Bottom Fauna of Dredging and Dredge Spoil Disposal Sites of a Tropical Estuary

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ABSTRACT

Sediment characteristics and bottom fauna were investigated extensively in and around Cochin harbour at 38 sampling stations grouped into seven areas, covering an area of 130 km^2, during premonsoon and monsoon periods. The seven areas were: (I) Ernakulam channel (4-10 m deep). (2) Mattanchery channel (2.5-5.5 m deep). (3) Vallarpadam (2.1-4.5 m deep). (4) Dredging channel (8.5-17.0 m deep). (5) North of dredging channel (6.6-14.0 m deep). (6) South of dredging channel (6 6-14.0 m deep) and (7) Disposal site (12.8-17.5 m deep). The silty clay and sandy clay substratum predominated the study area. In the dredging and disposal areas the values for organic matter were 3.40 and 4.51% during pre-monsoon and 3.51 and 4.00% during monsoon respectively. The standing stock in terms of total biomass (wet weight) in the study area varied from 37.47 to 297.30 g m^{-2} during premonsoon and 12.63 to 215.97 g m^{-2} during monsoon. The distribution of different faunal groups/species indicated a significant reduction in the dredging and disposal areas Polychaetes dominated the fauna. Bray-Curtis. Coefficient of Similarity between areas was higher during monsoon than during premonsoon in areas 4-6 with sediment characteristics controlling the occurrence of common species. Species which are highly abundant and more homogeneously distributed have low niche breadth preferably in sand dominated areas, particularly in areas 1 -4. In area 5, a similar trend was observed with high niche breadth associated *with* organic matter content, whereas in areas 6 and 7 a reverse in the trend was observed with finer sediment dwelling organisms showing high niche breadth. In general a decreasing trend in the species niche breadth was observed from area I to 7 with higher values during monsoon than during premonsoon for species niche breadth. Grouping of species obtained by group average linkage clustering and using R-mode analysis are compared:

Key Words:-Benthos, Dredging, Similarity, Multiple Regression Model, Sediment, Cochin Harbour.

INTRODUCTION

The Cochin backwaters (latitude 9°58' N, longitude 76°58' E) lie extending about 130 km parallel to the coast with a breadth varying from a few hundred meters to 130 km. Cochin backwaters face serious environmental threat by way of intertidal land reclamation, waste discharges, harbour development,- dredging activities, urbanisation, etc For the past several decades dredging is carried out in the Cochin harbour area as a part of the maintenance programme and the amount of material dredged during the study period was l0x 10^6 m^3 (Thresiamma et al. 1998). The possible impact of deepening of the navigational channel by dredging on the bottom fauna was assessed during the present study. The macrobenthic organisms were selected for the study because they arc permanent inhabitants of the sediments with low mobility and are good indicators of the conditions prevailing in the bottom. In addition they are also an important link of the estuarine food chain. The physical and chemical characteristics of the sediments and its change may be of great significance while studying the bottom fauna.

MATERIAL AND METHODS

Thirty eight sampling stations (sts) were fixed in and around the Cochin harbour, covering an area of 130 km^2 of estuarine and near shore areas for the collection of bottom sediment and benthic fauna (Figure 1). For spatial comparison, the study area was divided into seven areas viz., (1) Ernakulam channel (sts. 1-10 and 4-10 m deep). (2) Mattanchery channel (sts. 11-16 and

2.5-5.5 m deep). (3) Vallarpadam (sts. 17-21 and 2.1-4.5 m deep). (4) Dredging channel (sts. 22-28 and 8.5-17.0 m deep). (5) North of dredging channel (sts. 29-31 and 6.6-14.0 m deep). (6) South of dredging channel (sts. 32-34 and 6.6-14.0 m deep). (7) Disposal site (sts. 35-38 and 12.8-17.5 m deep).

Duplicate grab samples (Birkett and Mclntyre 1971) were collected from all stations during pre-monsoon and monsoon seasons using a van Veen grab (0.048 m^2) and sediments were sieved through a 500 m mesh and preserved in 5% neutral formalin mixed with rose bengal stain for subsequent identification. The actual number of organisms counted were converted to no. m"^{2}. The biomass values were expressed as wet weight (g m"^{2}, shell on weight). Samples for grain size and organic carbon content were treated separately.

Grain size (Krumbein and Petty John 1938) and organic carbon (El Wakeel and Riley 1957) were estimated by the conventional methods. Organic matter was calculated by multiplying the organic carbon values by a factor of 1.724 (Trask 1939). For studying the community structure different diversity indices (Margalef 1968, Simpson 1949, Shannon and Weaver 1963, Pielou 1958 and Heip 1974) and niche breadth were calculated (Ignatiades 1994). For determining ecologically important indicator species Q-mode and R-mode factor analysis was applied (Morrison 1978). Step up multiple regression model (Snedecor and Cochran 1967, Sokal and Rohlf 1981 and Tuckey 1949) was applied for understanding the relation between the benthic abundance, and the water quality and sediment characteristic parameters. Similarity between stations and species was studied using Bray-Curtis' Coefficient of Similarity (Bhat et al. 1997).

RESULTS AND DISCUSSION

Sediment Characteristics

Data on grain size distribution and organic matter content (Table 1) show that silty clay and sandy clay sediments dominated the study area except for one or two stations. Compared to the monsoon season, the organic matter content was low during pre-monsoon period. The average organic matter content in the areas 1 to 3 ranged from 3.71 to 4.27% during the pre-monsoon and 4.07 to 5.27% during the monsoon season. In the dredging channel, the values were 3.40% during pre-monsoon and 3.51 % during the monsoon. In the disposal area, the average organic matter content was 4.51 and 4% during pre-monsoon and monsoon respectively. On either side of the dredging channel the organic matter content varied from 3.61 to 4.34% and 3.83 to 4.53% during the pre-monsoon and monsoon seasons respectively.

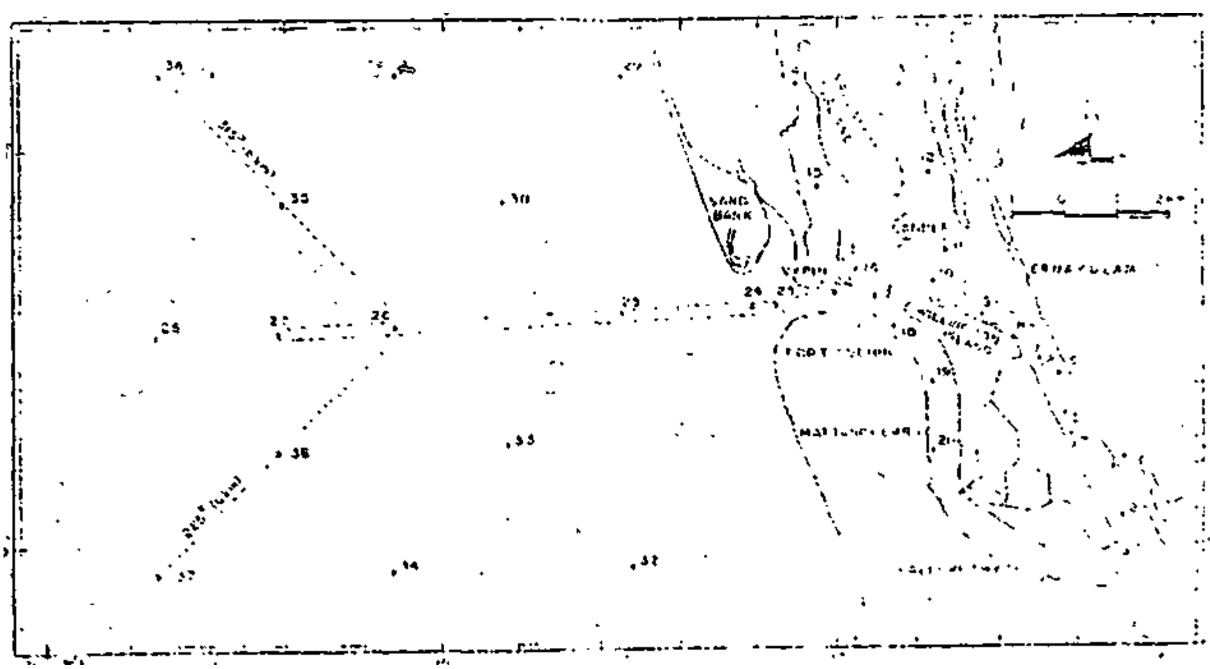


Figure 1. Location of sampling stations.

