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Full Length Research Paper

Macrobenthos of shelf zone off Dhamara estuary, Bay of Bengal

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The present study is an attempt to know the status of the macrobenthos at the shelf region off Dhamara Estuary. A total of 1870 individulas per square meter of macrobenthic organisms were encountered during the study period. Population density and species diversity was found to be higher as depth increased. Polychaeta emerged as dominate macrobenthic group. Among dominant benthic macroinvertebrates *Nereis*, *Nepthys*, *Capitella*, *Owennia*, *Prionospio*, *Gammarus*, *Ampelisca*, *Tellina*, *Donax*, *Dentallium*, *Echinus* etc were predominant in the study region. Environmental parameters like salinity, pH and dissolved oxygen exhibited strong correlation with population density of macrobenthic organisms. Factors 1 and 2 pooled from principal component analysis represented 64.09% of the total variability. The noteworthy aspect of the present study is higher value of population density marked at deeper regions with heterogeneous sediment than shallow depth.

Key words: Shelf region macrobenthos, correlation coefficient, PCA.

INTRODUCTION

Ocean covers about 71% of the earth's surface and is covered by continental land mass. A continental shelf is the moderately shallow region of seabed surrounding a continent which could be extended away from the exclusive economic zone (EEZ) measuring about 200 nautical miles (360 km) from the shoreline. In tropical regions, the continental shelf zone covers about 30% of the total geographical area and 40% of open sea (Alongi, 1990). These regions are the most productive areas in the world for vast exploitable fishery and petroleum hydrocarbon resource hence supports the socio-economic condition of the country.

In recent days, the stress over the continental shelf region is found to be higher due to over-fishing, excessive bottom trawling for demersal fishery, dredging activities, drilling operations for exploration of petroleum hydrocarbon and natural gas resources including accidental and occasional seepage of oil and natural gas from ships and cargo vessels etc. Other anthropogenic influence from radioactive pollutants, heavy metals, pesticides, insecticides, hydrocarbons, PPEs, toxic chemicals are also adding additional stress to this highly productive ecosystem.

Therefore, it is the need of the hour to monitor the status or health of such sensitive ecosystem using suitable indicator. Macrobenthic organisms are well known indicator of environmental stress due to their sedentary habitat (Dauer and Corner, 1980). They posses active participation in benthic-pelagic trophic relation (Boesch et al., 1977; Simboura et al., 1995) and shows direct link with other organisms of higher trophic groups in marine food web (Snelgrove, 1998). Snelgrove (1998) highlighted regarding the noteworthy features of benthic macroinvertebrates like significant contribution towards metabolism of pollutants, nutrient cycling,

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Abbreviation: PD, Population density (Number per square meter) salinity (ppt); **DO,** dissolved oxygen (mg/L); **WT,** water temperature (℃); **D,** dominance; **H',** shannon's diversity index; **J,** evenness; **d,** Margalef's species richness.

dispersion metabolism etc while Gerlach (1978) and McIntyre (1977) stated that benthic organisms provide food for larger epibenthic fauna. The feeding habits of demersal fishes is largely depended on benthic organisms as the chief source of nourishment (Ansari et al., 1977), while Parulekar et al. (1982) strongly argued to use them as a basic tool to access demersal fishery resource.

The shelf region of Bay of Bengal provides exploitable pelagic and demersal fishery resource. Thus, it needs to be monitored as priority basis. Benthic research in the shelf region of Bay of Bengal is few (Harkantra et al., 1982; Mahapatro, 2006) as compared with the shelf region of Arabian Sea of west coast of india (Parulekar and Wagh, 1975; Parulekar et al., 1976; Harkantra et al., 1980; Joydas and Damodaran, 2001; Joydas, 2002; Joydas and Damodaran 2009; Jayaraj et al., 2007, 2008).

The main objective of the present study was to provide comprehensive information regarding the status of benthic macroinvertebrates along with sediment texture analysis and physico-chemical parameters affecting significantly different macrobenthic groups of the continental shelf zone of north East Bay of Bengal, off Dhamara Estuary.

MATERIALS AND METHODS

Study area

The Bay of Bengal is as highly influenced by tropical climate and regarded as the 64th large marine ecosystems (LME) in the world. It measured as moderately productive (Class II) type of LME, that is, 150 to 300 g of carbon is produced per square meter per year located at 6°N and 80° E to 22°N and 80° 94°E (Mark, 2010). The Bay is situated at the monsoon belt and thus receives high fresh water from rainfall and discharges from major river systems (Dwivedi, 1993; Aziz et al., 1998). Recent seismic surveys indicated the presence of hydrocarbon deposits in the sea bed of Bay of Bengal over 300,000 km^2 area. The continental shelf region off Dhamara Estuary of Bay of Bengal falls in that region where the petroleum hydrocarbon deposit was noticed. Therefore the present study area confides to the shelf region off Dhamara Estuary.

Dhamara Estuary is located at 20° 80' North and 86^o 90' East. Four stations were named as D1, D2, D3, and D4 straight to the offshore region from the Dhamara River Estuary (Figure 1) and positioned by GPS. The sampling stations were located at a depth range from 20 to 60 m. Dhamara Estuary is the integral part of the Bhitarkanika mangrove forest and Gahirmatha sea turtle rookery endowed with fragile sandy beaches. These beaches are well known for mass nesting activity of endangered olive ridley sea turtles (*Lepidochyles olivacea*). The shelf region off Dhamara Estuary is a potential fishing ground for both pelagic and demersal fishery.

