

Macrobenthic assemblage in the soft sediment of Marmugao harbour, Goa (central west coast of India)

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Received 26 April 1994; revised 18 October 1994

Survey of the macroinvertebrate fauna in soft sediment of 18 stations in the Marmugao harbour revealed spatial heterogeneity based on environmental parameters and benthic assemblage. Based on the presence/absence of the families five associations were identified. The communities were not discrete and there was some overlap in the occurrence of the families. Influence of anthropogenic disturbances and environmental factors such as sediment type and availability of food were responsible for spatial heterogeneity.

Estuaries and harbours adjacent to cities are often subjected to environmental disturbances from various sources such as domestic sewage outfall, pesticides, heavy metals and petroleum hydrocarbons. Shipping harbours present different situation for the aquatic living organisms where physical factors determine large scale pattern of benthic distribution¹. Within these patterns spatial heterogeneity exists at various scales forming a mosaic of patches². Such studies involve sampling at close stations and collecting the number of replicates so as to obtain a representative picture of the area and the anthropogenic impact on it³.

Marmugao harbour, situated at the mouth of Zuari river estuary, displays various activities round the year. Parulekar *et al.*⁴ have studied the benthos of Marmugao bay along with that of the adjacent Zuari estuary. In view of the rapidly changing patterns observed in similar ecosystems elsewhere, a sampling programme has been initiated in Marmugao harbour to delineate the present distribution of macrobenthic communities of the subtidal soft bottom deposits.

Materials and Methods

Marmugao harbour forms a part of the Marmugao bay (Fig. 1). The depth in the main harbour basin varies from 6 to 15 m. The bottom deposit is mainly muddy in the centre with sand and silt of riverine origin towards the periphery. The washing in the form of red clay, cobble and pebble of iron ore are regularly added to the bottom from loading platform. It is a tide dominated harbour and bottom currents are

particularly strong with 1.5 m s^{-1} . The intense precipitation and land run-off during southwest monsoon brings about dynamic changes in hydrobiological features whereas during the dry season (post- and pre-monsoon) the water remains well mixed with more or less marine conditions.

Eighteen stations (Fig. 1) ranging in depth from 4 to 13 m were sampled during October 1992 using a van Veen grab (0.1 m^{-2} area). Each station was sampled thrice and only those grabs which were full and contained relatively undisturbed sediment were considered for quantitative analysis. Sediment of

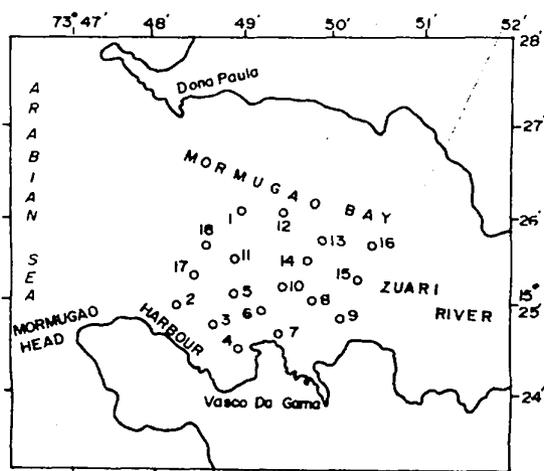


Fig. 1—Location of stations in Marmugao bay

each grab was passed through a sieve of 0.5 mm mesh size and the animals retained on the sieve were considered for macrofaunal analysis. After sieving, the animals were preserved in 5% formalin-Rose Bengal solution for further analysis and identification. Simultaneously samples of bottom water were collected from each sampled station for the analysis of dissolved oxygen and salinity. A small amount of sediment was also taken for granulometry. Macrofauna were identified up to family level in the laboratory, counted and wet weight taken after blotting excess water on a filter paper. Salinity, dissolved oxygen and suspended solid in the bottom water, sediment organic carbon and chlorophyll *a* were analysed^{5,6}.

Faunal density was compared by means of ANOVA. Regression analysis was done to find the relationship between two variables and the product moment correlation coefficient (*r*) was computed to understand the magnitude of variation between biotic and abiotic variables. Bray-Curtis⁷ similarity index was used to find the affinity between stations based on the density of families recorded at each station and dendrograms were drawn by group average sorting.

