

## BIODIVERSITY OF BENTHIC POLYCHAETES FROM THE COASTAL WATERS OF PARADIP, BAY OF BENGAL

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**Abstract** : Polychaete communities of the subtidal waters off Paradip (Lat. 20°05' - 20°20' N and Long. 86°35' - 86°60'E) in the Bay of Bengal were studied on a seasonal basis. Composition, distribution and diversity of macrobenthic assemblage were investigated by deploying a van Veen grab at 17 stations in 10 to 30-m water depths. The subtidal sediment off Paradip coast was predominantly of fine-to-very fine particles and rich in organic carbon (mean=1.59±0.85%, n=17). Macrobenthic community was rich and diverse comprising of annelid worms and small crustaceans. The composition of macrobenthos differed considerably between the seasons. The abundance (density and biomass) of macrofauna was higher at shallower depth (near-shore stations) mainly due to the dominance of polychaetes. A total of 79-macrofaunal invertebrate species belonging to 13 phyla and 45 families were identified. The fauna was mainly composed of polychaetes (41.3%), crustaceans (20.6%), molluscs (15.4%), echiurid worms (7.2%) and echinoderms (2.7%). The contribution of polychaetes in soft sediment macrofauna was almost 50%. Out of 20 tops ranked polychaete species, *Nephtys* sp., was the important in terms of "Biological Index of Dominance" (BID), whereas *Cossura longocirrata* was the most abundant. Both these species had wider distributional range and contributed over 27% to the polychaete density. Diversity of macrofauna was higher at offshore (deeper) stations whereas, density was higher at near-shore (shallower) stations. The lower polychaete diversity at near-shore was due to the persistent physical disturbance (dredging activity). Therefore, this study demands for precautionary measures before allowing further alteration in the sedimentary conditions of the area.

**Keywords**: Biodiversity; macrobenthos; polychaetes; distribution, anthropogenic activities; Orissa; Bay of Bengal; India

### INTRODUCTION :

In spite of the considerations, that near-shore waters of Paradip are rich in dissolved nutrients and supports rich demersal fishery (John and Sudarsan, 1990; Anon, 1998), benthic study of this region has received very little attention. Apart from the scientific reports of Zoological Survey of India (Anon, 1989), other published information on the subtidal benthic fauna of this area are very few (Ansari et al., 1982). Early reports, mostly qualitative (Kemp, 1913; Kemp and Chopra, 1915) are based on the material collected by *Golden Crown* and *RIMS Investigator* during 1908 -1909 and have

been concerned with taxonomy. Very little has been published on the distribution of benthos or on the benthic productivity. The sediment inhabited animal communities popularly known as macrobenthos (>0.5mm size), are very important in the coastal ecosystem, as it supports a variety of bottom feeding higher animals. These macroinvertebrates are also considered as good indicators of estuarine, near shore as well as abyssal conditions, because they are relatively sedentary within sediment-water interface and respond predictably to many kinds of natural and anthropogenic stress (Weisberg et al., 1997; Engle and Summers, 1999; Jennings et al., 2001).

Polychaetes are well represented in most marine and estuarine benthic environments, both in terms of number of individuals and species, and they typically contribute a significant percentage of the total macrofaunal diversity (Euzen, 1987; Mackie et al., 1997). Polychaetes dominate intertidal and subtidal macrofauna, constituting over 60-80% of the faunal abundance (Hutchings, 1998; Peterson et al., 1998; Ingole, 2002; Ingole et al., 2002) and species richness. In the abyssal depths, polychaetes form most important group among macrofauna (Hutchings, 1998; Borowski, 2001; Ingole et al., 2001; Ingole, 2003). They exhibit a broad range of feeding types and life-history strategies (Pratt, 1973). Polychaetes serve as the main food source for many commercial fish species and are an important factor in the evaluation of fishing grounds (Uschakov, 1965; Bromley and Kell, 1993; Capitoli et al., 1995; Philip, 1998; Labropoulou and Papadopoulou-Smith, 1999; Nishikawa et al., 2000; Olaso et al., 2000). They have wide range of environmental tolerance and being the major bioturbators (Fuller et al., 1988; Harkantra et al., 1989; Petersen et al., 1998), polychaetes play a very important role in regulating the benthic communities (Davis and Miller, 1979; Ambrose, 1984; Retrauburn et al., 1996). They exhibit considerable spatial and temporal variations in recruitment in both time and space and are known to adapt as *r* or *k* selected strategies to different gradients of pollution (Grall and Glemarec, 1997). They have short generation time (Nishikawa et al., 2000) and higher metabolic rate and are frequently used to evaluate anthropogenic disturbance in shallow-water habitats (McIntyre, 1969; Pratt, 1973; Ansari et al., 1986). The importance of polychaetes in the benthic community structure and environmental quality monitoring has been summarized in many studies (Ansari et al., 1986; Pocklington and Wells, 1992; Bromley and Kell, 1993; Mackie et al., 1997; Ingole et al., 2001). The use of polychaetes as bait or feed in shrimp and fish culture is a common practice, as they can

provide certain polyunsaturated fatty acids (Lytle et al., 1990; Gambi et al., 1994; Olive, 1999).