Sampling periodicity

Three offshore cruises were carried out for collection of hydrological, biological and sediment parameters. The first cruise program was held in February 2005, the second and the third cruise was in March 2005 and in April 2005, respectively. The entire cruise program was carried out by the help of research vessel "Sagar Paschimi" provided by NIOT, Chennai, India.

Sampling methodology

Environmental parameters such as salinity (ppt), dissolved oxygen (mg/L), pH and water temperature (°C) were measured in duplicate from four stations during three cruise programs. All the hydrographical parameters were analyzed according to standard procedures given by Strickland and Parson (1972).

Sediment samples were collected in triplicate by the help of a grab sampler having surface area of 0.25 m^2. The first sample was kept for sediment texture analysis. The sediment texture analysis was made according to Krumbein and John (1938). Other two sediment samples were wet-sieved on-board through a sieve having mesh size of 0.5 mm (Birkett and McIntyre, 1971). The remains over the sieve were collected carefully and preserved in with 5 to 7% neutralized formalin-Rose Bengal-sea water mixture. Rose Bengal is a dye which makes the macrobenthic organisms red or pink in color, so that they can be easily collected from the sediment. The collected macrobenthic samples were identified to their possible lower taxonomic level and grouped into five major groups such as polychaetes, bivalves, gastropods, crustacea and others group. The others group contains the organisms belonging to nematodes, tardigrada, gastrotricha, echinoderms and the representatives of some minor phyla. The population density of macrobenthos was calculated by the counting of individual organisms collected per grab and then converted in to number per square meter area. Station wise relative abundance was carried by taking the mean values of all three cruises.

Statistical analysis

In order to find out significant relation between environmental parameters like salinity, pH, dissolved oxygen and water temperature with population density and some macrobenthic groups like polychaets, crustaceans, bivalves, gastropods with others group with sediment composition like, sand , silt and clay, the Pearson's correlation coefficient was calculated. Correlation coefficient measures the strength of a relationship between variables by putting emphasis on the degree to which mean value of the variables differ from each other. To further validate the findings of correlation analysis, principal component analysis (PCA) was also carried out. PCA is an important statistical tool which helps to get the relation between non-correlated factors which are in linear combinations of the original variables. This statistical tool helps to quickly visualize and analyze the possible correlations between N variables in a 2 dimensional space where N refers to number of variables. The statistical analysis was carried out by XLSTAT statistical software. To find out the community structure, univariate analyses were carried out to the biological data. The diversity indices studied were Margalef's species richness index 'd' (Margalef, 1968), Pielou's eveness index 'J'' (Pielou, 1966) , and the Shannon species diversity index 'H''(Shannon and Weaver, 1963) and species dominance 'D'. All these analysis were carried out by PRIMER (Plymouth Routines in Multivariate Ecological Research, Version 5) as proposed by Clarke and Warwick (1994).

RESULTS

Hydrographical analysis

In the present study, the higher value of salinity was

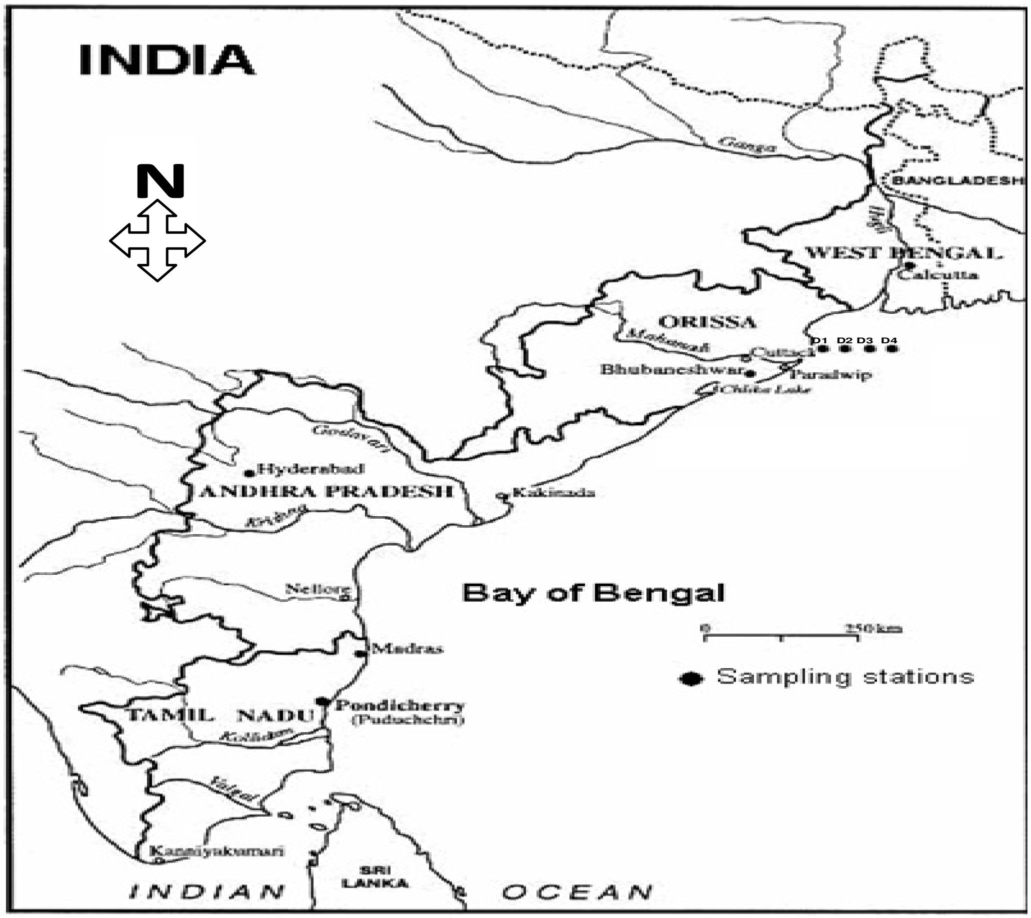

Figure 1. Explains India, Orissa state, Dhamara estuary and the sampling stations located at the northeastern region of Bay of Bengal. This region is becoming crucial for potential petroleum hydrocarbon resource.