Table 1. Sediment characteristics during pre-monsoon and monsoon.

Area	Stations	Pre-monsoon				Monsoon			
		Sand (%)	Silt (%)	Clay (%)	Organic matter (%)	Sand (%)	Silt (%)	Clay (%)	Organic matter (%)
Al	01	0.24	21.11	78.65	2.74	3.70	27.00	69.30	6.19
	02	0.46	14.04	85.50	4.47	14.62	34.63	50.75	4.52
	03	23.27	8.13	68.60	50.05	23.33	31.91	44.76	5.12
	04	15.50	4.45	80.05	50.05	1.59	40.06	58.35	5.59
	05	5.63	2.77	91.60	4.17	0.47	33.98	65.55	5.21
	06	20.07	8.53	71.40	3.57	37.42	19.33	43.25	4.64
	07	30.44	0.91	68.65	1.00	0.45	40.20	59.35	5.38
	08	19.31	5.94	74.75	4.59	8.96	43.14	47.90	4 59
	09	23.05	20.20	56.75	7.62	0.28	32.32	67.40	6.36
	10	27.93	1.97	70.10	4.45	3.59	41.46	54.95	5 05
A2	11	1.33	10.32	88.35	4.71	8.51	37.68	53.81	6.02
	12	7.49	14.81	77.70	4.76	14.88	35.52	49.60	7.38
	13	30.40	18.40	51.20	2.02	8.35	44.55	47.10	7.90
	14	28.00	22.00	50.00	3.15	62.05	15.60	22.35	4.29
	15	23.04	21.21	55.75	2.65	11.45	25.85	62.70	2.26
	16	4.17	27.08	68.75	2.79	40.55	27.80	31.65	3.53
A3	17	10.72	24.38	64.90	4.76	4.09	34.56	61.35	3.15
	18	1.41	35.69	62.90	4.71	0.27	52.63	47.10	5.48
	19	2.21	13.64	84.15	2.69	0.44	27.61	71.95	3.81
	20	4.69	24.06	71.25	5.36	2.35	30.20	67.45	5.19
	21	0.39	28.66	70.95	1.02	0.59	35.36	64.05	2.74
A4	22	23.39	4.86	71.75	3.33	-	-	-	-
	23	64.62	12.68	22.70	0.24	-	-	-	-
	24	50.69	6.41	42.90	4.43	94.20	0.50	5.30	0.53
	25	6.30	19.95	73.75	3.26	-	-	-	-
	26	1.47	15.58	82.95	4.65	1.00	44.45	54.55'	4.28
	27	-	-	-	-	0.50	36.20	63.30	4.76
	28	0.54	21.76	77.70	4.47	1.20	39.30	59.50	4.45
A5	29	0.13	12.22	87.65	2.98	11.43	39.62	48.95	4.52
	30	0.31	22.99	76.70	3.88	0.36	39.59	60.05	2.98
	31	.0.86	27.34	71.80	3.98	0.18	41.07	58.75	3.98
A6	32	20.16	7.49	72.35	2.67	6.10	46.80	47.10	4.64
	33	0.17	25.70	74.13 '	5.09	0.10	39.20	60.70	2.84
	34	0.85	11.40	87.75	5.26	3.50	39.80	56.70	6.12
A7	35	2.25	29.35	68.40	2.26	0.58	49.67	49.75	2.26
	36	4.99	29.56	65.45	5.41	0.20	41.20	58.60	5.41
	37	19.26	22.60	58.14	6.02	-	-	-	-
	38	16.64	10.66	72.70	4.34	1.10	33.20	65.70	4.34

The grain size analysis showed the presence of minor portions of sand during pre-monsoon. The silt portion marginally reduced giving way to deposition of clay material at the dredging site. These observations lead to the conclusion that finer material than silt is either sedimented or translocated on the seaward side of the dredged site. This factor also excludes the possibility of river-borne material to reach the dredged area under low river discharge rate during pre-monsoon season. The sediment characteristics and bottom topographic features will be restored after a period of intermittent dredging. The tidal flushing characteristics and river discharge plus material inputs help the dredged site to return to its initial status (Rasheed 1997).

High organic matter content in the region can be ascribed to high productivity of the overlying waters (Devassy 1983). Sewage and municipal discharge, and clayey nature of the sediments may also be responsible for high organic matter content. Moreover, land-derived organic matter finally deposit in the river channel. Strong tidal currents in the region continuously drain out available suspended organic matter in the sea without allowing sufficient limit for the deposition during the out flow of water.

Table 2. Benthic density (no. m^{-2}) and biomass (g m^{-2}) during pre-monsoon and monsoon seasons.

Area	Stations	Pre-monsoon		Monsoon	
		Density	Biomass	Density	Biomass
Al	01	9941	164.52	2815	2.97
	02	398	8.37	2148	. 9.26
	03	750	0.72	7524	43.64
	04	28672	22.24	5921	3.54
	05	231	10.83	189	5.41
	06	335	9.39	294	4.69
	07	689	10.68	1001	0.89
	08	168	0.91	1136	1.86
	09	188	3.58	42	0.09
	10	42	0.10	303	9.16
A2	11	377	18.33	680	1.88
	12	230	3.36	1038	10.64
	13	3104	4.41	292	4.51
	14	794	2.98	1283	6.85
	15	250	8.29	418	6.02
	16	272	0.80	971	4.87
A3	17	84	0.59	231	6.05
	18	21	0.10	898	2.31
	19	42	0.10	84	0.59
	20	218	2.46	156	2.68
	21	588 '	28.50	4073	i.oo
A4	22	629	31.74	-	-
	23	3355	203.09	-	-
	24	1106	44.65	1396	102.65
	25	42	1.13	-	-
	26	313	2.89	42	0.21
	27	-	_	1458	110.73
	28	1437	13.80	63	2.38
A5	29	167	1.18	3312	25.58
	30	1062	47.42	147	11.53
	31	396	12.76	42	0.67
A6	.32	.439	2.06	63	0.58
	33	1439	21.16	917	2.61
	34	605	14.25	5083	17.80
A7	35	2020	40.72	689	4.25
	36	483	17.80	1469	4.41
	37	304	90.99	-	-
	38	648	26.00	344	4.30

Benthic Standing Stock and Community Structure

The density and biomass of the different stations varied from 21 to 28672 m^{-2} and 0.10 to 203.09 g m^{-2}, respectively during pre-monsoon and from 42 to 7524 m^{-2} and 0.09 to 110.73 g m"^{2} respectively, during monsoon (Table 2). The high biomass values noticed at certain stations were attributed to the presence of large gastropods and bivalves.

Maximum numbers of faunal groups/species were encountered in area 1(11 groups) followed by 7 groups in areas 2 and 4, 4 groups in areas 5 and 6, and 3 groups in areas 3 and 7 during pre-monsoon. During monsoon also, the maximum number of groups/species were recorded in area 1 (10 groups) followed by 7 groups in areas 2 and 3. Five groups were encountered in areas 4 and 5, and 2 groups in areas 5 and 6. Molluscs, polychaetes and amphipods were dominant groups during both seasons.