This investigation deals with the macrobenthos of the subtidal sediment off Paradip, a extremely important but least known area, as far as benthic ecology is concerned. Since polychaetes formed a major portion of the macrobenthos and shown high species diversity, it was decided to describe the distribution, abundance and diversity of this dominant and vital community in relation to the environmental conditions. In addition to the rich dimersal fishery, the well-known turtle breeding ground "*Gahirmatha*", is also located in close vicinity of Paradip harbour and the near shore waters of Paradip are recognized as nursery grounds of two important keystone marine species viz, Olive ridley (Annon, 1998) and horseshoe crab, *Tachypleus gigas* (Chatterji et al., 1992). In spite of this, the industrial development around Paradip is going with towering speed and effluents from the growing industries, domestic, harbour activities are threatening the marine life. Accordingly, a detailed investigation was conducted on the subtidal benthic community structure to identify the indicator macro-invertebrate species that can be used in future environmental monitoring programmes.

#### MATERIALS AND METHODS :

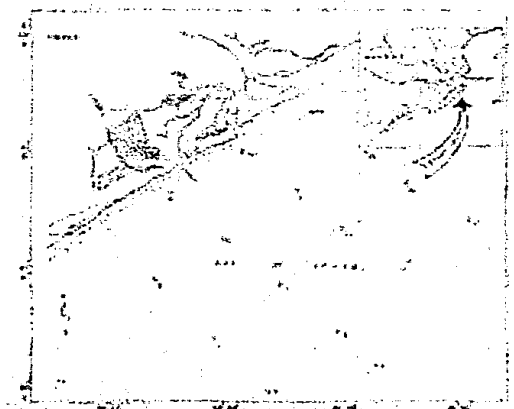


Fig. 1: Location of the sampling stations in the coastal waters of Paradip.

**Study area:** The study area is located on the open coast in the southwest direction of Paradip harbour between latitude 20°05'-20°17'N; longitude 86°35'-86°60'E (Fig. 1). It falls almost in the center of the coastal periphery of the Mahanadi delta. This area has a warm and humid climate and experience precipitation from two monsoons in a year viz., the southwest or summer (June-September) and northeast or winter (October-January). The average annual rainfall is 1500-mm. During summer-monsoon, the winds attain speeds up to 40km/hr and winter about 20 km/hr. During northeast monsoon, wind speed reaches up to 160 km/hr influenced by cyclones. Frequently the summer-monsoon period witnesses significant wave action along the coast resulting in littoral drift. The average water temperature during summer is 28°-30°C and the winter temperature between 20°-23°C. The river Mahanadi meets the Bay of Bengal at the north of the study area and discharges the seasonal freshwater laden sediment load around the study area. According to Konhauser et al., (1997) transport of bedload is higher during the monsoon episodes. Sediments are predominantly sandy comprised of fine-grained silt and clay. The topography of the area is steeply sloping towards the deeper depths and depicts a steep gradient.

**Bottom water sampling:** The spatial distribution of temperature in the water column was studied at several locations in the sampling area with CTD profiles (Anon, 1998). The bottom water samples were collected from selected stations for salinity, pH and dissolved oxygen, with the help of 5-liter Niskin sampler. The salinity and dissolved oxygen were estimated in field laboratory, according to Parsons et al., (1984).

**Field sampling:** A total of 17 stations were sampled in the depth zone of 10 to 30 meters. The deepest station (st.4) was about »8 km away from the harbour in S-W direction. Each station was sampled thrice covering three seasons from June 1996 to January 1997. Geographical position of the sites, water depth, sediment

characteristics are given in Table 1. Deploying a Van Veen grab (0.04 m<sup>2</sup> area) collected sediment samples (in triplicate). For macrofauna, sediment samples were washed through 0.5-mm mesh size sieve and preserved in 10% seawater formalin containing Rosebengal stain. A small portion of sediment was removed from each sample with an acrylic core liner (4.5-cm diameter) for the analysis of organic carbon and sediment texture.

**Laboratory analysis:** In the laboratory, macrofaunal samples were again washed through 0.5-mm mesh sieve in running water, to clear the adhering sediment. All stained organisms sorted from the samples were preserved in 90% alcohol, identified to the species level and enumerated. Species level identification was based primarily on the keys of Fauvel (1932), Gosner (1971), Parulekar (1972) and Day (1973).

**Sediment texture:** For sediment analysis, about 15 - 20-g (depending upon the fine material present) sediment was removed from each grab sample with 4.5-cm diameter core liner. The sediment was repeatedly washed in distilled water until all the chloride ions detectable with 4% silver nitrate were removed. These samples were treated with 10% sodium hexametaphosphate and kept overnight for dispersion before being subjected to grain size analysis (Folk, 1968). Sediment organic carbon was estimated by following the method of El Wakeel and Riley (1956).