observed in April 2005, that is, 35.09 ppt followed by March and lower at February 2005 having 31.4 ppt. Dissolved oxygen was found higher in April 2005 possessing 5.7 mg/L followed by February, 2005 (4.8 mg/L). Lower value was observed at March 2005 as 4.41 mg/L. pH value was higher at April 2005 (8.52) followed by March (8.28) and February 2005 (8.18). Water temperature was higher in April 2005 containing 29.8°C followed by March 27.8°C and February 2005 having 25.9°C. The mean and standard deviation of all environmental parameters are given in Table 1.

Diversity indices

The Shannon's diversity index H' was showed increasing trend as depth increases. The diversity value found higher during April 2005 possessed 2.75 followed by March (2.15) and lowest in February 2005 as 1.86. The dominance 'D' was found higher at February 2005 and lower at April 2005. Evenness J was higher in March 2005 followed by February 2005 and April 2005, while species richness was higher from February 2005 to April, 2005 (Table 1).

Sediment texture analysis

The results of sediment texture analysis are given in the Figure 2. During the study period, there was no great variation in the sediment. Broadly, the sediment can be categorized as mixed or heterogeneous type, that is, the combination of sand, silt and clay. During February 2005, lower content of clay fraction in the shelf sediment was marked and increased negligible towards April, 2005.

Population density

The population density of macrobenthos per station during three months is given in Figure 3 while the Figure 4 represented the mean and standard deviation at each station. In the first cruise program held on February, 2005, D2 showed higher values of macro benthic density

Table 1. Physico-chemical and diversity indices during February to April, 2005.

	February 2005		March 2005		April 2005	
Variables	**Mean**	**Std. dev**	**Mean**	**St. dev**	**Mean**	**St. dev**
PD	75	41.43	61.25	46.26	312.50	233.11
Salinity	31.94	0.65	33.55	0.00	35.09	0.61
pH	8.16	0.07	8.28	0.00	8.52	0.00
DO	4.8775	0.13	4.41	0.52	5.07	1.16
W.T.	25.9	1.4	27.8	0.5	29.5	1.2
D	0.2229	0.12	0.13	0.06	0.10	0.04
H'	1.863	0.51	2.15	0.52	2.75	0.36
J'	0.888	0.09	0.98	0.02	0.87	0.08
d	3.0088	1.13	3.68	1.38	5.95	1.63

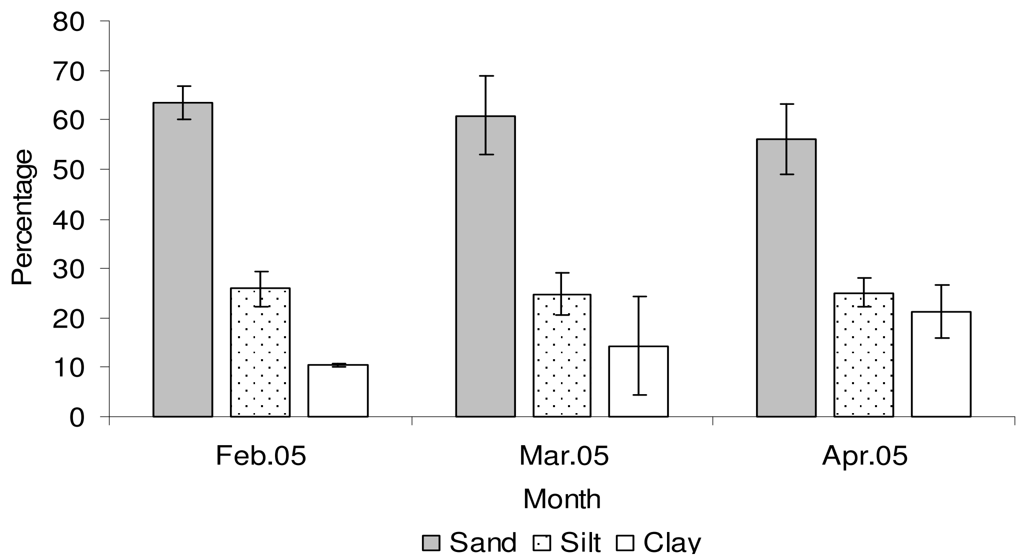

Figure 2. Mean values and standard deviation (error bars) of sand, silt and clay fraction within February to April, 2005.

while in the second cruise, it was D1. In third cruise program station, D4 showed highest values of macrobenthic density (Figure 4). The mean of population density observed during entire period was given in the Figure 5 which shows the mean value of macrobenthic density at first station D1 was 140±70.5) m^2, in D2 it was 108±58.3 m^2, in third station D3 it was 91±107.2 m^2 while in the last station D4, it was 258±349 m^2. Values in parenthesis showed standard deviation. The average population density per station was estimated as 149 No/m^2.

