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Research Article

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Macrobenthic assemblage and utility of diversity in assessing the health of an ecosystem, Southeast Coast of India

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Abstract

Present observation investigates the diversity and seasonal variations of benthic macrofauna and associated environmental parameters influencing the benthic community in the coastal waters of southeast 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 Thiruchendur, Tuticorin and Vembar coastal region of Southeast India. Altogether, 36 infaunal samples (Peterson grab 0.256 m^2*)* were collected which revealed the occurrences of 86 species representing five diverse groups. Polychaetes were the dominant group (58.67%), followed by Amphipods (10.67%,), Isopods (10.67%,). Bivalves (8%) and Gastropods (8%). Diversity (H'log2) ranged between 3.623 (station 3, monsoon) and 4.176 (station 2, summer). Cluster and MDS plots drawn showed that stations of Vembar, Tuticorin and Thiruchendur formed group among themselves indicating dissimilarity in their faunal composition and its abundance. Some polychaetes were abundant more than other species i.e.g., *Lumbrineris sp., Cossura coasta, Capitella capitata, Pisionidens indica* and *Arabella mutans,* in station 3 (Tuticorin) as they indicate the pollution of water due to the industrial and active harbor discharging their waste to the marine environment.

Keywords: Physico-chemical variation, macro-fauna, sediment characteristic and heavy-metal.

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Background:

The diversity variation of benthic fauna mainly depends on physical and chemical properties of the benthic environment. Further, benthic communities are known to respond to changes in the quality of water or habitat. Because of their extended residency period in specific habitats and presence or absence of particular benthic species in a particular environment, these can be used as bio-indicators of specific environment and habitat conditions. On account of the common tendency for disposal of wastes etc. in sewers, blockage and overflowing are usually seen everywhere. This causes pollution in almost all aquatic bodies (Sharma *at al.*, 2000). Bio-indicators are useful to assess the functional efficiency of water treatment plants which is one of the important practical considerations (Thomas, 1972). There are many different ways to relate benthic macro-invertebrate community structure to water quality with many new analysis systems. The benthic macroinvertebrate community has been used as an indicator of water quality (Roback, 1974 and Hellawell, 1986).

The input of increasing load of pollutants and toxic substance into the surface waters has been reported to cause serious disturbances to the aquatic ecosystems. However, this depends on the nature and quantity of pollutants. Usually, various physicochemical methods are used to detect the effect of pollution on the water quality changes. Such alterations in water quality are also very well reflected in the structure and composition of biotic community as shown by occurrence, diversity and abundance pattern of species (Kumar *et al.* 2006).

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 Parulekar and Wagh, 1975; Parulekar *et al.*, 1976; Harkantra *et al.*, 1980; Joydas and Damodaran, 2001 and 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. Kundu *et al.*, (2009) deals with the environmental parameters and benthic fauna diversity in East coast of India.

The main objective of this research is 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. 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 (LaFond, 1957; Varkey *et al.*, 1996; Madhupratap *et al.*, 2003). The annual range of the seawater temperature was 27.5 to 34 ^{o}C, while salinity varied from 27 to 34 psu. The isohaline of 34 and above is always outside the Bay (Ganapati, 1973).

MATERIALS AND METHODS

Four seasonal collections were made (January 2013 to December 2013), and altogether, 36 samples were taken from 3 stations (duplicate samples were collected from each station—4 seasons × 2 stations × 2) belonging to three transects, namely Thiruchendur Station 1) (08° 28′ 59.88″ N, 78° 7′ 0.12″) is a town at the southern tip of India, in Tuticorin district in the state of Tamil Nadu. Vembar (Station 2) (09°50'90"N 78°21'45"E) is situated along the East Coast road at the north end of Tuticorin district. Tuticorin (Station 3) (08° 48′ 36″ N, 78° 8′ 24″ E), is also known as Port city and an industrial city in Tuticorin district of the Indian state of Tamil Nadu. The city lies in the Coromandel Coast off Bay of Bengal. 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).