**Data processing:** All the data was analyzed following the standard method described by Clarke (1993) and Clarke and Warwick (1994) using the PRIMER (Plymouth Routine in Multivariate Ecological Research) software package and after square root transformation. The univariate measures such as Shanon – Wiener diversity index ( $H'$ ), species richness (Margalef  $d$ ) and evenness ( $J'$ ) were also calculated. The polychaete fauna was subjected to multidimensional scaling (MDS) ordination and cluster analysis. Ordination of all environmental data and those variables, which gave the best

Table 1: Geographical position and sediment characteristics of the sampling stations.

Sr.No.	Geographical position			Sediment characteristics			
	Latitude (N)	Longitude (E)	Depth (m)	Texture	Sand (%)	Silt and Clay (%)	O.C. (%)
1	20°11' 80'	86°35' 00'	16	Fine sand	88.4	11.6	0.76
2	20°09' 71'	86°37' 10'	20	Fine clay	3.95	96.05	0.8
3	20°07' 30'	86°39' 60'	24	Fine clay	9.4	90.6	2.18
4	20°05' 01'	86°41' 70'	30	Coarse Sand	86.5	13.5	0.9
5	20°13' 20'	86°37' 60'	16	Fine sand	98.3	1.7	0.96
6	20°11' 40'	86°39' 90'	15	Fine clay	7.3	92.7	2.9
7	20°09' 40'	86°42' 20'	24	Sandy clay	87.4	12.6	1.88
8	20°07' 50'	86°44' 70'	26	Coarse Sand	93.8	6.2	0.88
9	20°06' 10'	86°46' 40'	30	Fine clay	2.95	97.05	2.85
10	20°14' 90'	86°40' 86'	13	Silty clay	7.2	92.8	2.84
11	20°13' 30'	86°43' 10'	19	Sandy clay	97.4	2.6	1.29
12	20°11' 90'	86°45' 00'	20	Fine sand	90.8	9.2	0.86
13	20°10' 00'	86°47' 60'	26	Fine clay	5.7	94.3	2.6
14	20°16' 70'	86°43' 60'	10	Fine sand	87.9	12.1	1.2
15	20°15' 00'	86°46' 10'	20	Fine sand	92.9	7.1	0.96
16	20°13' 80'	86°47' 80'	24	Fine clay	2.8	97.2	2.18
17	20°12' 00'	86°50' 50'	24	Fine sand	96.2	3.8	0.88

correlation with the polychaete data, were carried out using correlation based principal component analysis (PCA). Variations in the diversity index at shallow and deeper sites were analyzed using two-way ANOVA. To study the faunal dominance of individual species a "Biological Index of Dominance" (BID) was computed using data on abundance of each species (no. of individuals) and frequency of occurrence in each sample (Ristich et al., 1977). The ten most abundant species in the sample (three replicates pooled) at each site were ranked from 1 to 10, with the most abundant species acquiring the highest (i.e., 10) rank. The rank of each species at each site

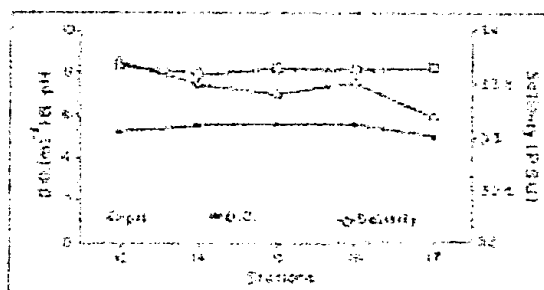


Fig. 2: Environmental parameters studied at selected stations.

was then summed to give an overall 'Biological Index of Dominance'. Correlation was sought between the biotic parameters (number of

species, number of specimens, diversity index) with the abiotic ones (sampling depth, substrate type).

**RESULTS:**

**Environmental setting:** The sea surface temperature in coastal waters of Paradip varies between 25°-29°C. Maximum temperatures were noticed during June and minimum during January. Generally, the near surface cold water (27.9°C) was recorded close to the coast and warm waters (29°C) in the offshore region. Vertically, the temperature gradient was very minimum due to intermixing (Anon, 1998). Salinity distribution showed high saline waters (33.7 PSU) close to the coast (st.10) and low saline waters (33.2 PSU) in the offshore region (st. 17, Fig.2). The values varied between 33.2 to 33.7 PSU (mean=33.5 ± 0.18). pH of the bottom water varied from 7.9 to 8.3 (mean = 8.12 ± 0.15). Dissolved oxygen (DO) in bottom waters showed less fluctuation and the values ranged from 5.0 to 5.6 ml<sup>-1</sup> (mean=5.36±0.27 SD, Fig.2).