Relative abundance of macrobenthos

The relative abundance (mean) of macrobenthos at four stations is given in Figure 5. Among four stations, D1 showed polychaeta as the dominant group contributed 49% followed by D4 sharing 34%. In D2 and D3, the contribution of polychaeta was 20 and 22%, respectively. Crustacean become dominant in the First station D1 having 23% followed by D4 contributing 20% while low contribution was found at D2 and D3 having 3 and 6% respectively. Bivalves which showed highest contribution in D2 contributed 32% followed by D1 having 21%. D3 and D4 Possessed 16 and 8% only. Major contribution of gastropods was observed in D3 contributing 34% and lowest value at D1 sharing 1% only. The second station D2 and fourth station D4 showed equal contribution 28% to the total macrobenthic bulk. Other group exhibited major sharing at D3 having 22% followed by D2 17% followed by D4 10% and least values at D1 6% only.

Dominant macrobenthic organisms

Dominant macrobenthic organisms encountered during the study period were *Nereis*, *Nepthys*, *Goniada*, *Sabella*,

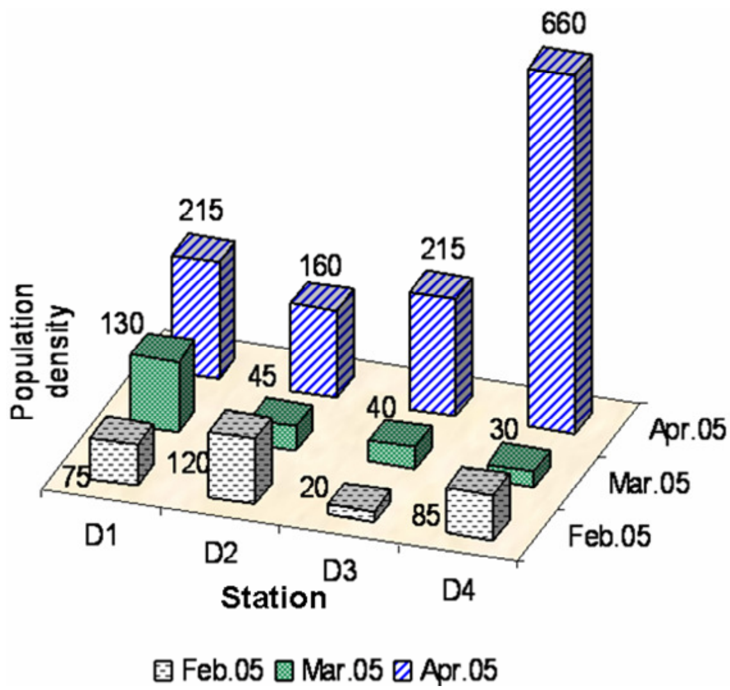

Figure 3. Population density of three months at different stations.

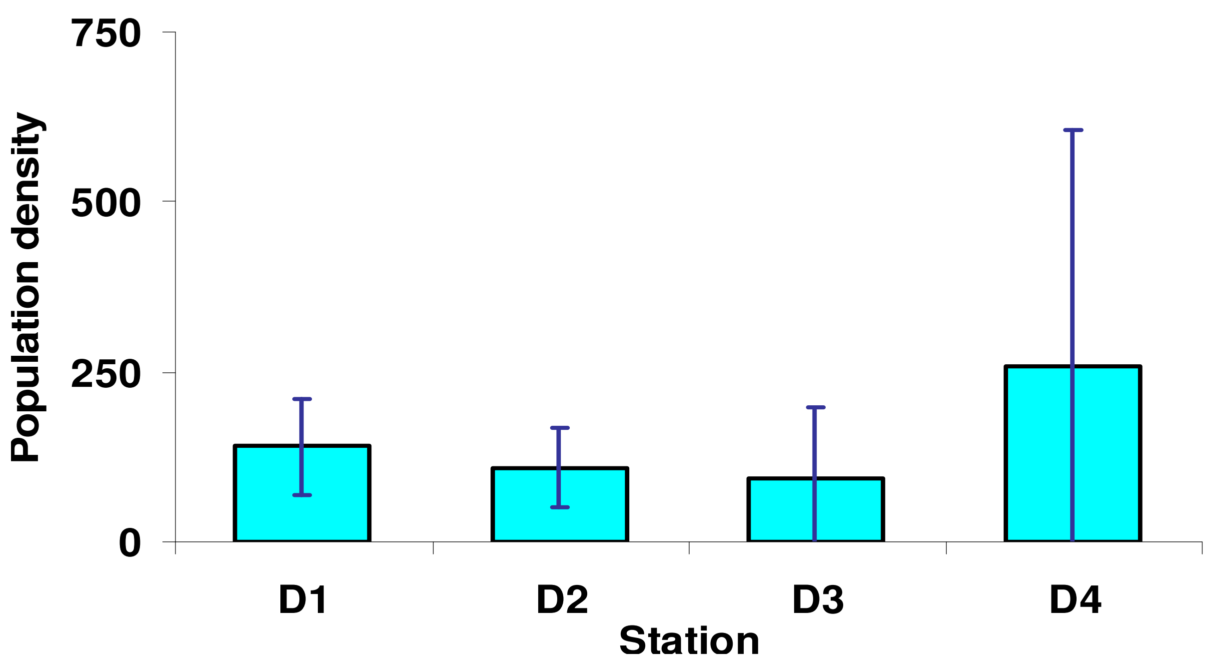

Figure 4. Mean and standard deviation of macrobenthic density at four satiations.