Large variation occurred in the distribution, abundance and composition of various fauna. This may be probably due to various physico-chemical and. environmental factors. Wide fluctuations in salinity and nature of the substratum and organic enrichment of the sediments are important factors restricting the abundance of benthos. Dredging of the sediments also exposes the fauna to a new substratum. A remarkable reduction in the faunal groups and species diversity was noticed in *the* dredging and disposal areas.

Polychaeta was the dominant group during both seasons (11.9 to 66.1% during pre-monsoon and 19.7 to 99.6% during monsoon). A total of 24 species of polychaetes were encountered during the study period. Twenty one species were recorded during monsoon and 19 species were noticed during pre-monsoon. Sixteen -' species were common to both seasons whereas 5 species were found only during monsoon period *(Lumbrinereis notocirrata, Glycera convolute, Maldanella capensis, Omnia fusiformis* and *Sternaspis scutata).* and 3 species were noticed only during pre-monsoon period (*Dendronereis aestuarina, Goniada emerita* and *Capitella capitata).*

Oligochaetes occurred during monsoon (areas 1 and 3) and pre-monsoon- (areas 1, 2, 4 and 5). The amphipod species, *Corophium triaenonyx* and *Quadrivisio bengalensis,* were collected in large numbers during both the seasons in the areas 1, 2 and 3 but were absent in-the dredging and disposal sites where only polychaetes, decapods, mysids, sergestids, gastropod, bivalves and juvenile fishes were present.

The perturbation in the environment as a result of dredging and dredge spoil dumping disturbs the bottom due to the turbidity developed. The expected changes in the benthic organisms are species replacement and an increase in the abundance of certain species. A perusal of the data collected from the near shore waters and the Cochin harbour area in the last two decades clearly indicated that there is no change either in the benthic biomass or in the faunal composition over the years.

Survival of the benthic species depends on the - thickness and other characteristics of the deposited material. Studies conducted elsewhere indicated that deposition of sediments up to 10 cm did not affect the benthic population provided there were no differences between the originally present and deposited sediments. Detailed analysis of the sediment samples collected from the dumping sites and the harbour area showed that the sediment characteristics are comparable. Hence the damage to the bottom community caused by dumping *the* spoil is minimal and is also reflected in the data. Therefore it can be concluded that an increase in the quantum of dredge material and disposal at the selected site is unlikely to cause any serious damage to the bottom community. The impacts observed if any were relatively short-term. The behaviour of organisms in the reference area was very similar to that in the disposal area and no definite impact could finally be established. It was not perceptible since the species composition of benthos was observed to be identical with that in the neighbouring areas over the years. The absence of accumulation of dead shells in this area in the present study suggests that there was no indication Gf mortality due to impact of dredging and dredges spoil disposal. Comparison of substrate and benthic community structure near the dredging and disposal site showed that benthic communities were resilient and was able to cope with the stress of anticipated additional loading.

A study by Rosenberg (1977) indicated that the reduction in the number and the diversity of organisms are the aftermath of the deleterious effects. For instance, Harrison (1967) reported a 71% reduction in the average number of benthic animals at a disposal site in the upper Chesapeake Bay at one month after dredging and disposal activities ceased. However within 18 months, the number of individuals and species diversity at the disposal site were same as irr surrounding areas.

The study of the benthic community at the Botany Bay showed that the benthic fauna at the dredged area is different from the nearby non-dredged areas with respect to species composition and richness, both of which are closely related to the sediment type (Jones and Candy 1981). A very recent report (Ray and Clarke 1995) narrates the outcome of dredging on benthic recovery in Galveston Bay, Texas. The detrimental effects on benthic macrofauna were minimal in the area of dredging and open water disposal of south Carolina estuary. On the other hand, in freshwater in the marine environment, showed important increase in the total number of individuals in newly deposited sediment caused by rapid recolonization by opportunistic species (Grassle and Grassle 1974), the species that can quickly respond to open or unexploited habitats by either a high reproduction rate or a high dispersal ability.

The studies by Rosenberg (1977) and Jones and Candy (1981) suggested that *the* benthic fauna of dredged areas differs from that of non-dredged areas with respect to species composftion and diversity and also noticed variation in sediment texture during dredging. The dredged site showed a slight increase in the number of organisms, especially of polychaetes, which indicates the onset of colonisation in this area. Higher species density were noted at the non-dredged location compared to dredged area and under favourable conditions, the recolonization is possible in this dynamic environment.

Community Structure

In this study we were interested to see whether distinct broad communities could be oudined within the back-water system on the basis of the community composition and community diversity profiles. We also tried to identify two spatial/time coordinates along which benthic profiles vary. Biotic diversity index is used as an indicator of environmental stress. A high level of environmental stress will generally tend to lower biotic diversity. But using different diversity indices one reaches different conclusions (Sanders 1958). Among the various diversity indices Shannon Weiner index has been found to be sadsfactory with regard to changes in the index value with the variadon in pollution intensity (Patil and Taille 1979).

Similarity Between Stations

Similarity between stations was studied using Bray-Curds' Coefficient of Similarity and using community coefficient, which is a non-parametric method (using only the presence and absence of species).

In area 1 during premonsoon >90% similarity was observed between stadons 1, 2 and 3 and between stations 8, 9 and 10 using Bray Curtis index. Very low similarity is obtained based on common occurrence of species in this area. Differences in the species occurrence was highly related to sediment characteristics. In monsoon season also more or less the same pattern of similarity was obtained between stations except that based on parameteric method where only 65% common occurrence was observed between stations 2 and 4, and 5 and 7. On the whole, a marginal increase in the common occurrence of species during this season was observed. In area 2 during premonsoon highest similarity was observed between station 13 and other stations. But stations 11 and 12 showed <50% similarity with stations 15 and 16. This indicates that migrating tendency was not very crucial. But with community coefficient only less similarity was observed between stations 13 and other stations. During monsoon season, a slight reshuffling was observed in the occurrence of common species with station 13 keeping a lower level of similarity with the rest of the stations even though the trend remained almost the same. Regarding the presence and absence of species not much significant difference could be observed in the pattern of station-wise similarity during the two seasons indicating that the change whatever.had been observed was only indicative of sampling variability but not ecologically attributed. Area 3 did not depict much difference in the station-wise similarity during the two seasons where as the community coefficient values were higher during monsoon season than during pre-monsoon season except stations 18 and 19. Quantitative analysis of area 4 showed almost the same pattern in both seasons except stations 23 and 28 (<60%) and stations 26 and 28 (<70%). Premonsoon season showed less occurrence of common species than monsoon season, particularly station 24 with, other stations. In areas 5 and 6 higher similarity was observed between stations during monsoon season than during premonsoon season with a reverse trend in area 7.

Species Niche Breadth

The concept of niche breadth is not easily understood except in very abstract terms. Often micropaleontologists and protozoologists think of niche in a spatial or habitat sense and commonly express it only in terms of data gathered at a single point in time. These studies are valuable even though they give only very little insight into the biotic constraints which are highly important in the dynamic processes which establish the real niches of animals. Niche concept is more applicable to microhabitats. It remains as a theoretical ideal rather than a pracdcal objective. In general it appears that niche can be defined as a taxa/species specialization indie community, the share of the community resources that it utilizes and its particularity/selectivity in relation to other species and to intra-community conditions of environment, space and time. Indeed it may prove more useful to know broad distribution patterns rather than the miniature of the niche of each taxa/species, for the interaction of environmental controls may cause the realized niche to vary from one region to another.