Sample collection

Peterson grab (0.256 m^2*)* was used for unit sampling. The subtidal benthic samples were collected monthly from each station. Composite samples were collected from each station and put into 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 macro benthos 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. Polychaeta: (Fauvel, 1953; Day, 1967); 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 metre. Sediment samples were subjected to pipette analysis according to the standard method (Krumbein and Pettijohn, 1938).

Data analysis

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.

RESULT AND DISCUSSION

The environmental and physical characteristics recorded from all the stations, the atmospheric temperature varied from 28.5^{o} C to 35^{o} C (Fig. 2). The minimum was recorded in station 2 & 3 and the maximum was recorded in stations 1 & 2. And the surface water temperature varied between 27.5^{o} C to 34.5^{o} C (Fig. 2). The minimum values were recorded in stations 3. And the maximum was recorded in station 2. The higher surface water temperature recorded during summer season might be possibly due to the influence of the 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).

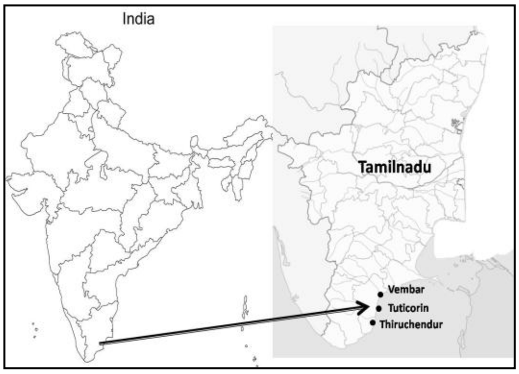

Fig. 1. The map showing the study area

The minimum value of salinity recorded was 26 psu and the maximum was 34 psu (Fig. 2). The minimum salinity recorded was in station 1. And the maximum was recorded in all other stations. Salinity was maximum 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 and Asha and Diwakar, 2007).

The dissolved oxygen varied from 3.86 to 6.66 mg/l^{-1} (Fig. 2). The minimum level of dissolved oxygen recorded at station 2 during summer and the maximum was recorded in 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 (Fig. 2). The pH level increased from the minimum values recorded during the monsoon season at station 2 to reach the maximum during summer. 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 CO2 by photosynthesis through bicorbonate degradation, dilution of seawater by freshwater influx, reduction of salinity and temperature, and decomposition of organic matter (Ragothaman and Patil 1995; 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. 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 0.326 and 1.677 µmol l^{-1} (Fig. 2). The nitrate values ranged between 2.846 and 9.95 µmol l^{-1} (Fig. 3). The ammonia values ranged between 0.061 and 0.263 µmol l^{-1} (Fig. 3). The total nitrogen values ranged between 10.594 and 24.898 µmol l^{-1} (Fig. 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).

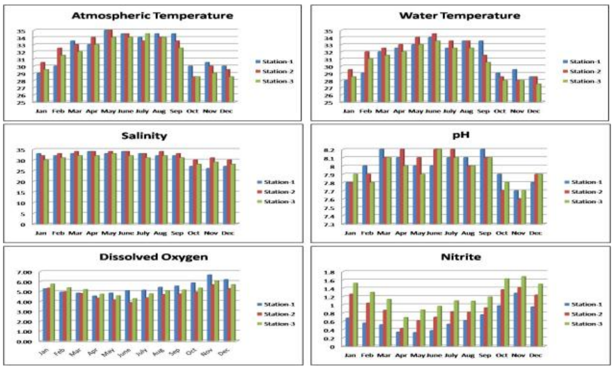

Fig. 2. Water quality parameters Temperature, salinity, pH, Dissolved oxygen and nitrite recorded in stations I to III

The inorganic phosphate values ranged between 0.235 and 0.979 µmol l^{-1} (Fig. 3). The total phosphorus values ranged between 0.594 and 2.416 µmol l^{-1} (Fig. 3). In the present study maximum level of inorganic phosphate and total phosphorus were recorded during monsoon season and the minimum values were noticed in summer period. The high concentration of inorganic phosphate observed during monsoon season was high 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 10.62 and 21.45 µmol l^{-1} (Fig. 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 (Govindasamy *et al*., 2000; 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).