Clymenella, *Glycera*, *Myriochele*, *Phyllodoce*, *Cossura*, *Capitella*, *Axiothelaa*, *Owennia* from polychaeta group. Among bivalves, *Tellina*, *Donax*, *Thyasira*, *Tagelus*, *Anadora*, *Bathyarea*, etc. While among gastropods, the common species were *Apporahis*, *Buccinum*, *Hyanssa*. *Retusa*, *Dentallium*, *Bursa* etc. Crustacean representatives were dominated by gammarid amphipods, *Gammarus*, *Ampelisca* and *Ampithoe*, Harpecticoid copepod, stomatopods, *Echinus* (Sand dollar), Sipunculids, nematodes, Cumacea, Gastrotrichs, Tardigrada, etc. The images of macrobenthic organisms are given in Figure 8.

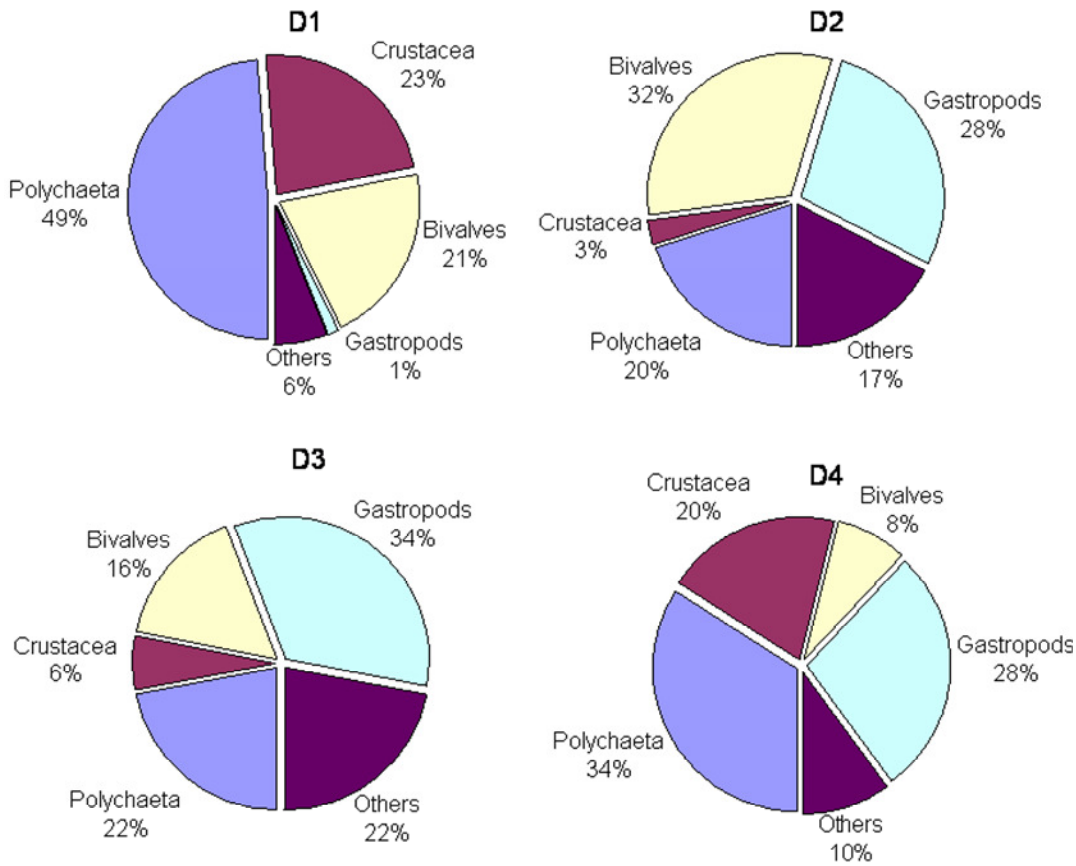

Figure 5. Relative abundance of macrobenthic groups of four stations.

Statistical analysis

Pearson's correlation coefficient

The Pearson's correlation coefficient (Table 2) explains about the possible relationship between the population density, macrobenthic groups and environmental parameters. During the present study, 13 parameters were taken such as population density, polychaeta, bivalves, gastropods, crustaceans, others, salinity, pH, dissolved oxygen, water temperature, sand, silt and clay.

Population density was significantly correlated with salinity, dissolved oxygen and pH ($p<0.05$). Polychaetes and gastropod are significantly correlated with salinity ($p<0.05$). Bivalve was significantly interrelated with water temperature, while dissolved oxygen becomes more essential for gastropod density ($p<0.05$). Crustacean did not show any statistically significant relation with any of the parameter.

Principal component analysis

Figure 6 represented the eigenvalues of different factors. Eigenvalues provides the information related to the quality of the projection of the variables from higher to lower number. Each eigenvalue represents a factor which is a linear combination of the initial un-correlated variables. In the present study (where N=13), the first eigenvalue was calculated as 6.219 which represented 47.84% of variability. Similarly, the second eigenvalue was equal to 2.11 represented 16.24% of the variability. Thus the eigenvalue of first two factors represented 64.09% of the total variability. This represented that the first two factors have the highest variability as compared to others. Figure 6 showed the scree plot where X-axis represents the projection of the factors and Y-axis represents the corresponding eigenvalue.

Figure 7 represents the correlation circle where first factor (F1) represented 47.84% of the variability at X-axis; second factor (F2) represented 16.25% of variability at Y. Variables nearer and closer to each other represented positive correlation, while located on opposite side of the centre represented negative correlation while those variables found closer to the center have no relationship. Silt and others posses no strong correlation in the correlation circle. Table 3 represents squared cosines values of variables in relation to the respective factor axes. Values closer to 1 were significantly related with the variables. In the present

Table 2. Pearson's correlation coefficient showing the strength of relationship between variables. Values in bold are significant at 95 % confidence limit.