**Sediment texture and organic carbon content:** The sediment from the coastal waters of Paradip was predominantly of fine-to-very fine particles at most of the sampling stations. However, coastal stations had higher content of sand whereas offshore, deeper stations had high content of silt and clay. The percentage of sand particles varied from 2.80% to 98.3% (mean = 56.41 ± 43.95, Table 1) and silt-clay fraction varied from 1.70% to 97.2% (mean = 43.59 ± 43.90) during June 1996. The substratum at the near-shore stations, especially in the vicinity of Paradip harbour was muddy, black in color (due to the unloading of the coal) with high content of silt. In deeper waters (>20-m), the sediment was of fine grain size.

Organic carbon in the sediment varied from 0.76% to 2.90% (mean = 1.59± 0.85). Sandy sediments had low organic carbon content whereas, salty sediments showed relatively higher values of organic carbon (Table 1).

Table 2: Abundance of macrobenthos (nos. m<sup>-2</sup> and biomass g. (wet.wt) m<sup>-2</sup> mean of three replicates) in the subtidal sediments off Paradip.

Sr. No.	Sampling season					
	Jun-96		Nov-96		Jan-97	
	Densit	Biomass	Density	Biomass	Density	Biomass
1	2500	10.5	***	***	5650	18.25
2	4425	12.9	***	***	2505	8.82
3	1996	6.96	6595	21.2	4595	16.18
4	4100	13.5	***	***	3388	11.92
5	2975	9.73	5500	17.38	4395	15.47
6	***	***	1955	6.88	3225	11.35
7	2925	7.61	1980	6.97	12600	37.8
8	1500	11.1	3118	10.6	5825	20.5
9	2150	8.15	4098	14.2	11625	33.87
10	6050	22.3	2275	8.01	5090	17.9
11	***	***	4725	16.23	13950	40.76
12	2775	12.2	1175	4.14	7975	23.06
13	2300	8.8	4350	15.31	8050	24.33
14	***	***	1125	3.96	2960	10.42
15	2150	7.8	5400	19	6776	23.83
16	2575	9.17	2925	10.23	11550	30.26
17	***	***	4025	14.17	6150	19.6
Mean	2956	10.83	3517.58	12.02	6841.7	21.43

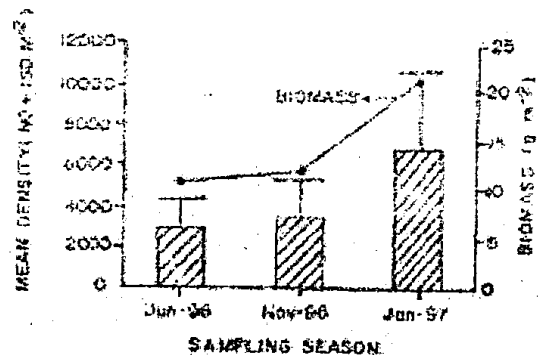


Fig. 3: Mean density and biomass of macrofauna during three sampling seasons.

\*\*\*: Indicates that sediment sampling was not possible due to rough sea-conditions.

Although no distinct distributional pattern was discernable in the organic carbon, sediment samples from deeper stations (20-30 m depth) had relatively higher (> 2.0%) content of organic carbon (except station 10 located in the harbour) as compared to other stations. Although st. 10

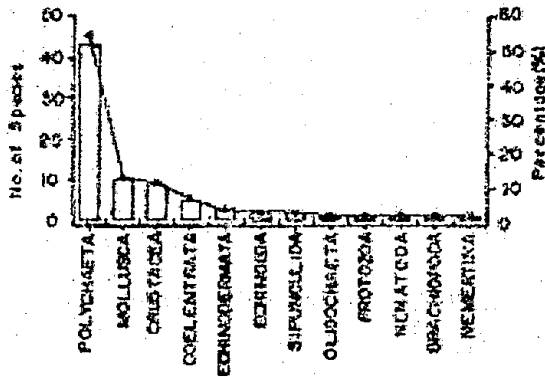


Fig. 4: Major macrobenthic taxon and total number of species.

was located in the shallower depth (13m), it had higher value (2.85%) organic carbon.

Composition and abundance of macrofauna: A total of 79-macroinvertebrate species belonging to 13 phyla and 45 families were recorded. Data on the abundance of benthic fauna (density and biomass) at all the sampling stations is presented in Table 2. The fauna mainly composed of polychaetes (41.3%) belonging to Spionidae, Glyceridae, Nereidae and Sabellidae. Crustacea (20.6%) was represented by Decapoda, Isopoda, Amphipoda and Cumacea. Mollusca (15.4%), echiurid worms (7.2%) and Echinodermata (2.7%) were the other major faunal groups (Fig.3). The other miscellaneous forms included Sipunculida, Brachiopoda, Coelenterata, Nemertina and Nematoda. These together formed 12.8 % of the total faunal composition. The most important in terms of total number of species was Polychaeta (43 species, Fig. 3) followed by Mollusca (10 spp.) and Crustacea (09 spp.).