During pre-monsoon season in area 1 with 28 • species, high niche breadth (5.44) was obtained for *Prionospio pinnata)* (average, X=123 m^{-2}) with low variation and other species with average abundance ranging between 6 and 50 m^{-2} have niche breadth >3.10; for all other species the value was <2. *Corophium triaenonyx* with average spatial abundance of 837.5 m^{-3} and high variation controlled by silt concentration (r=0.5414) has low niche breadth of value, 1.6651. Similarly, *Sabellid* sp. which is highly abundant (X=2252 m^{-2}) and high scattered distribution also had low niche breaddi (1.4791). In area 2 with 24 species, this parameter ranged from 1.066 *(Corophium trianonyx* with X=242.74 m^{-2} and C.V.% = 409.7) to 5.195 *(Nephthys dibranchis* with X=17.5) with *Corophium trianonyx* being dependent on sand concentration (r=0.563). Nearly 37% of the species had low values ranging between 1.066 *(Corophium trianonyx)* and 1.752 *(Heteromastides bifidus* with X=24.33 m^{-2} and low variation, 187.7%). Sediment characteristics were observed to control the species niche breaddi only to a moderate level while low niche breadth species were found to dwell in sand dominated sediments. In area 3, out of the 9 species, *Nephthys dibranchis* and *Prionospio polybranchiata* (X=12.6 m^{-2}), both with low spatial variation (C.V. = 133.3%) have the maximum niche breaddi of value 2.32. For the other species, it ranged between 1.084 *(Scyphoproctus djiboutiensis* with X=67.2 m^{-2} and C.V.% = 200 and moderately correlated with silt (r=0.24)) and 1.938 *(Ancistrosyllis constricta* with X=4.20 m''^2, C.V.% = 200 and it is not associated with any sediment structure, P>0.05). *Lumbrinereis simplex* (X= 16.80 rn^2, C.V. = 200%) depending on sandy sediment structure (r=0.51) has 1.825 as niche breaddi. In area 4, out of the 18, species, maximum niche breaddi (2.877) was obtained for *Prionospio pinnata* (X=24.5 nV^2, C.V. = 125%) and it has moderate correlation with organic matter (r=-0.216). For the rest of the species, niche breadth ranged between 1.195 *(Dentalium* sp. X=27.83 m^{-2}, C.V. = 223.6%) and 2.305 *(Lumbrinereis simplex* X=7.63 m^{-2}, C.V. = 143%) and it is highly controlled by sand structure (r=0.68). In this area it is observed that higher the niche breadth higher the association with sediment characteristics. In area 5, the niche breadth had a still narrower range - from 1.079 *(Gastropod sp.* X=277.7 m^{-2}, C.V. = 141.4% and r with organic matter = 0.419) to 2.055 *(Cossura coasta* X=69.33 m^{-2}, C.V. = 70.7% and r with organic matter = 0.996). Similarly, *Nephthys dibranchis* (X=34.67 m^{-2}, *c.v.*. = 101%) and *Lumbrinereis' simplex* (X=118 m^{-2}, rV. = 79.3%) both highly correlated with organic matter (r=0.628-0.686) has low value for niche breadth(1.85). In area 6, distribution of niche breadth ranged between 1.113 *(Scyphoproctus djiboutiensis,* X=34.7m^{-2}, C.V. = 141.4%, r with sand = 0.999) and 2.75 *(Cossura coasta,* X=42 m^{-2}, C.V. = 40.8%, r with silt = 0.95 and *Lycastis indica,* X=104 m^{-2}, C.V. = 42.9% and r with clay content = 0.956). in this area also sediment characteristics showed that finer the structure higher the niche breadth. In area 7 higher value for niche breadth was obtained than in other areas, with highest value (3.16) for *Gastropod* sp. (X=592.2 m^{-2}, C.V. = 73.4%, r with sand = -0.76 and r with organic matter = -0.95). For the rest of the species niche breadth ranged between 1.265 *(Dentalium* sp., X= 15.75 m^{-2}, C.V. = 173.2%, r with sand = 0.67, with clay = -0.87 and r with organic matter = 0.61) and 2.639 *(Cossura coasta,* X=52.25 m^{-2}, C.V. = 82.3%, r with clay = 0.838, r with organic matter = -0.93). During premonsoon season, higher was the variation o\er space, lower was the niche breadth.

Monsoon season appears to be favourable for benthic production. In areas 1-7 maximum values for the niche breadth are 6.31 *(Patraheteromastus tenuis,* X=21.4, C.V. = 94.9%, r with sand = 0.386). 4.518 (*Scyphoproctus djiboutiensis,* X= 120.8, C.V. = 69.5%, r with clay = 0.593), 3.106 *(Ancistrosyllis constricta,X=4,* C.V. = 122.5%, rwith silt = 0.70, r with clay = 0.796), 3.563 *(Prionospio pinnata,* X=18, C.V. = 48.6%, rwith Organic matter = 0.578), 2.733 *(Lumbrinereis simplex,* X=4S.67, C.V. = 40.21%. r with sand = 0.493), 1.76 (*Perinereis cavifrons,Hestromastides bifidus,* X=3.33, C.V. = 141.45, r with organic matter = 0.70) and 12.44, *Prionospio pinnata, X=708,* C.V. = 64.1%, r with sand = 0.95 and r with organic matter = 0.538), respectively. This season presents comparatively higher values for niche breadth compared to premonsoon season. It again follows that high niche breadth was followed by high relation with organic matter content.

Q-mode Factor Analysis

Q-mode analysis applied to dredging areas 1, 2 and 4 during premonsoon season produced 4, 3 and 3 significant factor groups *(l* > 1), respectively. In area 1, the four factor groups are those containing the stations 2. 3. 5 and 7 in factor group 1, stations 4 and 9 in facto group 2 and station 6 in factor group 3 and station 8-in factor group 4 together with explained variability of about 68% of the spatial variations in the benthic faunal distribution. In area 3, 3 factor groups were ecologically significant with respect to benthic distribution containing stations 12 and 16 in factor group I, stations 11 and 15 in factor group 2, stations 13 and 14 in factor group 3, explaining about 77.06% of the* spatial variation in this area. In area 4, 3 significant factor groups were delineated explaining about 80.48% of the spatial variations containing the stations, 23, 26 and 27 in factor group 1, station 22 and station 25 in the next two factor groups. For all factor groups, the factor loadings were numerically high indicating that there was unique difference between the stations included in the various factor groups and between-groups difference were more significant than within-group difference, since the stations included in each factor group, have high factor loadings of the same sign. In this area of study, the first two factor groups were differential factor groups explaining >50% of the spatial variations in the benthic faunal distribution in these areas.

During monsoon season, Q-mode analysis was carried out only for areas 1, 2 and 3. In area 1, only 3 factor groups, containing stations 7 and 9 in the first, stations 1 and 3 in the second and station 6 in the third factor group, with high positive factor loadings were determined. They formed the differential factor groups that explain 51.79% of the spatial variability. In area 2, the first two factor groups were important: both have high negative factor loadings, and the first one is the differential factor group. In this area, stations 12, 13, 14 and 16 provided maximum information and explained about 2.5 times the information gathered from station 15 of this area. In area 3, all the four groups were ecologically important as they explain almost the same amount of variability in the benthic distribution and the first 3 form the differential factor groups with positive factor loadings for the first two factors. A significant seasonal difference is clearly depicted by the difference in the stations included in the differential factor groups of the two seasons.

R-mode Factor Analysis

This analysis was applied in areas 1, 2 and 4 during premonsoon season and areas 1, 2 and 3 during monsoon season. 28 species in area 1 during premonsoon season were classified into 8 significant factor groups of which the factor groups I and 2 containing respectively 12 and 3 species were differential factor "groups. There were 12, 3, 5, 3, 2 and 1 species, each in the factor groups 3 to 8. Factor groups 1 and 2 have high negative factor loading indicating coexistence between species of these two factor groups. The last but three factors have high positive factor loadings. But their distribution did not add much to the information gathered from the factors 1' and 2, which explain about 65.4% of the spatial variability in the benthic distribution. In area 2, 24 species of benthos were classified into 5 ecologically significant factor groups. Of these 5 factors, first two were differential groups containing 8 and 6 species with high negative loadings, explaining about 51.52% *of the* spatial variations. In area 4 with 18 species, 5 ecologically important factorgroups of benthic species with high positive factor loading for the first factor, being designated as the differential factor group (54.02% explained variability) were obtained.