Variable	PD	Poly.	Biva.	Gast.	Crust.	Oth.	Salin.	pH	DO	W.T.	Sand	Silt	Clay
PD	**1**												
Poly.	**0.90**	**1**											
Biva.	0.33	0.20	**1**										
Gast.	**0.89**	**0.64**	0.37	**1**									
Crust.	**0.92**	**0.85**	0.18	**0.75**	**1**								
Oth.	0.20	0.18	-0.28	0.04	0.21	**1**							
Salin.	**0.69**	**0.62**	0.56	**0.68**	0.51	0.01	**1**						
pH	**0.63**	0.55	0.44	**0.68**	0.47	-0.14	**0.92**	**1**					
DO	**0.60**	0.37	0.15	**0.74**	0.45	-0.09	0.12	0.18	**1**				
W.T.	0.32	0.21	**0.68**	0.39	0.14	-0.02	**0.86**	**0.75**	-0.10	**1**			
Sand	-0.45	-0.22	0.07	**-0.65**	-0.30	-0.39	-0.49	-0.47	-0.38	-0.40	**1**		
Silt	-0.06	0.20	-0.17	-0.30	-0.22	0.17	-0.04	-0.06	-0.13	-0.11	0.29	**1**	
Clay	0.57	0.51	0.17	**0.61**	0.47	-0.02	**0.81**	**0.90**	0.04	0.56	-0.48	-0.08	**1**

Values in bold are different from 0 with a significance level alpha=0.05. Abbreviation: PD =population density, Poly.=Polychaeta, Biva.= Bivalves, Gast..= Gastropod, Crust..=Crustacea, Oth.=Other, Salin.=Salinity, DO=Dissolved oxygen and W.T.=Water temperature.

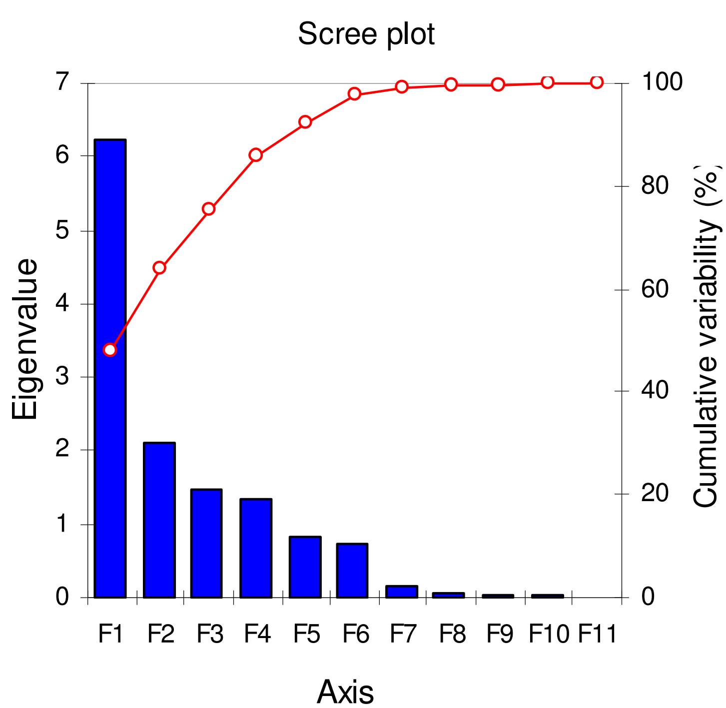

Figure 6. Scree plot showing factor with Eigenvalue.

study, salinity and pH (F1 axis), water temperature and dissolved oxygen (F2 axis) emerged as principal components that were remarkably putting impact over macrobenthos.

DISSCUSSION

The population density of macrobenthos of shelf region of north-eastern part of Bay of Bengal is comparable with Harkantra et al. (1982), Vijaya Kumar et al. (1991) and Mahapatro (2006) who studied the offshore region off Dhamara Estuary. The population density of macrobenthos was lower as compared to the Arabian sea of west coast of India as reported elsewhere (Joydas, 2002; Joydas and Damodaran, 2001). This is in concurrence with the work of Parulekar et al. (1982) who studied the benthos of the Indian seas and opined that

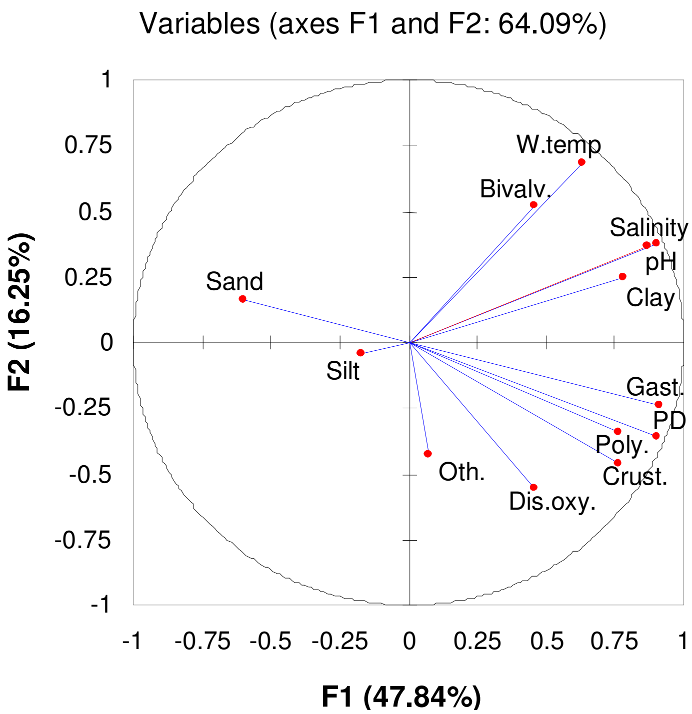

Figure 7. Correlation circles of principal components in two axis.