As depicted in Fig.4, faunal composition and abundance differed considerably between the seasons. The population density of macrofauna varied from 1500 to 6050 nos. per m<sup>2</sup> (mean=2955 ±1231; n=13) during southwest monsoon (June 1996) and 2509 to 13950 nos. per m<sup>2</sup> (mean=5341.±3317;n=31) during northeast monsoon (November 1996 and January 1997)

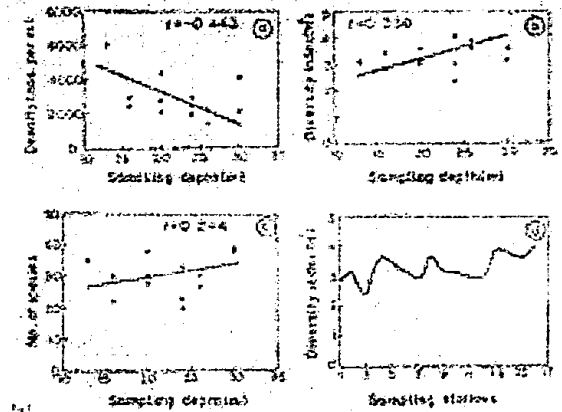


Fig. 5: Correlation between macrofaunal diversity, no. of species and sampling depth.

season. The polychaetes and small crustaceans (amphipods, isopods, tanaids, cumaceans and pycnogonids) mainly contributed to the increased population density. The macrobenthic biomass (wet wt.) fluctuated between 3.96 to 28.30 g.m<sup>-2</sup> with an overall annual average of 13.45±6.10 g.m<sup>-2</sup> (n=44). The maximum biomass was recorded during January 1997 at st. 13 located in intermediate water depths (26m), whereas the minimum biomass of 3.96 g.m<sup>-2</sup> was observed at st.14 during November 1996. Among the three sampling seasons, maximum mean benthic standing stock (density=4645 nos.m<sup>-2</sup> and biomass=16.35 g.m<sup>-2</sup>) was observed in January 1997 (Fig. 4), indicating that northeast monsoon was more favorable for colonization of subtidal macrobenthos. The faunal density (nos.m<sup>-2</sup>) and species diversity (number of species per station) were relatively higher at near-shore stations (sts. 3, 10 and 11) located between 13-24m water depths.

Macrobenthic diversity: As shown in figure 5, sts. 8, 13 and 16 dominated in terms of species diversity (*H'*) and species richness (SR). The values for *H'* varied between 2.37 and 4.09 (mean = 3.31 ± 0.47; n=13) and poorly correlated with water depth (r=0.338;n=13, Fig. 5d). The values for macrofaunal diversity and species richness differed between the sampling stations (Table 3). The highest macrobenthic diversity

Table 3: Diversity indices of macrofauna from the subtidal sediment off Paradip.

Sr. No.	No. of	Diversity (H')	Evenness (J)
	Species		
1	22	3.69	1.91
2	38	4.5	2.35
3	20	3.68	1.91
4	38	4.48	2.32
5	30	3.73	1.9
6	26	3.92	1.65
7	23	3.67	1.94
8	27	4.38	2.27
9	39	4.53	2.41
11	24	3.22	1.8
10	35	4.12	2.14
12	28	4.17	2.16
13	30	4.22	2.19
15	30	4.33	2.25
16	33	4.24	2.2
17	37	4.35	2.11

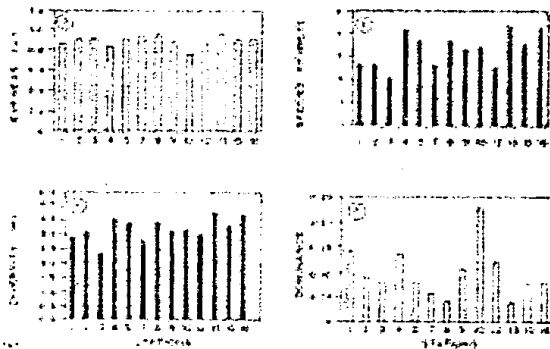


Fig. 6: Index of diversity, evenness, dominance and species richness for polychaete species.

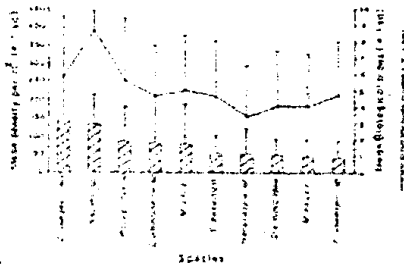


Fig. 7: Mean biological index of dominance (BID) and mean density of 10 top ranked polychaete species.

( $H' = 4.53$ ) and evenness ( $J = 2.41$ ) was registered at station 9 located at 30-m water depth. The values for species dominance ( $D$ ) showed greater variation among the sampling stations. As shown in figure 5, there was a poor correlation between species richness and water depth ( $r = 0.244; n = 13$ , Fig. 5c). Although, the biodiversity peak (39 species) was at the deepest station (st. 9), however, if the contribution of each faunal group is calculated, a percentage proportion of each group at each station was relatively constant.