Results

Environmental features—Hydrographical parameters are given in Table 1. Sampling depth varied from 4 to 13.5 m. Temperature of the bottom water ranged from 27.1 to 28.3 °C and salinity from 23.6 to 25.4 × 10⁻³. Dissolved oxygen was high (3.5-4.2 ml l⁻¹)

at the bottom suggesting that there is a continuous renewal of bottom water by the tidal currents. Values of suspended solids were in the range of 0.75 to 1.06 g l⁻¹.

Sediment granulometry is given in Table 2. Sediment texture of the harbour comprised of fine to very fine grains with varying proportion of sand, silt and clay. The median grain size (Md) varied from 0.033 mm at st. 12 to 0.171 mm at st. 13. The percentage of organic carbon varied from 0.82 at st. 18 to 3.12 at st. 12. Chlorophyll *a* ranged from 2.32 µg g⁻¹ sediment at st. 2 to 7.83 µg g⁻¹ sediment at st. 18. A considerable amount of red clay, derived from the loading of iron ore at the harbour, was found deposited at the top layer. There was distinct change in the sediment type of inner and outer harbour.

Faunal density and biomass—There was a great deal of spatial variation in the total count of macroinvertebrates (Table 3). Faunal density (no. m⁻²) ranged from a minimum of 498 at st. 4 to a maximum of 1107 at st. 7. Mean faunal density showed significant variation among stations, when tested by ANOVA (*P* < 0.05). Total biomass (g m⁻² wet weight) also showed wide variation, ranging from 2.54 at st. 2 to 46.02 at st. 9. Biomass did not follow the same trend as that of the density due to the presence/absence of large size organisms such as bivalves (*Gafrarium pectinatum*, *Meretrix casta*), crustacea and gobiid fish (*Tripauchen vagina*) which were encountered at some stations. (Those stations having sandy sediments recorded higher biomass.)

Table 1—Environmental parameters of the bottom water of the stations studied in Marmugao harbour

St. no.	Depth (m)	Temp. (°C)	Salinity (× 10 ⁻³)	Dis.Oxy (ml l ⁻¹)	Seston (g l ⁻¹)
1	9.5	27.8	23.6	3.9	0.83
2	6.5	27.9	24.2	3.6	0.89
3	6.0	27.2	24.7	3.8	0.96
4	4.5	27.5	23.9	4.1	1.06
5	10.5	28.2	24.2	4.2	0.81
6	10.0	27.6	24.3	3.7	0.77
7	4.0	27.4	24.1	3.5	0.80
8	9.5	28.1	25.0	3.8	0.79
9	4.5	28.3	24.6	3.8	0.88
10	12.0	27.9	24.8	3.6	0.92
11	12.5	27.5	23.8	3.5	0.78
12	10.0	27.5	23.6	3.9	0.94
13	11.5	27.8	24.2	4.1	0.83
14	11.5	27.3	24.3	3.9	0.85
15	9.0	27.4	24.3	3.5	0.75
16	8.0	27.4	24.2	3.7	0.79
17	13.5	27.1	25.4	3.6	0.82
18	12.5	27.3	24.9	3.9	0.90

Table 2—Granulometric properties of the sediments at the study sites

St. no.	Sand (%)	Silt (%)	Clay (%)	Md (mm)	Organic carbon (%)	Chl <i>a</i> (µg g ⁻¹)	Sediment type
1	84.4	9.6	6.0	0.089	1.88	6.85	Sand
2	8.0	55.5	36.5	0.041	1.42	2.32	Clayey silt
3	3.5	53.5	43.0	0.039	2.03	4.24	Silty clay
4	18.5	37.0	44.5	0.037	2.93	4.45	Silty clay
5	13.5	77.0	9.5	0.047	1.25	5.72	Sandy silt
6	8.2	42.3	49.5	0.038	1.96	3.94	Silty clay
7	33.5	59.5	26.0	0.049	2.98	5.53	Clayey silt
8	9.5	56.0	34.5	0.047	2.47	2.42	Clayey silt
9	80.5	11.5	9.0	0.099	1.47	7.68	Sand
10	14.0	38.5	47.5	0.037	2.15	3.68	Silty clay
11	5.6	56.4	38.0	0.039	3.05	4.77	Clayey silt
12	9.5	39.2	51.3	0.033	3.12	3.31	Silty clay
13	92.6	5.2	2.2	0.171	0.96	7.64	Sand
14	55.3	32.5	12.2	0.125	0.94	4.82	Silty sand
15	36.0	60.5	3.5	0.055	1.17	4.52	Sandy silt
16	42.8	45.2	11.0	0.059	1.27	4.75	Sandy silt
17	92.0	5.5	2.5	0.127	0.90	6.37	Sand
18	86.0	12.4	1.6	0.122	0.82	7.83	Sand