Table 3. Shows squared Cosine values of different parameters pooled out against Different factors up on X and Y axis.

Squared cosines of the variables					
	F1	F2	F3	F4	F5
Population density	**0.82**	0.13	0.00	0.04	0.01
Polychaeta	**0.58**	0.11	0.05	0.19	0.00
Bivalves	0.21	**0.27**	0.15	0.09	0.25
Gastropods	**0.83**	0.06	0.07	0.01	0.00
Crustaceans	**0.59**	0.21	0.00	0.03	0.00
Other	0.01	0.18	**0.43**	0.12	0.23
Salinity	**0.81**	0.14	0.03	0.00	0.00
pH	**0.76**	0.14	0.01	0.00	0.06
Dissolved oxygen	0.21	**0.31**	0.27	0.00	0.00
W. Temperature	0.40	**0.47**	0.01	0.02	0.07
Sand	0.36	0.03	0.01	**0.51**	0.00
Silt	0.03	0.00	**0.39**	0.32	0.00
Clay	**0.61**	0.06	0.06	0.01	0.19

Values in bold correspond for each variable to the factor for which the squared cosine is the largest.

the Bay of Bengal posses lower values of macrobenthic density as compared with Arabian Sea and also he pointed out the reasons of lower values are due to fresh water flux during monsoon, unprecedented storm surges, and tropical cyclones. Again, out flux from large riverine systems such as the Ganges, the Bramhputra, the Mahanadi, the Godavari, the Krishna and the Cauvery carries huge quantity of silt borne freshwater (Dwivedi, 1993; Aziz et al., 1998). The riverine systems and the environmental parameter together might have influenced the phytoplankton productivity. It is proved that phytoplankton productivity has significant influence on benthic productivity (Ingole et al., 2010) which further strengthen the fact that surface water chlorophyll have

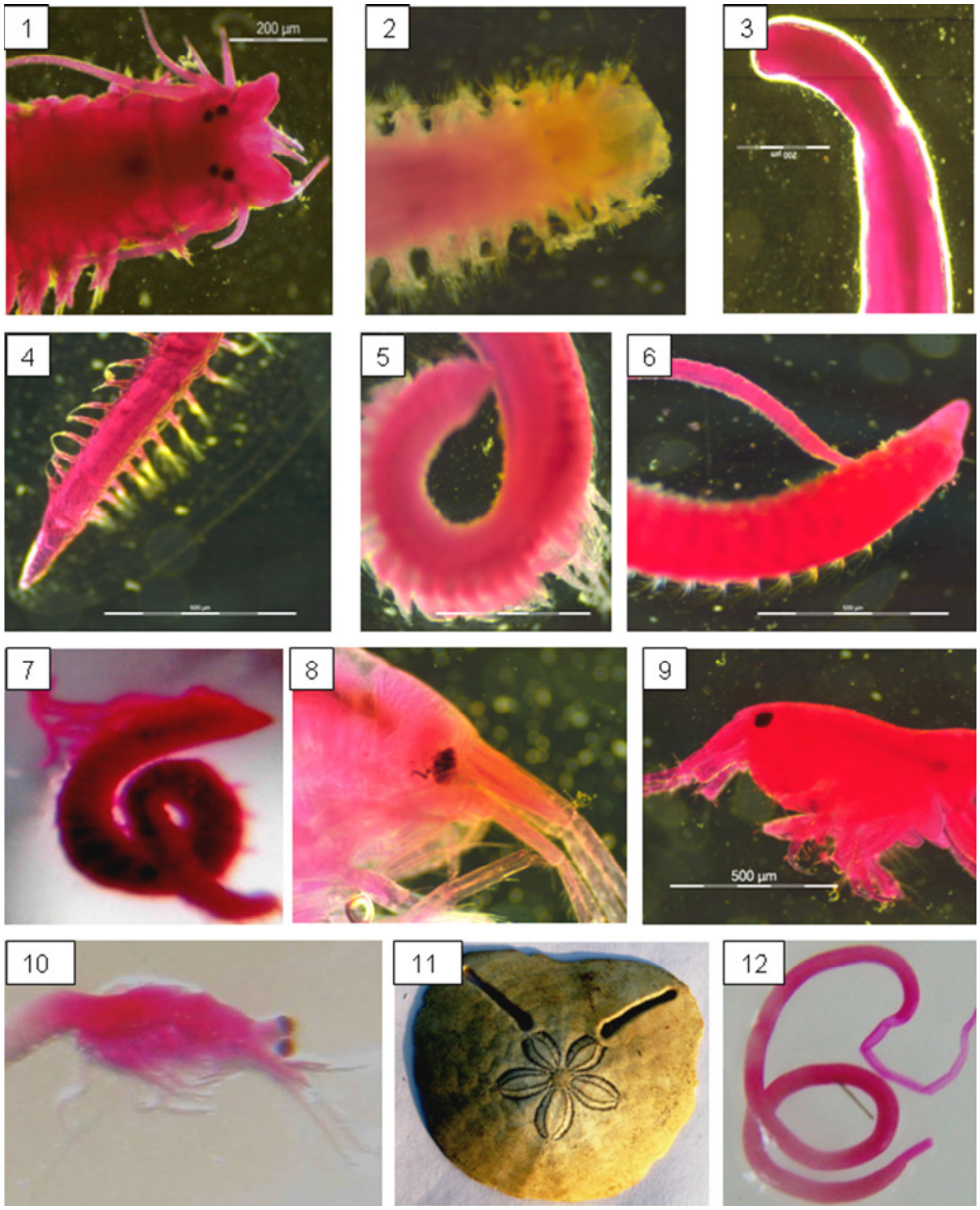

Figure 8. Images of macrobenthos of shelf region off Dhamra estuary. 1. *Nereis sp.*; 2. *Nepthys sp.*; 3. *Capitella sp.*: 4. *Goniada sp.*; 5. *Prionospio sp.*; 6. *Cossura sp.*; 7.*Cirratulus sp.*; 8. *Gammarus sp.*; 9. *Ampelisca sp.*; 10. *Mysis sp.*; 11. Sand dolar, 12. Nematoda.