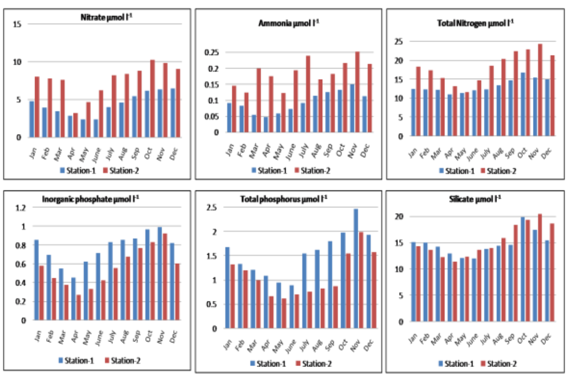

Fig. 3. Water quality parameters Nitrate, Ammonia, Total nitrogen, Inorganic phosphate Total phosphorus and silicate recorded in stations I to III

The sediment temperature ranged between 27 °C and 34 °C (Fig. 4). The maximum sediment temperature value was recorded at station 2 and the minimum was recorded in other stations. 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 physico-chemical characterization of sediments in three different coastal stations. 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 ranged between 25.5 psu and 35 psu (Fig. 4). The maximum values were recorded in stations 1 & 2 and the minimum were recorded in station 3. The sediment pH was ranged between 7.7 and 8.2 (Fig. 4). The maximum value was recorded in station 2 and the minimum was recorded in station 1. These physical parameters of the sediment characteristics were maximum during summer and the minimum during monsoon. Total organic carbon of the sediment ranged between 0.435 and 3.884 mgC/g soil (Fig. 4). The minimum TOC recorded during premonsoon period at station 2 and the maximum were 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 (Reddy and Hariharan, 1986; Raghunath and Sreedhara Murthy, 1996; Harkantra *et al*., 1980: Prabhu and Reddy 1987).

Percentage of sand particles varied from 16.8% to 99.2% (Fig. 4). The maximum level of sand particles was present in station 2 and minimum sized particles were present in station 3. Percentage of silt particles varied from 0.5% to 59.1% (Fig. 4). The maximum level of silt particles was present in station 1 and minimum sized particles were present in station 3. Percentage of clay particles varied from 0.4% to 46.8% (Fig. 4). The maximum level of silt particles was present in station 3 and minimum sized particles were present in station 2. Sand, slit and Clay was supported by following research articles (Badarudeen *et al.*, 1996; Chanda *et al.*, 1996).

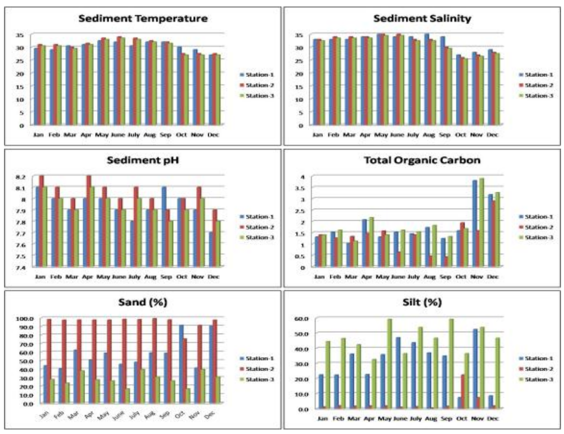

Fig. 4. Sediment parameters Temperature, pH, TOC, Salinity Sand % and Silt% recorded in stations I to III

The concentration of heavy metal was found to be low due to the meager metal rich fresh water influx. The sediment heavy metal values were recorded as follow as. The cadmium levels ranged between 0.12µg/g and 2.74µg/g (Fig. 4). The maximum was found in station 2 during premonsoon and the minimum was recorded in station 1 during summer. The chromium levels were ranged between 0.15µg/g and 37.34µg/g (Fig. 4). The maximum was found in station 1 during premonsoon and the minimum was recorded in station 2 during postmonsoon. The copper levels ranged between 3.97µg/g and 59.43µg/g (Fig. 5).