Faunal composition—Macrofaunal assemblage was mainly represented by three groups: polychaetes, molluscs and crustaceans in order of abundance. The less abundant taxons include nemertean worms, echiurid worms, bryozoans,

sipunculids and fishes. List of families collected in the grab samples is given in Table 4. There was considerable variability in the occurrence and relative abundance of numerically dominant families. The most widespread family was Nereidae, recorded from 16 stations, followed by Cirratulidae and Cirralonidae. Maximum families were recorded from st. 9. Overlapping of families was observed indicating that many similar species co-exist, distributed among stations having similar environmental conditions. Polychaetes were more dominant in sandy and clayey while molluscs in particular bivalves, were dominant in the sandy bottom. Crustaceans being detritivores, were not restricted to any particular substratum.

Diversity—Number of species as a measure of the species diversity is a useful parameter for the study of communities, but the information about the community would be contained in a parameter that also encompassed the number of specimen. The Shannon-Weaver information index was used to describe the faunal diversity and evenness. The diversity ('H') in the present study gives the information content of the sample (bits per individual) of a randomly selected individual (family in the present case) from the collections (Table 5). The vaues of 'H' ranged from 0.77 (st. 16) to 3.05 (st. 9) while those of evenness ('E') ranged from 0.16 (st. 16)

Table 3—Percentage (%) of faunal composition, density (no. m⁻²) and wet weight (g m⁻²) at the stations studied

St. no.	Polychaeta	Mollusca	Crustacea	Others	Density	Bio-mass
1	34	45	12	9	699	24.6
2	55	14	26	5	707	2.5
3	49	12	29	10	572	3.2
4	56	8	28	8	498	3.3
5	44	11	30	15	908	4.3
6	42	6	38	14	592	6.2
7	60	16	14	10	1107	12.8
8	32	58	6	4	911	4.3
9	48	16	24	12	829	46.2
10	42	40	10	8	615	3.3
11	47	34	12	7	764	5.9
12	48	25	14	13	562	6.1
13	36	47	13	4	1026	44.3
14	40	45	9	6	608	18.2
15	42	38	15	5	515	10.2
16	47	33	12	8	588	14.2
17	31	54	10	5	882	42.4
18	28	52	12	8	907	45.2

Table 4—Distribution of taxonomic attributes (families) at the sampled stations

Families	Stations																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Polychaeta																		
Nereidae	+	+	+	+	+	+	+	+	-	+	+	+	+	+	-	+	+	+
Nephtyidae	-	-	+	+	-	+	-	-	-	+	+	-	+	-	+	-	-	+
Glyceridae	-	+	+	+	-	+	+	+	+	+	+	-	-	+	-	+	+	-
Spionidae	+	-	+	+	-	+	+	-	+	+	+	+	+	+	-	-	+	+
Cirratulidae	+	+	-	+	+	-	+	+	+	-	+	-	-	+	+	+	+	+
Sabellidae	+	+	+	-	+	-	-	+	-	+	-	+	+	+	-	+	-	-
Capitellidae	-	+	+	-	+	-	-	-	+	+	+	+	-	+	+	-	+	-
Mollusca																		
Veneridae	+	+	-	-	-	+	+	-	+	+	+	-	+	+	+	-	+	-
Nassaridae	-	-	+	-	+	-	+	+	+	-	+	-	+	+	-	-	+	+
Cardiidae	+	+	-	+	+	-	+	-	+	-	+	+	-	-	-	-	+	-
Crustacea																		
Gammaridae	+	+	-	-	-	+	+	-	+	+	+	-	+	+	+	-	+	-
Cirolanidae	-	+	+	-	+	+	+	+	-	-	+	+	+	+	+	-	-	+
Caprellidae	+	+	+	+	+	+	-	+	+	+	+	-	-	+	-	+	-	+
Caridae	+	+	+	+	+	+	-	-	+	-	-	+	-	+	-	+	-	-
Other phyla																		
Echiuridae	+	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	-	+
Sipunculidae	+	+	+	-	-	+	+	-	+	-	-	+	+	+	-	-	+	+
Bryozoa	+	+	+	+	+	-	+	+	+	+	+	-	+	+	+	+	+	+
Nemertenea	-	+	-	-	+	-	-	-	+	+	+	-	-	-	-	+	+	+
Gobiidae	+	-	-	-	-	-	+	-	+	-	-	-	+	+	+	+	+	+

