Cuddalore and Parangipettai

Station	S	N	d	J'	H'(loge)	1-Lambda'
St1-Post-monsoon	64	116	13.26	0.9949	4.138	0.9923
St1-Summer	63	87	13.87	0.9957	4.125	0.9949
St1-Premonsoon	60	74	13.7	0.996	4.078	0.9962
St1-Monsoon	58	81	12.97	0.9924	4.03	0.9939
St2-Postmonsoon	75	119	15.48	0.9969	4.304	0.9947
St2-Summer	61	81	13.64	0.9966	4.097	0.9954
St2-Premonsoon	59	76	13.37	0.9962	4.062	0.9955
St2-Monsoon	67	90	14.65	0.9957	4.186	0.9955

Multiple *K*- dominance plot facilitated the discrimination of benthos according to species- relative contribution to Standard stock. When all the stations belonging to all the seasons were plotted together, the curve for station 2 (postmonsoon) was lying low and was '∫' shaped, indicating highest diversity, whereas the curve for station 1 (monsoon) was lying high, showing lowest diversity (Figure 6). When the *k*-dominance plot was also plotted for the season, and the curve for the summer season was lying low, indicating highest diversity, whereas the curve for the pre-monsoon season, which showed the lowest diversity, was lying high (Figure 6). The *k*- dominance plat for station 2 during all the seasons shows the highest diversity in station 2 during the postmonsoon and the lowest during the monsoon seasons.

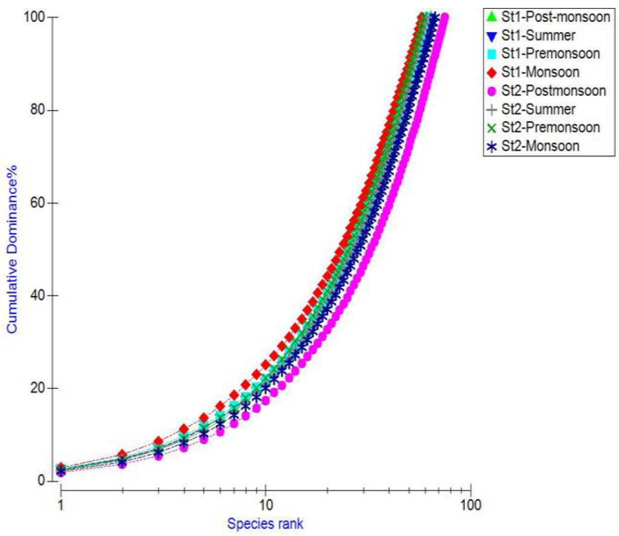

Figure 6 *K*- Dominance plot for all stations and seasons

From the resulting dendrogram, it was not possible to classify the results according to stations, but it was possible for seasons. The monsoon season showed separation from the remaining samples. In the dendrogram plot (Figure 7), it was found that all the monsoonal samples were ordinated separately from all other samples which conform to the dendogram.

The dominant species belonging to all groups are shown in Table 1. Classification analyses (using Bray–Curtis similarity) followed by an ordination through MDS on benthos abundance data (numbers/0.1 m^2) independently for infauna (86 species) was undertaken. The results of hierarchical clustering and MDS ordination, respectively, on species abundance data representing 2 stations during four seasons (post-monsoon, summer, pre-monsoon and monsoon) (Figure 8). The two-dimensional plot, otherwise referred to as Ellipse, supported the MDS ordination, and it showed that the monsoonal samples were occurring outside the contour.