Distribution, dominance and diversity of Polychaeta: Polychaeta was by far the most abundant in terms of number of species. Total 43 species belonging to 20 polychaete genera were identified from the subtidal sediment (Fig. 3). The most important species in terms of "Biological Index of Dominance" (BID) was *Nephtys sp.*, whereas *Cossura longocirrata* was the most abundant. Both these species had wider distributional range and contributed over 27% to the polychaete density. The mean BID calculated for 10 top ranked species is presented in figure 7. Having BID value of  $8.61 \pm 1.19$  and 100% occurrence, *Nephtys sp.* was top ranked followed by *C. longocirrata* with 84.6% occurrence and BID value of  $6.2 \pm 0.00$ . Other species occurring with higher frequency (>50%) and higher BID (>3) were *Polycirrus eximius*, *Lumbrinereis sp.*, *Maldane sarsi*, *Streblospio benedicti*, *Heterospio sp.*, *Sternaspidae*, and *Magelona rosea* (Table 4; Fig. 7). The population density of polychaete varied between 275 to 3250 nos.m<sup>2</sup> (mean =  $1009.6 \pm 747.8$  n=44) with maximum abundance at station 10. The values for Shannon diversity ( $H'$ ) varied from 1.95 to 2.78 (mean =  $3.24 \pm 0.41$ ; n=13). Maximum  $H'$  and  $J$  values were recorded at station 16, 7 (Fig.6) whereas, species dominance varied between 0.04 to 0.23 (mean =  $0.16 \pm 0.24$ ) and maximum  $J$  value being at station 10 located at shallower depth, in the entrance of harbour. Data on the macrobenthic biomass (wet wt.) was subjected for PCA analysis. A PCA plot in figure 8 divided the sampling locations in to two discrete groups. All the sampling stations,

Table 4: Abundance (number per m<sup>2</sup>) of polychaete species in the coastal sediment of Paradip studied during May 1996.

Genus/Species	Mean	± Sd	Occurrence	Frequency
			(%)	(%)
<i>Cossura longocirrata</i> Webster & Benedict 1887	142.31	285.61	14.09	84.6
<i>Nephtys</i> sp.	132.69	74.93	13.14	100
<i>Polycirrus eximius</i> (Leidy) 1855	84.61	87.45	8.38	77
<i>Lumbrinereis</i> sp.	80.77	142.83	8	61.5
<i>Maldane sarsi</i> Malmgren 1865	78.85	94.49	7.81	77
<i>Heterospio</i> sp.	50	75.96	4.95	69.2
<i>Streblospio benedicti</i> Webster 1879	50	50	4.95	77
<i>Sternaspidae</i>	46.15	41.43	4.57	69.2
<i>Magelona rosea</i> Moore 1907	44.23	29.67	4.38	77
<i>Prionospio</i> sp.	40.38	49.56	4	23.1
<i>Cirriformia filigera</i> (delle Chiaje) 1828	34.62	33.31	3.43	61.5
<i>Lacydoniidae</i>	26.92	54.12	2.66	30.8
<i>Dodecaceria</i> sp.	23.08	40.98	2.28	30.7
<i>Hypaniola grayi</i> Pettibone 1953	21.15	35.15	2.09	38.5
<i>Goniada</i> sp.	17.31	15.14	1.71	61.5
<i>Prionospio pinnata</i> Ehlers 1901	15.38	39.88	1.52	61.5
<i>Pisionidae</i>	15.38	31.83	1.52	23.1
<i>Aglaophamus</i> sp.	11.54	39.97	1.14	7.7
<i>Nereidae</i>	9.62	18.45	0.95	23.1
<i>Lysaretidae</i>	7.69	20.53	0.76	15.4
<i>Polycirrus</i> sp.	7.69	15.14	0.76	23.1
<i>Tomopteris</i> sp.	5.77	14.39	0.57	15.4
<i>Syllidae</i>	5.77	14.39	0.57	15.4
<i>Travisia carnea</i> Verrill 1873	5.77	10.53	0.57	23.1
<i>Poecilochaetidae</i>	5.77	10.53	0.57	23.1
<i>Eteone flava</i> (Fabricius) 1780	3.85	13.32	0.38	15.4
<i>Eteone trilineata</i> Webster and Benedict	3.85	13.32	0.38	15.4
<i>Glycera capitata</i> Oersted 1843	3.85	13.32	0.38	7.7
<i>Hyalinoecia tubicola</i> (Mueller) 1776	3.85	13.32	0.38	7.7
<i>Fabricia sabella</i> (Ehrenbera) 1837	3.85	9.02	0.38	15.4
<i>Amphitrite cirrata</i> Mueller 1771	3.85	9.02	0.38	15.4
<i>Nephtys picta</i> Ehlers 1913	1.92	6.66	0.19	7.7
<i>Paralacydonia paradoxa</i> Fauvel 1913	1.92	6.66	0.19	7.7
<i>Maldanopsis elongata</i> (Verrill) 1873	1.92	6.66	0.19	7.7
<i>Myriochele heeri</i> Malmgren 1867	1.92	6.66	0.19	7.7
<i>Axiiothella</i> sp.	1.92	6.66	0.19	7.7
<i>Scololepis</i> sp.	1.92	6.66	0.19	7.7
<i>Eunice</i> sp.	1.92	6.66	0.19	7.7
<i>Goniadella</i> sp.	1.92	6.66	0.19	7.7
<i>Sabellaria vulgaris</i> Verrill 1873	1.92	6.66	0.19	7.7
<i>Apistobranchidae</i>	1.92	6.66	0.19	7.7
<i>Sigalionidae</i>	1.92	6.66	0.19	7.7
<i>Isopilidae</i>	1.92	6.66	0.19	7.7