During monsoon season, area 1 with 36 species were subjected to factor analysis which classified these species into 8 statistically significant factor groups with 10, 7, 5, 5, 4, 2, 1 and 2 species assigned with high positive factor loadings for factors 2, 3, 6 and 8. Factor groups 3 and 4 were equally weighed in the matter of extracting information regarding the benthic distribution. In area 2, 21 species were classified into 4 ecologically informative factor groups with 5 species each in each of the factor groups identified with high positive loadings for factors 2 and 4. The first three factor groups were differential factor groups explaining about 71.71% of the spatial variability in the benthic production in this area. Area 3 having still less number of species, delineated 4 unique groups of species containing 9, 5, 2 and 1 species respectively all with high negative loadings thereby indicating preying mortality the minimum in this area. However the 9 species of the first factor were statistically sufficient to infer about the spatial distribution of the species in this area, being the differentia] factor group (explains about 56.30% of the variability). Ecologically significant factor groups were presented through cluster analysis by group averaging based *on* Bray-Curtis' Coefficient of Similarity and a comparison was made between the species clusters obtained by factor analysis and cluster analysis (Figures 2 and 3 for dendrograms and Figures 4 and 5 for factor groups).

Community Structure

During premonsoon period, species richness was higher in areas 1 and 2 than in other areas. At about 60% of the stations in area 1 had species richness >4.05 whereas more than 83% stations in area 2 has species richness >4.62. In all other areas, it ranged between 0.93 (station 26) and 4.36 (station 32) except station 22 (7.40) where it was considerably high. Average value was highest in area 2 (5.41) and lowest in area 3 (1.36). Area 3 had the highest and area 5 the lowest variability.

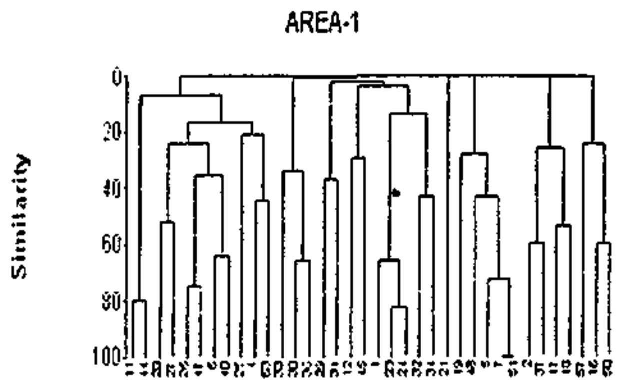
Species concentration index was highest at stations in area 1 (range is 0.42-0.85) and area 2 (0.37-0.84). A decreasing trend was observed for this index from area I to area 7, but not so conspicuously as in the case of species richness. More uniformity is observed in the higher values in areas 1 and 2. This distribution pattern was clearly observed in the variation factor (20.78% (area 1) to 41.95% (area 4)).

Shannon Weaver Diversity Index ranged from 1.00 to 2.96 in area 1, 1.00 to 2.88 in area 2, 1.26 to 3.00 in area 3 and with a still higher range in areas 4 to 7 (0.94 at station 28 to 3.53 at station 32). The highest average diversity was recorded in area 2 (2.14) with less variability (26.43%) and lowest diversity in area 3 (0.78) with maximum variability (90.69%). In area 5 species diversity was distributed with most uniformity (17.86%) indicating lesser fluctuation in the environmental conditions. Sudden unexpected changes were observed in area 3.

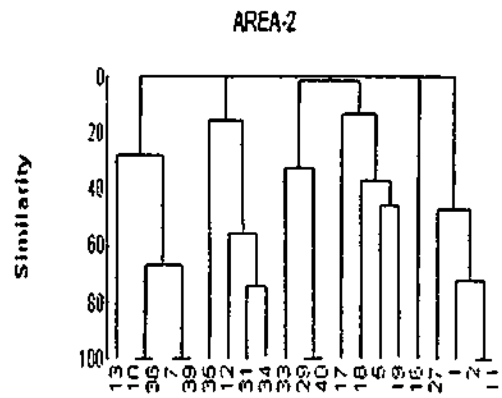
Species dominance index (Pielou's measure of diversity) ranged between 0.62 (station 10) to 1.83 (station 5) in area 1, 0.31 (station 13) to 1.90 (station 16) in area 2 and between 0.24 (station 23) and 1.58 (station 22) in area 3 except station 20 (2.033) where it was slightly more. In this study region, high richness, high species concentration and high diversity were followed by high dominance, which is a specific feature of a pollution-affected area. Based on the average distribution it was observed that species dominance was highest in area 5 (1.64) followed by area 2 (1.37) and area 1 (1.15). Least dominance was obtained in area 4 (0.43) followed by area 3, 7 and 6. Dominance index was highly varying in area 3 (90.7%) followed by area 4 (58.95%)" and least variable in area 6 (25.6%) This observation again indicates that some unexpected changes occurred in area 3.

Species evenness in the distribution of benthic species as measured by Heip's index, a function of Shannon index, showed higher values at station 5 (2.06) and station 6 (2.28) of area 1 and station 22 (2.13) of area 4. In general, higher diversity was followed by lower level of evenness or equitability in distribution. Thus, common species were present in larger numbers than the rarer species leading to disparity in the species distribution. It indicates that the existing conditions are favouring polludon tolerant species. Average spatial distribution showed high evenness in area 1(1.38) followed by area 4(1.15), with least variation for evenness in area 5 (28.03%) and maximum in area 3 (83.32%). This disparity in the community structure could be attributed to the dredging effect, particularly in areas 3 to 7 which are highly disturbed due to dumping of the dredged material from areas 1 and2.

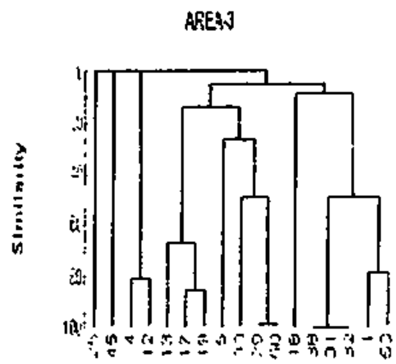
During monsoon season, not much variation was observed in the species richness except that peak values were observed for the stations with higher richness in the pre-monsoon season, and that the disparity between the richer stations and perishing stations had increased.