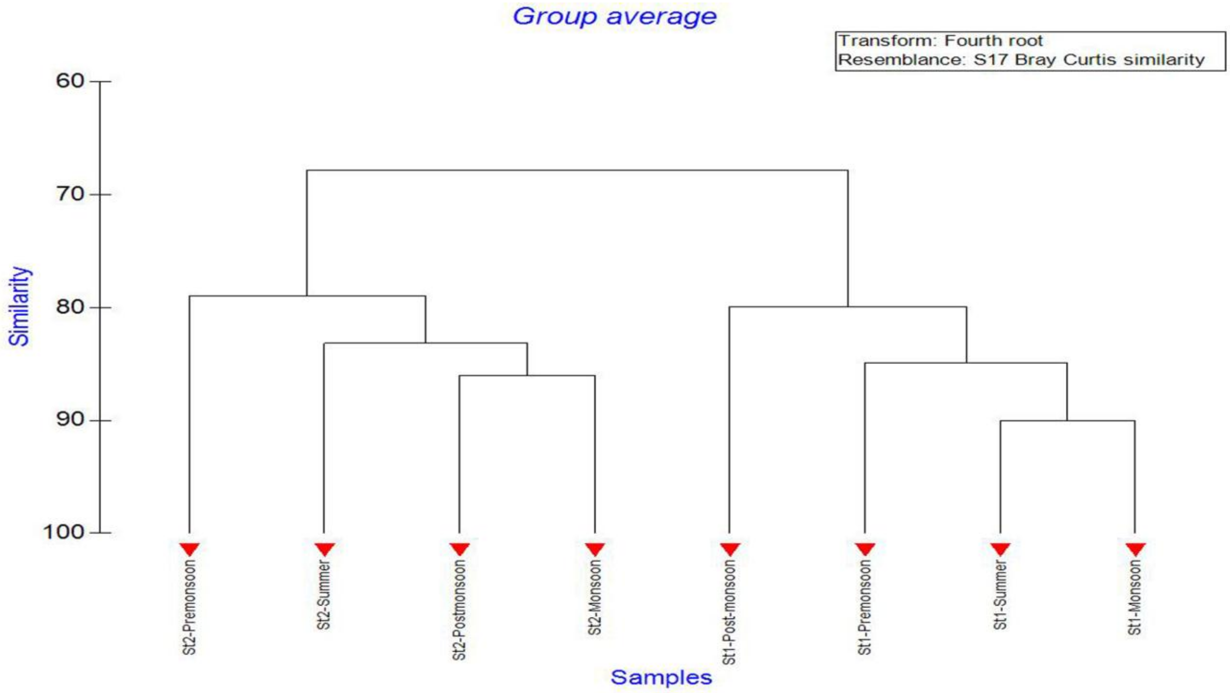

Figure 7 Dendrogram showing grouping of stations sampled during different seasons for infauna

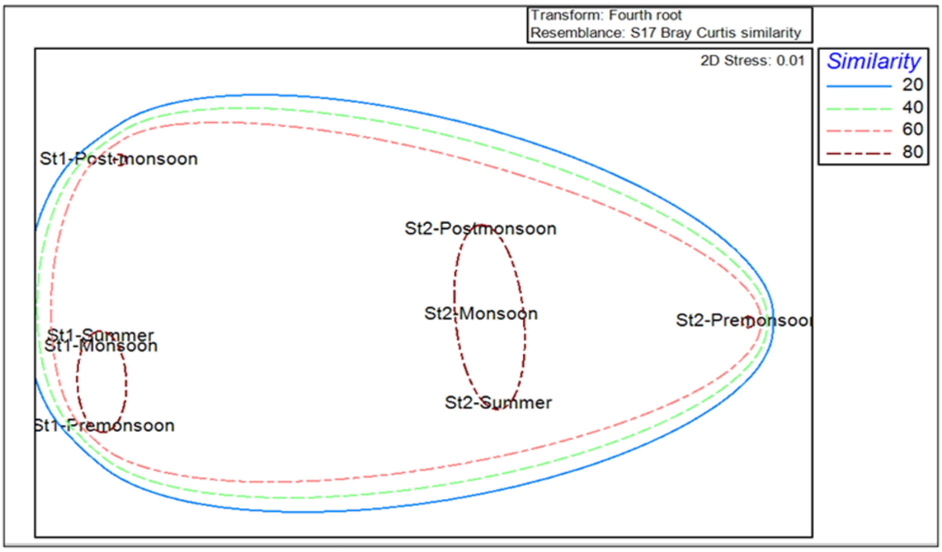

Figure 8 MDS plot for all seasons and stations of Cuddalore and Parangipettai

3 Conclusion

The temporal distribution of macro benthos exhibited not only higher density during the pre-monsoon season but also consisted of more diverse fauna low benthic production, especially polychaetes, during monsoon could be due to the low temperature and salinity prevailing in that area. The decrease of benthos in monsoon may be attributable to the low temperature and salinity. A medium amount of organic matter and salinity supports more benthic production. So, it can be deduced from the study that ecological factors like temperature, salinity and dissolved oxygen have great influence on the abundance and distribution of benthic organisms. Some species of polychaetes were abundant more than other species i.e.g., *Arabella mutans*, *Capitella capitata*, *Cossura coasta*, *Lumbrineris* sp. and *Pisionidens indica* in station 1 (Cuddalore). They are indicating the pollution of water due to the State Industrial Promotion Council of Tamilnadu (SIPCOT Cuddalore) discharging their waste to the marine environment.

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