The maximum was found in station 1 during summer and the minimum was recorded in station 2 during monsoon. The trace elements Cr, Cu and Cd display 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 from the industries and domestic waste affected areas suggest 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.

The Iron levels ranged between 153.34µg/g and 6587µg/g (Fig. 5). It was maximum in station 3 during monsoon and the minimum was recorded in station 2 during postmonsoon. 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 ranged between 13.88µg/g and 162.33µg/g (Fig. 5). The maximum was found in station 1 during monsoon and the minimum was recorded in station 3 during postmonsoon. 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 of 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 0.41µg/g and 9.74µg/g (Fig. 5). The maximum was found in station 1 during monsoon and the minimum was recorded in station 2 during postmonsoon. The lead levels ranged between 2.49µg/g and 16.94µg/g (Fig. 5). It was maximum in station 1 during monsoon and the minimum was recorded in station 3 during postmonsoon. The zinc levels ranged between 0.95µg/g and 27.87µg/g (Fig. 5). It was maximum in station 3 during monsoon and the minimum was recorded in station 2 during postmonsoon. This observation supports Pichavaram mangrove (Glory Dally, 1984) and in the Kodiakkarai coastal area (Pragatheeswaran *et al*., 1986).

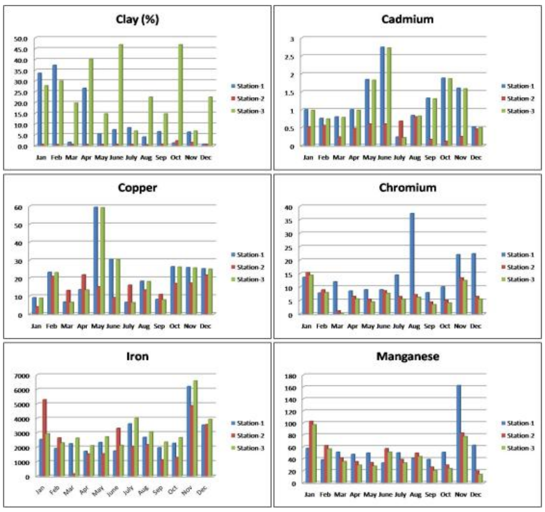

Fig. 5. Sediment parameters Clay, Cadmium, Chromium, Copper, Iron and Manganese recorded in stations I to III

Totally 75 species of macrofauna represented by six diverse groups were encountered, of which polychaetes, bivalves, gastropods, amphipod, isopods and other families were the most important groups. Polychaetes dominated the infauna (44 species) and contributed numerically up to 58.67% of the population. Bivalves were consisting of 6 species and contributed 8% of total infauna production. Gastropods consisted of 6 species and contributed 8%, amphipods were 8 species and contributed 10.67%, Isopods were 8 species (10.76%) and the other families of the infauna were 3 species and contributed 4% of the total population (Table1). 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 Ansari *et al.,* (1986), Mohammed(1995) and Kumar (2001).

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 m2*)* independently for infauna (75 species) was undertaken. Figures 6 and 7 display results of hierarchical clustering and MDS ordination, respectively, on species abundance data representing 3 stations during four seasons (post-monsoon, summer, pre-monsoon and monsoon).