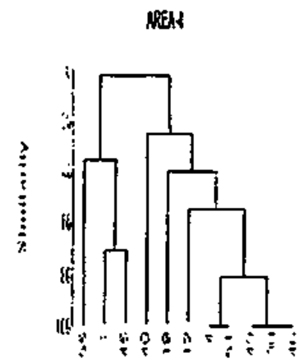
Species of area 1 during monsson season



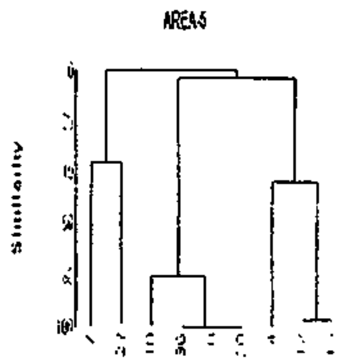
Species of area 2 during monsoon season



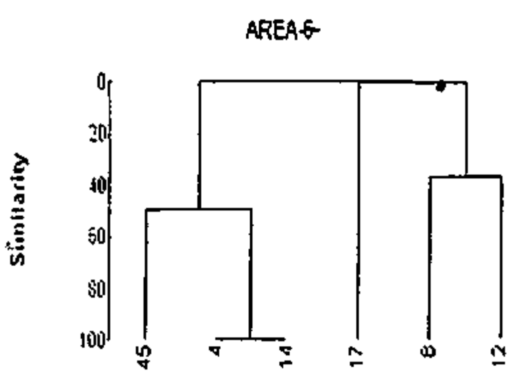
Species of area 3 during monsoon season



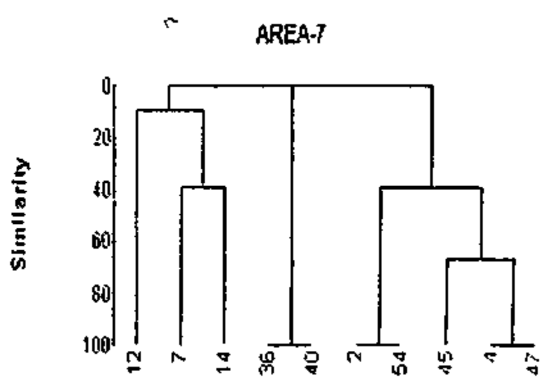
Species of area 4 during monsoon season



Species of area 5 during monsoon season

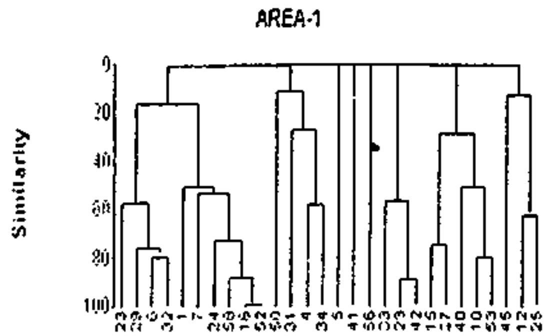


Species of area 6 during monsoon season

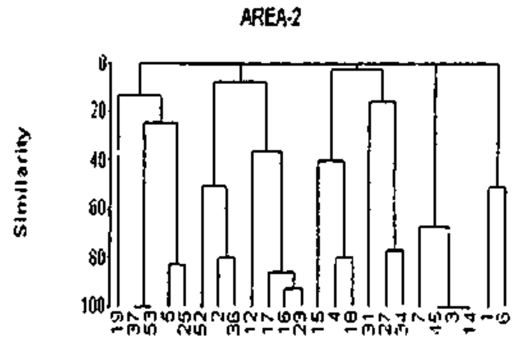


Species of area 7 during monsoon season

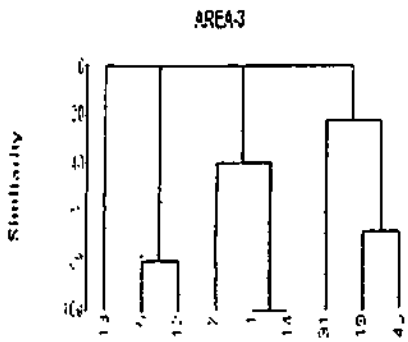
Figure 2. Dendrogram for species grouping during monsoon.
The numbers on the horizontal axis correspond to the number in the list of species (Appendix 1)



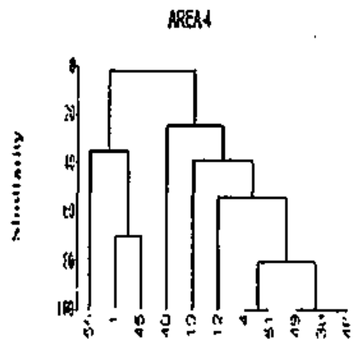
Species of area 1 during premonsoon season



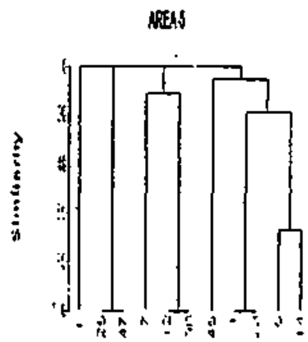
Species of area 2 during premonsoon season



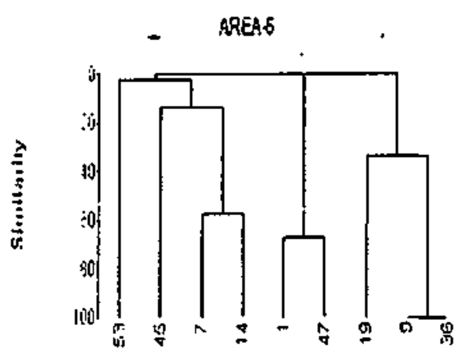
Species of area 3 during premonsoon season



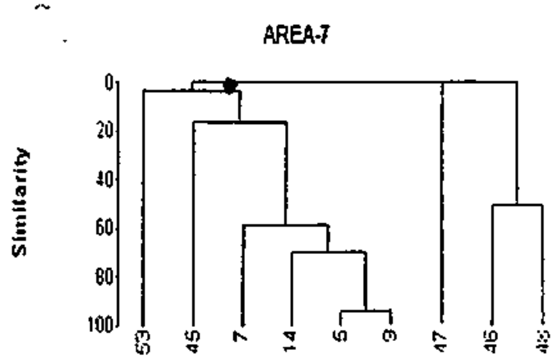
Species of area 4 during premonsoon season



Species of area 5 during premonsoon seas'



Species of area 6 during premonsoon season



Species of area 7 during premonsoon season

Figure 3. Dendrogram for species grouping during premonsoon.
The numbers on the horizontal axis correspond to the number in the list of species (Appendix 1)

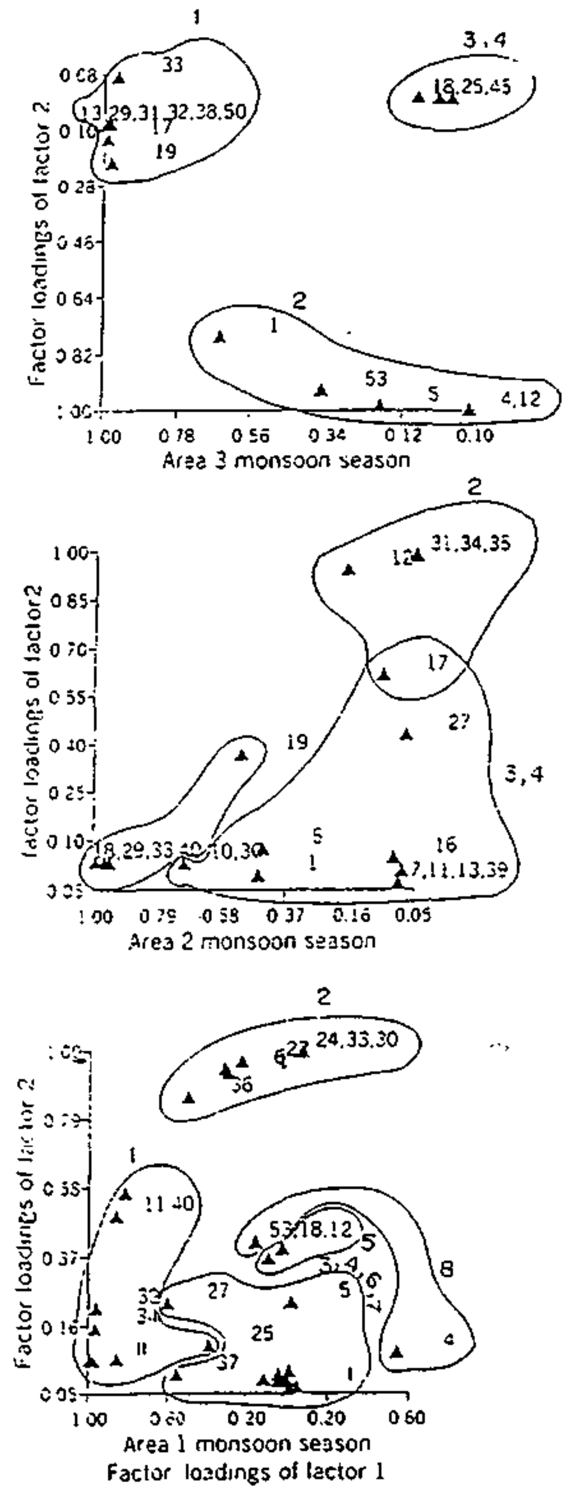


Figure 4. R-mode factor loadings of factors 1 and 2 plot for grouping of species during monsoon. The numbers within clusters refer to the number of the species in the list (Appendix 1).