Table 5: Correlation matrix between the biotic parameters (density, biomass No. of species, diversity indices) with the abiotic ones (sampling depth, substrate type).

	Depth	No. Spp.	Diversity	Evenness	Density	Biomass	Sand	Silt & Clay	O.C.
Depth	—								
No.	0.244	—							
Diversity	0.338	0.817***	—						
Evenness	0.355	0.803***	0.996***	—					
Density	-0.443*	0.599**	0.102	0.108	—				
Biomass	-0.469*	0.419*	0.194	0.184	0.864***	—			
Sand	-0.286	-0.369	-0.277	-0.295	-0.239	-0.133	—		
Silt & Clay	0.286	0.369	0.277	0.295	0.239	0.133	-1	—	
O.C.	0.23	0.155	0.036	0.059	0.119	0.072	-0.745***	0.745***	—

\* p<0.1; \*\*:p<0.05; \*\*\* p<0.001 significance, (O.C.: organic carbon).

except st. 9 and 10, formed a single cluster, while, st. 9 and 10 were placed far away from rest of sampling sites. Off which st. 9 was located at deeper depth whereas st. 10 was located with in the harbour.

**DISCUSSION :**

The study area demonstrated high diversity of macrobenthic communities and the highest group diversity being those of polychaetes. It can be shown in Fig. 5, the number of species (species richness) and index of diversity ( $H'$ ) increased corresponding to the increase in water depth of the sampling station, however, the correlation was rather weak ( $r=0.338;n=13$  Fig.5b). The variation of diversity index presented in Fig.6c shows higher polychaete diversity at deeper stations, located in the offshore region (Sr. 4,13 and16, Table 3) whereas species dominance was very prominent at shallower station (#10). This was largely due to the dominance of polychaetes, which are known to adapt as  $r$  or  $k$  selected strategies to different gradients of environmental pollution (Pocklington, et al., 1992;Grall and Glemarec, 1997). A comparison of diversity values between <20-m water depth and >20-m water depth also revealed significant variation (One-way ANOVA  $F=6.733$ ;

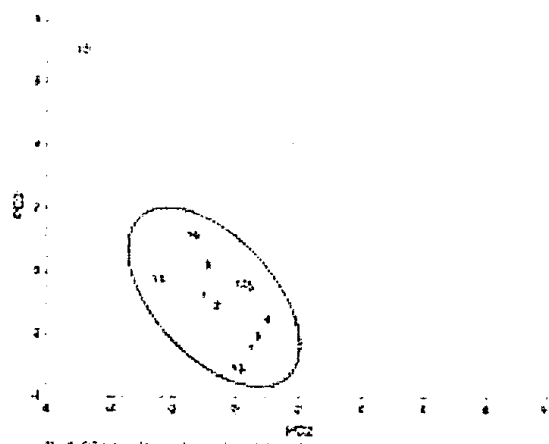


Fig.8: PCA for different sampling stations based on the macrobenthic biomass

Fig.8: Principal component analysis for different sampling stations based on the macrobenthic biomass

$p<0.01, df=5$ ) indicating that offshore areas between 20-40m off Paradip harbour provide better conditions for benthic colonization. Similar results have been reported from Southern Irish Sea where, gravelly sediment in the offshore area was responsible for higher polychaete diversity (Mackie et al., 1997). On the other hand, as might be expected, the abundance of benthic fauna (population density) showed negative correlation with the sampling depth ( $r= -0.443;p<0.01$ ; Table 5). The near-shore (north portion of the study

site) area is dredged regularly to maintain the water depth of navigational channel, causing occasional disturbance to the seabed. In addition to this, the nearby industrial establishments also release their effluents in this area. Further, seasonal discharge of freshwater laden sediment around this area, especially from the Mahanadi River, may disturb the benthic communities occasionally. Hence, the level of pollution and disturbance could be much higher in the near-shore area as compared to the offshore deeper stations. Therefore, the ongoing labor as well as other anthropogenic activities were mainly responsible for reduced benthic diversity at near shore stations.