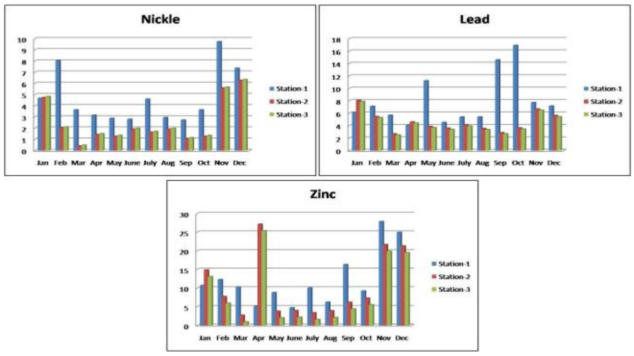

Fig. 6. Sediment parameters Lead, Nickle and Zinc recorded in stations I to III

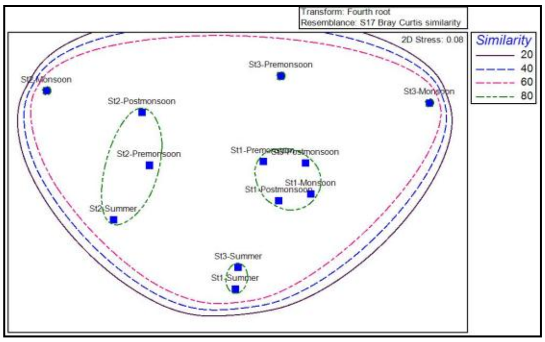

Fig.7. MDS ordination generated for the macrofaunal groups in stations of Vembar, Tuticorin and Thiruchendur

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 MDS plot (Fig. 8), it was found that all the monsoonal samples were ordinate separately from all other samples which conform to the dendogram. 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.

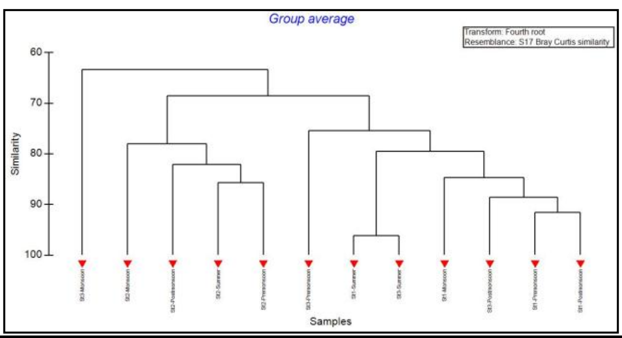

Fig. 8. Dendrogram for hierarchical clustering of the macrofaunal groups in stations of Vembar, Tuticorin and Thiruchendur

The species count was at the maximum (66) in station 2 during summer and minimum (38) in station 3 during monsoon. The maximum number of organisms was 106 animals/0.1 m2 (station 2, summer) (Table 2), and the minimum was 45 animals/0.1 m2 (station 3, monsoon). 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 lowered 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 3.623 (station 3, monsoon) and 4.176 (station 2, summer). Species diversity is a simple and useful measure of a biological system. Sanders, (1968) and Redding & 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 Chandran, (1987) and Pazhyar Devi, (1994). The evenness component (*J*') (Table. 2) varied from 0.9933 (station 1, premonsoon) to 0.9968 (station 2, summer). 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 9.724 (station 3, monsoon) and 13.95 (station 2, summer). Similar observation was reported by Kumar, (1995) in Cochin waters.

Table 2. Diversity indices calculated for the stations of I to III

Stations	S	N	d	*J'*	Brillouin	Fisher	H'(loge)	1-Lambda'
St1-Postmonsoon	57	79	12.83	0.9959	3.321	93.34	4.026	0.9945
St1-Summer	58	105	12.26	0.9956	3.356	53.64	4.042	0.9916
St1-Premonsoon	54	74	12.33	0.9933	3.224	91.63	3.962	0.9939
St1-Monsoon	55	67	12.82	0.9966	3.208	139.6	3.994	0.9961
St2-Postmonsoon	53	71	12.21	0.9962	3.198	95.53	3.955	0.9946
St2-Summer	66	106	13.95	0.9968	3.452	75.18	4.176	0.9938
St2-Premonsoon	59	79	13.26	0.9954	3.295	104.1	4.059	0.9949
St2-Monsoon	51	66	11.94	0.9957	3.13	103.2	3.915	0.9948
St3-Postmonsoon	50	66	11.71	0.9956	3.151	96.17	3.895	0.9944
St3-Summer	57	97	12.25	0.9967	3.296	58.15	4.03	0.9922
St3-Premonsoon	40	55	9.752	0.9941	2.934	67.61	3.667	0.9921
St3-Monsoon	38	45	9.724	0.9961	2.823	116.5	3.623	0.9951