major authority over macrobenthic productivity and helped for benthic pelagic coupling (Snelgrove, 1998) while Pavithran et al. (2009) found significant correlation between surface chlorophyll-a with macrobenthic density and sediment organic matter in Central Indian Ocean Basin. In Arabian Sea, the surface water chlorophyll was found higher than Bay of Bengal as reported by Prasanna et al. (2002) and Madhuparatap et al. (2003). This was due to upwelling, less disturbance from cyclone and storm surges and a consistent environmental condition unlike Bay of Bengal.

So far, the present study was concerned with the salinity value along with dissolved oxygen, water temperature, macrobenthic density and species richness, was increased from February to April 2005 which showed the strong relationship between macrobenthic organisms with environmental (Table 2). There was a clear evidence of increasing rate of population density and deeper regions than the shallow depth. Because in shallow depth regions, high turbidity, often fluctuation of environmental parameters and more fishing pressure disturbs habitat condition, while in deeper region favoring condition is existed due to stable environmental parameters. Similar results were obtained by Ingole et al. (2010) in the shelf region of Arabian Sea.

Salinity is a major influencing parameter for the abundance and distribution of marine organisms. A constant range of salinity favors the proliferation of macrobenthic organisms. Vizakat (1991) reported that recolonisation of benthos with increased salinity value at Konkan West coast of India. He further opined that in tropical waters, salinity is the most influencing parameter over benthic productivity. Same observation was made in the present study from the squared cosine table (Table 3) which is pooled from the principal component analysis that showed salinity and pH as major guiding factors. Harkantra and Parulekar, (1991) suggested that no single factor could be considered as an ecological master factor that totally responsible for community structure of macrobenthos. This is rightly evidenced from the present study that four environmental parameters such as salinity, pH, dissolved oxygen and water temperature were significantly affecting the macrobenthic density off Dhamara Estuary (Correlation Table 2). In contrast to this, northwest shelf of Arabian Sea exhibited none of the physico-chemical parameter that significantly correlated with the macrobenthos (Jayaraj et al., 2007, 2008). This corroborate that the macrobenthos off Dhamara Estuary of Bay of Bengal was significantly influenced by physico-chemical parameters as compared to Arabian Sea. Harkantra et al. (1982) studied the shelf region of Bay of Bengal stated that other than physico-chemical parameters, sediment texture and community interaction are the possible cause of low values of macrobenthic density. The results of granulometric analysis revealed that there was no great variation in the texture composition of the study region. Whereas the community interaction such as predation, competition, recruitment and mortality are such factors which can significantly alter the numerical density of macrobenthos (Mahapatro, 2006; Harkantra and Parulekar, 1991).

Perusal of literature at Indian context revealed that polychaeta was a major component of macrobenthos at the shelf region of east coast and west coast of India (Harkantra et al., 1980; Harkantra et al., 1982, Ingole et al., 2002, Mahapatro, 2006; Joydas and Damodaran 2009; Jayaraj et al., 2007; 2008; Ingole et al., 2010). In the present study, polychaeta group emerged as a major stuff among all other macrobenthic groups. The station wise distribution of relative abundance of different macrobenthic groups during the study period exposed that the first station D1 and the last station D4 possessed higher contribution of polychaets in the shelf waters of Bay of Bengal. This supports the fact that deeper areas of the Bay of Bengal posses higher density of macrobenthos is in agreement with Harkantra et al. (1982) (Joydas and Damodaran, 2009; Pavithran et al., 200; Ingole et al., 2010).

From the study of PCA, three principal components were pooled out, such as salinity (F1), Water temperature (F2) and silt (F3). The variability of first two factor was 64.09% of the total variance. Salinity along with pH (F1) was found most significant among other variables having good relation with population density, specifically with polychaeta, gastropods, and crustaceans, while F2 scores correspond to higher values of water temperature, dissolved oxygen and bivalves. These parameters commonly favor high colonization of macrobenthic organisms (Jayaraj et al., 2007, 2008; Ingole et al., 2009, 2010). Under low turbidity, fair transparency and optimal temperature favors high photosynthetic rate. This causes high dissolved oxygen content favoring good colonization of benthic organisms.

Conclusion

It is concluded from the above study that multiple environmental parameter exhibited significant impact over the macrobenthic organisms in the shelf region of Bay of Bengal. Certain parameters such as salinity, water temperature, dissolved oxygen and pH were considerably influencing over macrobenthic density. No great variation was exhibited in the sediment composition. The role of community interaction could not be ruled out completely regarding the lower values of macrobenthic density. Polychaetes was emerged as major macrobenthic group during the present study, which can act as an indicator of environmental stress. In the future, more study should be carried out regarding the physico-chemical status along with macrobenthos in the shelf region of Dhamara Estuary in general and macrobenthic polychaets in particular to assess demersal fishery and to evaluate natural and anthropogenic stress.

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