+ = Present; - = Absent

Table 5—Diversity indices of the stations studied

St. no.	No. of families	Diversity (H')	Evenness (E')
1	12	2.39	0.39
2	12	2.78	0.27
3	13	2.97	0.25
4	9	1.27	0.28
5	14	2.96	0.30
6	10	1.89	0.24
7	12	2.14	0.19
8	8	1.02	0.17
9	14	3.05	0.23
10	10	2.04	0.18
11	13	2.98	0.24
12	9	1.12	0.21
13	11	2.47	0.26
14	14	2.92	0.18
15	9	0.94	0.21
16	8	0.77	0.16
17	13	2.06	0.22
18	13	2.52	0.18

to 0.39 (st. 1). Changes in the diversity were related to changes in the sediment type. Therefore, the index of diversity can be useful parameter for describing the effect of changes in the environment on the fauna.

Faunal similarity—Faunal affinity was calculated using the density of families which were recorded at each station. The percent similarity index is presented in the form of Trellis diagram (Fig. 2). The stations could be grouped into five broad groupings. The degree of affinity ranged widely, thus suggesting high variability in the occurrence of representative taxa (families). Each assemblage was supported by different families which assembled in different sediment types. A number of stations showed high degree of affinity among themselves, largely based on the type of substratum with those of comparable substrata with greater affinity. They had representative families having similar feeding types.

Macroinvertebrate assemblage was analysed by cluster analysis. The dendrogram drawn from the group average sorting of the similarity coefficient

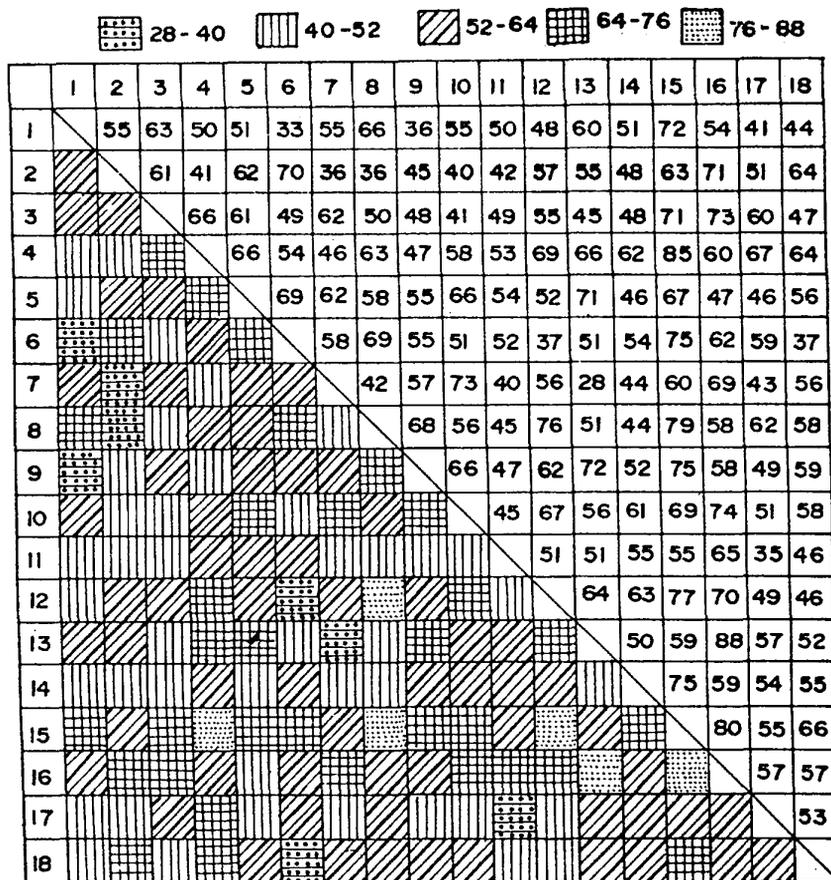


Fig. 2—Trellis diagram for 18 stations showing degree of macroinvertebrate affinity on families abundance