In general, the substratum in deeper water is less subjected to wave action, thus providing better and stable environment for survival and colonization of different benthic communities (Gage, 1996; Mackie et al., 1997; Gray, et al., 1997). This was very clear from two-way ANOVA between number of species and water depth, which exhibited highly significant variation between the shallow (<20-m depth) and deeper (>20-m depth) sampling area ( $F=0.826$ ;  $p<0.001$ ;  $df=5$ ). Further, the positive correlation between water depth and diversity index ( $H'$ ) (Fig.5) also support the earlier views that deeper waters harbor higher diversities. The higher abundance (density and biomass) of macrofauna at shallower depth (near-shore stations except #10) was mainly due to the dominance of polychaetes. A PCA plot shown in figure, 8 is clearly interpretable as it divided the sampling locations in to two different clusters. All the sampling stations, except st. 9 and 10, formed a single cluster, while, st. 9 and 10 were placed far away from rest of sampling sites. Thus, it clearly suggests that benthic community at st. 9 and 10 were different from rest of the study area (Grall and Glemarec, 1997; Harvey et al., 1998), and perhaps was influenced by the various anthropogenic activities. In addition to higher organic carbon, the nearshore, shallow waters may contain greater amount of aquatic macrophytes and shell

debris, thereby increasing habitat complexity (Castel et al., 1989). Diversity indices presented in figure show that dominance was higher at stn 10. High abundance *C. longocirrata*, which is known to dominate the polychaete assemblages (Hilbig and Blake, 1998) at st. 10, signifies that the proliferation of polychaete communities in inshore waters of Paradip were mainly because the fauna was comprised of the species which were capable of exploiting the prevailing benthic conditions.

Among the physical parameter temperature, salinity and nature of the substrate are considered to be the most significant in regulating the distribution and abundance of benthic fauna (Margaret and Potter, 1996; Ingole and Parulekar, 1998). The distribution of temperature and salinity in the coastal waters of Paradip (study area) indicate very little vertical gradient, due to intensive vertical mixing brought out by the strong monsoon winds (Hacker et al., 1998). Sediment along the Paradip coast is heterogeneous having base of sandy-mud, represented by fine sand particles, and decayed wood, dead molluscan shells and silt-clay. A strong positive correlation between the organic carbon and silt-clay fraction ( $r=0.745$ ;  $p<0.001$ ;  $n=13$ , Table 5) indicate that subtidal sediments off Paradip coast are very productive and support a very rich demersal fishery (John and Sudarsan 1990). Since the clay content of the sediment determine the relative amount of biomass (Sanders, 1958), the sedimentary conditions off Paradip can be considered as stable that can provide a large number of species richness for macrofaunal colonization (Sanders, 1958; McArthur, 1965).

Out of 20 tops ranked polychaete species, *Nephtys sp.*, was the important species in terms of "Biological Index of Dominance" (BID), whereas *Cossura longocirrata* was the most abundant. Both these species had wider distribution range and contributed over 27% to the polychaete density. A typical opportunistic *C. longocirrata* has worldwide distribution,

occurring in temperate (Gagaev, 1996; Wlodarska-kowalczyk et al., 1998) as well as tropical waters (Rosenfeldt, 1989) and is known to dominate the polychaete assemblages (Olsgard and Hasle, 1993; Hilbig and Blake, 1998). Further, the Cossuridae family has been recognized as indicator species in estuarine pollution studies (Harvey et al., 1998). Even though, the present study was not intended to examine the environmental health, higher abundance of *C. longocirrata* in near shore sediments (#10), certainly sets alarming signal towards the deteriorating benthic conditions along the Paradip coast.

In conclusion, the high abundance and diversity of macrofauna in the subtidal sediment of Paradip is a result of seabed heterogeneity and the sediment texture could be the major factor dictating the abundance of benthos. It shows that while; the diversity increased towards offshore the density of macrofauna decreased gradually towards offshore. The contribution of polychaetes in soft sediment macrofauna was almost 50%. The polychaetes, echiurid worms and small crustaceans form main food items of demersal fish along the Orissa coast (Philip, 1998). Since demersal fish stock account for  $\geq 59\%$  of the total marine fish production along the Orissa-West Bengal coast (John and Sudarsan, 1990) therefore, the dominance of polychaetes and small crustaceans in the benthic samples may contribute for high benthic biomass, which can support the good demersal fishery of the region. The super cyclone hit Orissa coast near Paradip on 29 October 1999. It created havoc in the coastal Orissa, with wave heights reaching to tens of meters association with very strong winds (~300-mk/h speed) and damaged the coastal ecology to the great extent. Since the sampling for present study was conducted prior to the 'Super Cyclone' that altered the sedimentary conditions off Paradip, the information on subtidal macro-invertebrates provided here therefore, gained significant importance and may act as a baseline for future studies. Furthermore, the

baseline data sets, such as the present one, has been considered as fundamental in evaluating the impact of natural disaster, such as "cyclone and tsunami" on the coastal and near shore ecology (Altaff et al., 2005). In addition, it could be useful in monitoring the coastal marine pollution levels and predicting its impact on coastal fisheries. The multivariate techniques such as diversity indices and PCA were found to be simple and effective statistical tools to distinguish different ecological habitat.

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