Multiple *K*- dominance plots 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 (summer) was lying low and was S-shaped, indicating highest diversity, whereas the curve for station 3 (monsoon) was lying high, showing lowest diversity (Fig. 9). When the *k*- dominance plot was also plotted for the season the curve for the summer season was lying low, indicating highest diversity, whereas the curve for the summer season, which showed the lowest diversity, was lying high (Fig. 9). The *k*- dominance plat for station 2 during all the seasons showed the highest diversity in station 2 during the summer and the lowest during the monsoon seasons.

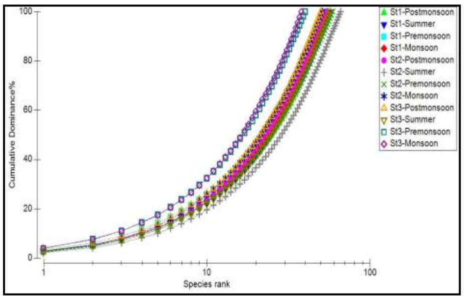

Fig .9. *K*- Dominance plot for stations of I to III

Conclusion

The temporal distribution of macro benthos exhibited not only higher density during the summer 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 polychaetes were abundant more than other species i.e.g., *Lumbrineris sp., Cossura coasta, Capitella capitata, Pisionidens indica* and *Arabella mutans*, in station 3 (Tuticorin) because they indicate the pollution of water due to the industrial and active harbor discharge into the marine environment.

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Table 1. Total number f benthic fauna recorded in stations I to III

	Polychaetes	**St1-POM**	**St1-SUM**	**St1-PRM**	**St1-MON**	**St2-POM**	**St2-SUM**	**St2-PRM**	**St2-MON**	**St3-POM**	**St3-SUM**	**St3-PRM**	**St3-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	*Cirriformia* sp.	-	-	-	-	*	*	-	-	-	-	-	-
10	*Cossura coasta*	*	*	*	*	*	*	*	*	*	*	*	*
11	*Epidiopatra gilchristi*	*	*	*	*	*	*	*	*	*	*	-	*
12	*Eulalia bilineata*	*	*	*	*	*	*	-	*	*	*	*	-
13	*Eunice indica*	*	*	*	*	*	**	*	*	*	*	*	*
14	*Exogone clavator*	*	*	*	*	-	*	*	-	*	*	-	-
15	*Fabricia filamentosa*	*	*	-	*	-	-	-	-	*	*	-	*
16	*Glycera alba*	*	*	*	*	*	*	*	*	*	*	*	*
17	*Glycinde capensis*	-	-	-	-	-	*	-	*	-	-	-	-
18	*Goniada emerita*	*	*	*	*	-	*	*	*	*	*	*	*
19	*Goniadides falcigera*	*	*	*	*	*	*	*	*	*	*	*	-
20	*Hesione* sp.	*	*	*	*	*	*	*	*	*	*	*	*
21	*Hesionura laubieri*	*	*	*	*	*	*	*	-	*	*	*	*
22	*Jaeropsis beuroisi*	*	*	*	*	*	*	*	*	*	*	-	*
23	*Leanira hystricis*	*	*	-	*	-	-	-	-	*	*	-	*
24	*Lumbrinereis aberrans*	-	-	-	-	*	*	-	*	-	-	-	-
25	*Lumbrineris sp*	-	-	-	-	-	*	*	*	-	-	-	-
26	*Nephtys dibranchis*	*	*	*	*	*	*	*	*	*	*	*	*
27	*Nephtys sphaerocirrata*	*	*	*	*	*	*	*	*	*	*	*	*
28	*Nereis capensis*	-	-	-	-	*	*	*	*	-	-	-	-
29	*Notocirrus australis*	*	*	*	*	*	*	*	*	-	*	*	*
30	*Notomastus aberans*	*	*	*	*	*	*	*	*	*	*	*	-
31	*Onuphis* sp.	*	*	*	*	*	*	*	*	*	*	-	-
32	*Ophelia* sp.	*	*	*	*	*	*	*	*	*	*	*	*
33	*Phyllocomus hiltoni*	-	-	-	-	*	*	-	*	-	-	-	-
34	*Pisione africana*	*	*	*	*	*	*	*	*	*	*	*	*
35	*Pisionidens indica*	*	*	*	*	*	*	*	*	*	*	*	*
36	*Polydora ciliata*	*	*	*	*	*	*	*	*	*	*	*	*
37	*Pontdora pelagica*	-	-	-	-	-	*	*	*	-	-	-	-
38	*Prionospio pinnata*	*	*	*	*	*	*	*	*	*	*	*	*