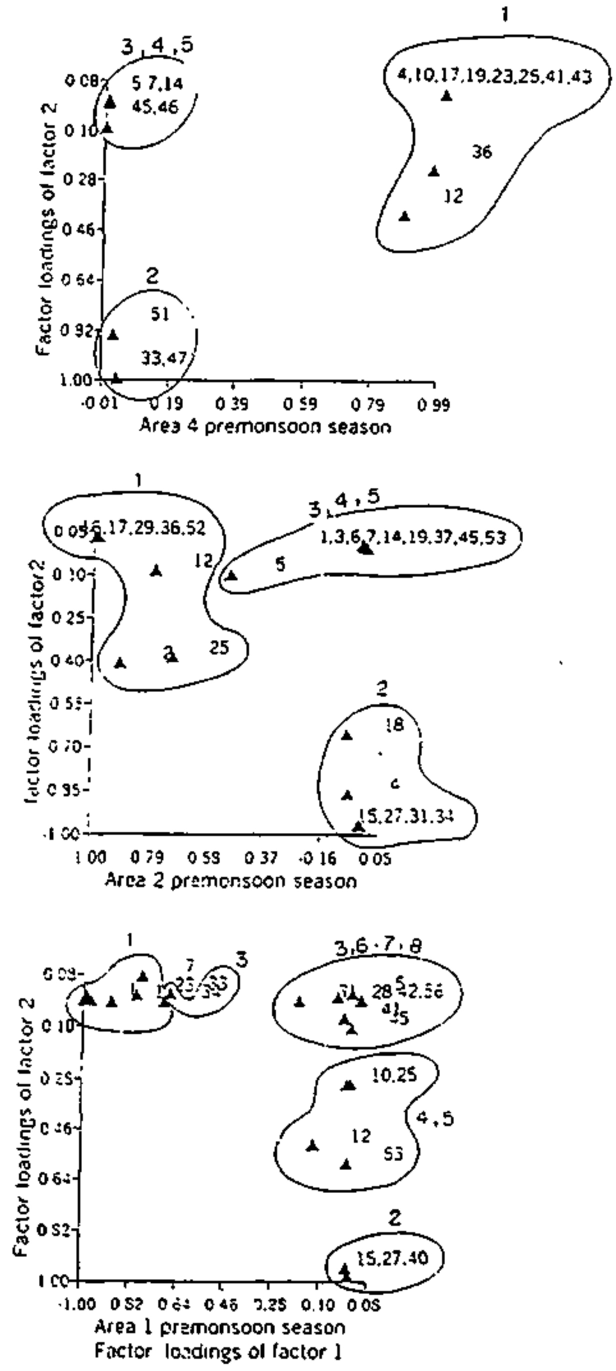


Figure 5. R-mode factor loadings of factors ! and 2 plot for grouping of species during pre-monsoon. The numbers within clusters refer to the number of the species in the list (Appendix 1).

Higher richness was observed at station 4 (12.82) of area 1, station 11 (8.23) of area 2, station 18 (9.40) of area 3, Station 27 (7.27) of area 4, station 29 (4.58) of area 5 and station 36 (4.37) of area 7. Low values were obtained at station 10 (2.79), station 15 (1.75), stations 19-21 (1.23), station 26 (1.54) and stations 31 -33 (1.45) of areas 1 -4 and area 6 respectively. Based on the spatial distribution of richness index, a steady decrease was observed from area 1 (6.97) to area 6 (1.79) with a peak point at area 4 (4.44) and another increase at area 7 (3.18) with an overall decreasing trend. The variability in the richness distribution also followed a similar pattern with maximum variation at area 3 (89.34%) and decreasing steadily from area 4 to area 7 showing increasing uniformity in the species richness in area 4 to area 7.

Species concentration showed a pattern of distribution similar to that of premonsoon period but further marginal upward increase in areas 1 and 2 where as a significant increase was observed in the other areas. Seasonal variation was not felt much in this aspect. On comparing the average values of concentration factor, it was observed that higher average values were obtained in area 1 (0.54), area 2 (0.58), area 4 *(0.57)* and area 5 (0.56) with least value for the concentration factor at area 6 (0.23). Highest variation was obtained at area 3 (63.76%) and least variation at area 5 (18.09%).

Diversity measured by Shannon Weaver Index, decreased from area 1 to area 7. Maximum diversity was recorded at Station 2 (3.40) and station 6 (3.20) of area 1 and the lowest diversity occurred (<0.96) at stations 31 to 36 and stations 7, 20 and 21. Average distribution showed a steady sloping down tendency from area 1 (1.82) to area 6 (0.57). Highest variation was obtained at area 3 (74.15.%) and least at area 7 (22.69%). This shows that higher diversity was maintained at moderate uniform manner in areas 1 and 2, while lower diversity was maintained at a more uniform manner at area 7. Tramer (1969) suggested that communities from rigorous environment, e.g., adverse environmental conditions, will vary in diversity according to their equitability component while diversity in non-rigorous (favourable environment) will be a function of species richness. This changing role of equitability and species richness in governing species diversity is clearly demonstrated in this study even though species richness seems to be all that is required to describe diversity in many situations (Whittaker 1972 and Magurran 1988).

The species dominance was much less compared to the pre-monsoon season in areas 1 to 3, but without a significant difference at areas 4 to 7. Highest dominance was 2.76 at station 34 whereas the lowest was observed at station 20 (0.21). The range of distribution of species dominance (highest in area 6 and least in area 1) indicates lower level of sudden variations in areas 1 and 2 and higher level of environmental variations in areas 4 to 7 during this season.

The dominance index was high in areas 5 (1.25) and 6 (1.66) and low in areas 3 (0.48) and 1 (0.54). The variation in the dominance index distribution over space was maximum in area 3 (74.5%) and relatively high in areas 1 (57.4%) and 6 (48.1%) and in the remaining areas it was between 22.6% (area 7) and 35.2% (area 5).

Species Equitability Index showed that not much significant difference could be observed in monsoon season when compared to pre-monsoon season and it ranged between 0.20 (station 7) and 2.33 (station 6) in area 1,0.60 (station 16) to 1.61 (station 11) in area 2, 0.06 (station 21) to 1.77 (station 20) in area 3, 0.67 (station 24) to 1.79 (station 28) in area 4, 0.88 (station 30) to 1.87 (station 3) in area 5, 0.09 (station 33) to 1.03 (station 32) in area 6 and 0.15 (station 36) to 0.69 (station 38) in area 7, respectively. The average distribution showed that Heip's Evenness Index was lowest in areas 6 and 7 and average value ranged between 0.91 (area 1) and 1.29 (area 5) with a steady increase from area 1 to area 5. The factors affecting equitability may be of great ecological interest. Grouping of species obtained by R-mode factor analysis and multi-linkage cluster analysis based on Bray-Curtis' Similarity Index are almost similar and contain nearly 60% same species, and therefore it can be concluded that the cluster analysis does not impose significant hierarchical structure on the data for which there is no prior evidence.

CONCLUSIONS

In areas 1 and 2 only a marginal increase in the similarity between stations was observed. Areas 3, 4 and 7 presented more similarity (based on commonness of species) during monsoon than during premonsoon season with a reverse scenario in areas 5 and 6.

In monsoon season higher values for species niche breadth are obtained and these are associated with species whose distribution is controlled by organic matter content in the sediment.