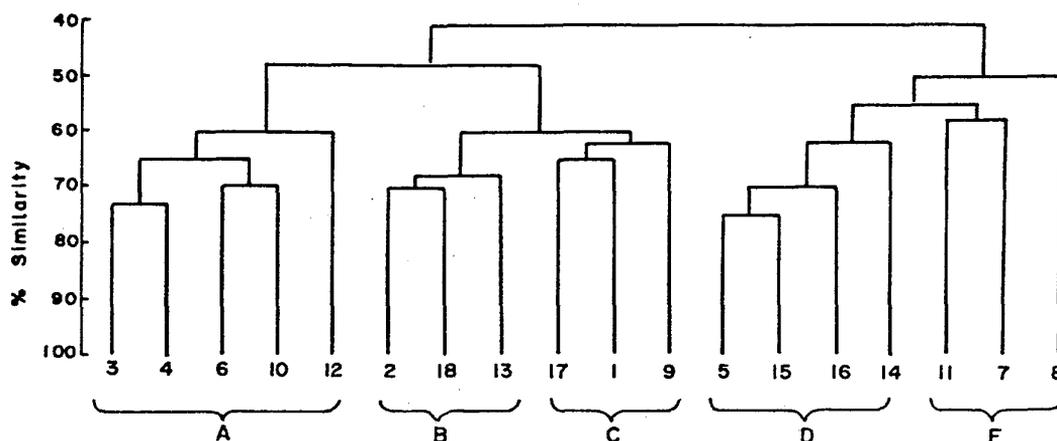


Fig. 3—Dendrogram of stations similarity produced by group average sorting

classified the stations into five groups, based on the dominance of samples of 17 families (Fig. 3). Samples in close proximity cluster with each other, depending on sediment type. Five main samples/stations could be distinguished. The largest cluster (A) formed by five stations was located in silty clay. The second largest cluster (B) was of those stations having clayey silt and sand. The third cluster (C) was of sandy bottom. The fourth and fifth clusters were formed in the sandy silt and clayey silty bottom respectively. Families such as Nereidae, Spionidae, Sabellidae and Capitellidae of polychaeta have large representative of deposit feeding form and are more common in the silty muddy deposit. The members of the family Veneridae are filter feeders and occur in sandy deposit while Cirolanidae are epibenthic form and depend on detritus. The wide occurrence of these common forms gave rise to many clusters and reemphasized that wide variations occur in the macroinvertebrate assemblage of Marmugao harbour.

Discussion

Differences in invertebrate abundance, biomass and species composition were accompanied by changes in the physical and chemical character of the sediment, resulting from anthropogenic influence on the ecosystem⁸. However, the lack of consistency in the occurrence of individuals make it difficult to differentiate between stochastic variability and human interference. Patches of homogenous community structure can also be caused by disturbing events⁹. The analysis of macroinvertebrate community in the Marmugao harbour has delineated 5 groups (station-wise), based on the

presence/absence of families each representing an assemblage of benthic animals of different sediment types. Parulekar *et al.*⁴ have also described the macrobenthic community of Marmugao bay in which they distinguished soft bottom communities using criteria of environmental stability. They also reported macrobenthic community dominated by polychaetes and molluscs as observed in the present study. However, the biological parameters indicated that the individual numbers and biomass have decreased when compared to the earlier data⁴. Also an obvious increase in the opportunistic small polychaetes was recorded in the present study. One reason for this change might be disturbances caused by anthropogenic activities. In similar studies carried out elsewhere, benthic community changes have been related to instability of the environment¹⁰. This is reflected in wider grouping of individuals and stations as observed in this study.

Benthic communities respond differently to the environmental changes¹¹. Within a harbour, benthos respond to the gradients of salinity, wave action, tidal currents, water depth and substratum. These parameters are likely to favour populations of those species that are adapted to withstand such prevailing conditions. The macroinvertebrate community of the Marmugao harbour appears to be composed of more tolerant species, living in a variety of microhabitats, and under disturbing environmental conditions. This allows an overlap of the species resulting in many closely related groups of individuals, as can be seen in the present study.