39	*Prionospio capensis*	*	*	*	*	*	*	*-	*	*	*	*	-
40	*Scololepis squamata*	*	*	*	*	*	*-	*	*	*	*	*	*
41	*Scoloplella capensis*	*	*	*	*	-	*	*	-	*	*	-	-
42	*Scoloplos johnstonei*	-	*	-	*	-	*	-	-	-	*	-	-
43	*Syllis longocirrata*	*	*	*	*	*	*	*	*	*	*	*	*
44	*Terebellides* sp.	*	*	*	*	*	*	*	*	*	*	*	*
	Bivalves												
1	*Anadara granosa*	*	*	*	*	*	*	*	*	-	*	-	*
2	*Anadara rhombea*	-	-	-	-	*	*	*	*	-	-	-	-
3	*Cardium setosum*	*	*	*	*	*	*	*	-	*	*	-	*
4	*Donax cuneatus*	*	*	*	-	*	*	*	-	*	*-	*	-
5	*Meretrix casta*	-	-	-	-	*	*	*	*	-	-	-	-
6	*Perna viridis*	*	*	*	*	-	-	-	-	*	*	*	*
	Gastropods												
1	*Littorina scabra*	*	*	*	*	*	*	*	*	*	*	-	-
2	*Nassarius* sp.	-	-	-	-	*	*	*	*	-	-	-	-
3	*Natica sp.*	*	*	*	-	*	*	*	*	*	*	*	-
4	*Oliva nebulosa*	*	*	*	*	*	*	*	-	-	*	-	-
5	*Turritella attenuata*	*	*	*	*	*	*	*	-	*	*	*	*
6	*Umbonium vestiarium*	*	*	*	*	*	*	*	*	*	*	*	*
	Amphipods												
1	*Ampithoe romondi*	*	*	*	*	-	*	*	*	*	-	*	*
2	*Caprella mendax*	*	-	-	-	-	-	-	-	*	-	-	-
3	*Eisothistos* sp.	-	*	-	*	-	-	-	-	-	*	-	*
4	*Gammarus salinus*	*	-	*	*	*	*	*	-	*	-	*	*
5	*Grandidirerella sp.*	*	*	*	-	*	*	*	*	-	*	*	-
6	*Harpinia laevis*	-	-	-	-	*	*	*	*	-	-	-	-
7	*Phaxocephalus holbolli*	-	-	-	-	*	*	*	*	-	-	-	-
8	*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*	*	*	*	*	*	*	*	*	*	*	*	*
	Others												
1	Amphioxus	*	*	*	*	*	*	*	-	-	*	*	-
2	*Penaeid shrimp larvae*	*	*	*	*	-	*	*	*	*	*	*	-
3	Sipunculida	*	*	*	-	-	-	-	-	-	*	-	-