Q-mode multivariate factor analysis delineated relatively less number of differential factor groups of stations during monsoon than during premonsoon season indicating more environmental fluctuations in the latter case. Also R-mode multivariate factor analysis delineated more number of differential factor groups of species during premonsoon season justifying the observation pointed out above.

A more uniform pattern of species distribution was obtained in area 3 than in other areas, thus separating the dredged area from the dumping area during premonsoon season whereas a definite trend could be observed for the community structure indices, more *obviously* a decreasing trend from area 1 to area 6. It is concluded that both components of diversity viz., richness and evenness are necessary to provide adequate description of species diversity. Species diversity is a self-augmenting evolutionary phenomenon. Concept of diversity is particularly important since it is generally regarded as a parameter of a natural or organized community. Observed diversities are to be interpreted as products of evolution, through time under the influence of different environmental factors that affect the survival, niche differentiation and accumulation of species communities. An inverse relationship between richness and evenness component of diversity is mathematically expected and it is true in this study also. Diversity can often been related to various community attributes such as productivity, structure, dynamics, stability, evolution and environmental predictability.

It is suggested that non-random patterns in taxonomic domination may be linked with life history traits that promote speciation and reduce extinction rates, ie short generation time and high resource availability.

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REFERENCES

Bhat, U.G., Skora, K.E. and Kotwicki, S. 1997. Subtidal benthic meiofauna of puck Bay, Polish Baltic Coast, Indian Journal of Marine Science 26(1): 16-19.

Birkett, L and Mclntyre, AD. 1971. Methods for the Study of Marine Benthos. Treatment and Sorting of Samples. IBP Handbook No. 16. Blackwell Scientific Publications, Oxford. 157 pages.

Devassy. V.P., Bhattathiri, P.M.A. and Radhakrishna, K. 1983. Primary production in the Bay of Bengal during ' 1977. Mahasagar, Bulletin of the National Institute *of* Oceanography 16: 443.

EL Wakeel, S.K and Riley, J.P. 1957. Determination of organic *carbon in* marine mud. Journal du Conseil - Conseil International pour 1'ExpIoration de la Mer (CIEM/ICES) 22 (1938): 180-183.

Grassle, J.F. and Grassle, J.P. 1974. Opportunistic life histories and genetic systems in marine benthic polychaetes. Journal of Marine Research 32: 253-284.

Harrison, W. 1967. Environmental effects of dredging and spoil deposition. Proceedings of WODCOM, World Dredging Conference (Palos Verdes Estates, California): 353-359.

Heip, C. 1974. A new index measuring evenness. Journal *of* the Marine Biology Association (UK) 54:555-557.

Jones, G. and Candy, S. 1981. Effects of dredging on the macrobenthic infauna of Botany Bay. Australian Journal of Marine and Freshwater Research 32: 379-398.

ICrumbein and Petti John, F.J. 1938. Manual of Sedimentary Petrography. Appleton Century Crafts, New York. 549 pages.

Ignatiades, Lydia. 1994. Species dominance and niche breadth in bloom and non-bloom phytoplankton populations. Oceanologia Acta 17(1): 89-96.

Magurran, A.E. 1988. Ecological Diversity and Its Measurement. Croom Helm, London. 179 pages.

Margalef, R. 1968. Perspectives in Ecological Theory, University Chicago Press, Chicago. 111 pages.

Morrison Donald, F. 1978. Multivariate Statistical Methods. McGraw-Hill, New York. 415 pages.

Patil. G.P. and Taille, C. 1979b. Species abundance models, ecological diversity and the canonical hypothesis. Bulletin of the International Statistical Institute, Voorburg 44: 1-23.

Pielou, E.C. 1969. An Introduction to Mathematical Ecology. John Wiley, New York.

Rasheed, K. 1997. Studies on Dredging Impact Assessment (DIA) at Cochin, a Tropical Estuarine Harbour. Ph.D. Thesis, Cochin University of Science and Technology, Cochin, India. • 227 pages.

Ray, G. and Clarke. A 1995. Benthic recovery on new work dredged material in Galveston Bay, Texas. In: Grassle, J.P., Kesley, A, Oates. E. and Snelgrove, P.V. (Editors) Proceedings *of* the 23rd Benthic Ecology Meeting. Rutgers State University, New Bruswick. 245 pages.

Rosenberg, R. 1977. Effects of dredging operations on estuarine benthic macrofauna. Marine Pollution Bulletin 8: 102-105.

Sanders, H.L. 1958. Benthic studies in Buzzards Bay. I. animal-sediment relationships, Limnology and Oceanography 3: 245-258.

Shannon, C.E. and Weaver, W. 1963. The Mathematical Theory of Communication. University of Illinois Press, Urbana, Illinois. 69 pages

Simpson, E.H. 1949. Measurement of diversity. Nature, London 163:688.

Snedecor, G.W. and Cochran, W.G. 1967. Statistical Methods, 6th Edition, Oxford and IBH Publishing, New Delhi. 535 pages.

Sokal Robert, R. and James Rohlf, F. 1981. Biometry. The principles and practice of statistics in biological research. 2nd Edition. W.H. Freeman, New York. 659 pages.

Thresiamma Joseph, K.K., Balachandran, Nair, Maheswari, Venugopal, P. and Sankaranarayanan, V.N. 1998. Changes in water quality at Cochin harbour dredging site, south west coast of India. Indian J. Mar. Sci. 27: 250-252.

Tramer, E.J. 1969. Bird species diversity: Components of Shannon's formula. Ecology 50: 927-929.

Trask, P.D. 1939. Organic content of recent marine sediments. In: Recent Marine sediments. Amer. Assoc. Petrol. Geol. Tulsa, (Editor) Trask. pages 428-453.

Tuckey, J.W. 1949. One degree of freedom for Non-additivity. Biometrics 5: 232-242.

Whittaker, R.H. 1972. Evolution and measurement of species diversity. Taxon 21:213-251.

Appendix 1. List of species recorded in the study area

01. *Ancistrosyllis constricta*
02. *Lycastis indica*
03. *Dendronereis aestuarina*
04. *Perinereis cavitrons*
05. *Nephthys dibranchis*
06. *Diopatra neapolitana*
07. *Lumbrinereis simplex*
08. *Lumbrineries notocirrata*
09. *Gonida emerita*
10. *Glycera alba*
11. *Glycera convoluta*
12. *Prionospio pinnata*
13. *Prionospio polybranchiata*
14. *Cossura coasta*
15. *Capitella capitata*
16. *Heteromastus similes*
17. *Heteromastides bifidus*
18. *Paraheteromastus tenuis*
19. *Scyphoproctus djiboutiensis*
20. *Maldanella capensis*
21. *Owenia fusiformis*
11. *Sternaspis scutata*
23. *Pista indica*
24. *Sabellid sp.*
25. *Oligochacte* sp.
26. *Grandidierella bonneri*
27. *Grandidierella gitesi*
28. *Melita zeylanica*
• 29. *Quadrivisio bengalensis*
30. *Eriopisa chitkensis*
31. *Corophium triaenonyx*
32. *Apseudes chitkensis*
33. *Apseudes gymnophobium*
34. *Isopod* sp.
35. Anthuridae
36. *Decapod* sp.
37. Crab
38. *Mysid* sp.
39. *Cumacea* sp.
40. *Sergestid* sp.
41. *Alpheid* sp.
42. Barnacles
43. *Balanus*
44. Nudibranchs
45. *Gastropod* sp.
46. *Dentalium* sp.
47. Bivalve
48. *Cavolina* sp.
49. *Cardium* sp.
50. *Modiolus striatulus*
51. *Paphia papilliens*
52. *Donax* sp.
53. Juvenile fish
54. Amphioxus
55. Foraminifera
56. Sea anemone
57. Nematodes
58. Echinoderms