The availability of food is one of the major factors controlling distribution pattern of benthos¹². There

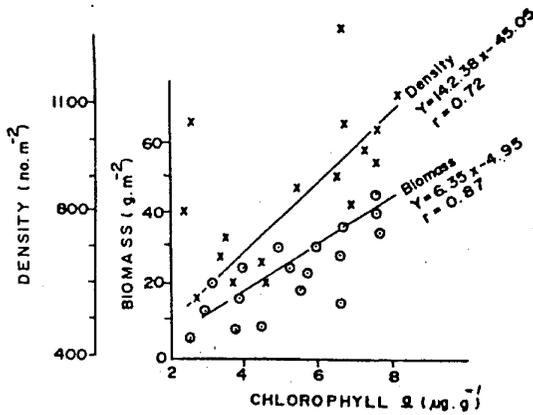


Fig. 4—Regression coefficient of macroinvertebrates density and biomass with chlorophyll *a*

were number of attempts to distinguish the effect of surface productivity in determining the biomass of subtidal benthos. A rather clear indication of the effect of surface productivity can be had by the regression of benthic biomass on chl *a*¹³. This technique was applied and the results obtained are shown in Fig. 4. It yielded statistically significant regression equation of the following -

$$Y = 142.38 \times -45.05 \text{ density}$$

$$Y = 6.36 \times -4.95 \text{ biomass}$$

The above equations corroborate with the earlier findings¹² and suggest that microphytobenthic productivity can also be used in the benthic production processes.

In addition to any direct influence on benthos, changes in sediment particle size are also important because of the correlation that often exist between grain size and organic content. Knight¹⁴ identified benthic communities in Lyttelton harbour by correlating the species present with the organic enrichment of the sediment. One of the several hypotheses for the apparent changes in benthic communities is the enrichment of organic carbon. The Marmugao harbour receives sufficient quantity of domestic sewage and organic enrichment from the city municipal area and fishing activities in the harbour. It is believed that moderate enrichment has a biostimulating effect on benthic community as observed elsewhere¹⁵. However, high enrichment by organics will lead to eutrophication and unsuitable environmental conditions for benthic life. There was no consistent pattern between organic carbon and benthic biomass (Fig. 5). Absence of such a pattern was also noticed by others¹⁶. Despite this, the importance of organic matter in the distribution and

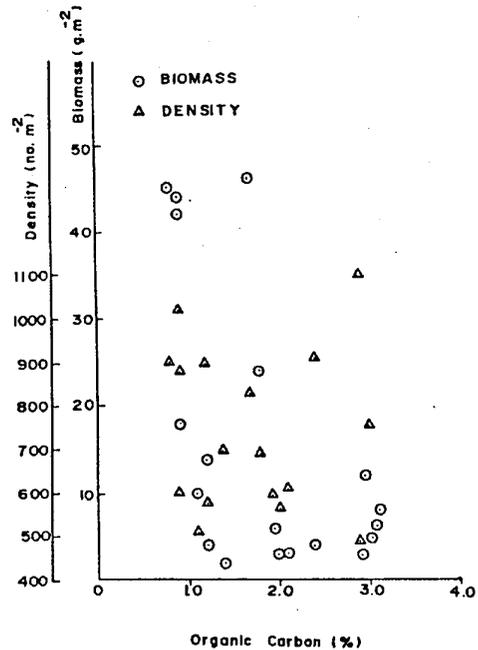


Fig. 5—Correlation between sediment organic carbon and the density and biomass of macroinvertebrate

abundance of benthic communities cannot be undermined since a number of opportunistic species among benthic animals depend heavily on it.

It may be concluded that the numerically dominant taxa (families) of the present study occur over a wide variety of sediment types, responding to sedimentary gradients with changes in abundance. The pattern of community structure revealed by similarity analysis was correlated with types of sediment and the availability of food. Changes in benthic community structure can also be caused by turbulent events such as sediment scouring and heavy rainfall and colonization of adults and juveniles of various species. These processes could also be responsible for spatial differences in the distribution of benthic macroinvertebrate of the Marmugao harbour.

Acknowledgement

The authors are thankful to the Director, National Institute of Oceanography, Dona Paula, Goa for encouragement and facilities. They are also thankful to Dr. A.H. Parulekar for encouragement.

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