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Diversity of Macrofauna from Continental Shelf off Singarayakonda (Southeast Coast of India)

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Abstract: The present study was undertaken to study the benthic productivity of shelf region off Krishna River mouth. Standing stock of macrobenthos and its distribution were studied. Sampling was done onboard FORV Sagar Sampada from depths as 30, 50, 75, 100, 150 and 200 m using Smith-McIntyre grab having a bite area of 0.2 m^2. After identification, data were treated using statistical package PRIMER v6. The nature of the sediment was medium sand up to 150 m depth and fine silt at 200 m. The benthic biomass (0.2977-3.1091 mg 0.2 m^{-2}), abundance (58-289 nos. 0.2 m^{-2} and number of species (12-48) decreased with increase in depth. The total number of species recorded was 69. Species estimators showed the possibility of collecting 129 species (Chao1) with intense sampling. Polychaetes formed the largest group with 40 species followed by molluscs (15 species) and crustaceans (14 species). The Spearman rank correlation (Rho) value (0.513) which was significant at 1.1% showed gradual change in species composition with increase in depth. The Pi value (3.78) comparing the similarity of benthos at 200 m depth with those of other depths (30, 150, 100, 75 and 50 m) showed significant differences (0.6%). Matching of biotic variables with that of environment showed the influence of dissolved oxygen on the distribution of macrobenthos (Rho 0.757). Intense sampling should be done to record all the species as shown by species estimators besides studying shelf productivity off other rivers and relating it with nutrient discharge and other environmental factors including sediment nature.

Key words: Macrobenthos, diversity, continental shelf, singarayakonda, Bay of Bengal

INTRODUCTION

The Bay of Bengal is a unique basin receiving considerable amount of freshwater and sediment discharge from major rivers and therefore surface production per unit area is higher here (Shi *et al*., 2002). Another reason behind the surface productivity of Bay of Bengal is the heavy load of nitrogen and phosphorous contributed by about 1300 km^3 of River run -off from India (Sen Gupta *et al*., 1977) and another 50% of this volume by the river systems of Bangladesh and Myanmar forming total volume of about 2000 km^3 (Qasim, 1977). A number of investigations were conducted on shelf benthos from both the west and east coasts of India (Ansari *et al*., 1996; Joydas, 2002; Ganesh, 2003; Vijayakumaran, 2003; Ganesh and Raman, 2007; Jayaraj *et al*., 2008; Joydas and Damodaran, 2009). The Andhra shelf has an average width of about 39 km and depth at the outer edge is around 183 m. It is narrowest opposite Krishna and Godavari Rivers, which have built up protruding deltas across the entire shelf. As benthic productivity of this shelf has not been studied intensively, the present study was undertaken to find out the standing stock of macro benthos and its distribution in relation to depth, sediments and other environmental factors.

MATERIALS AND METHODS

Study area: The study area off Singarayakonda (Fig. 1) extends over Lat. 15°14'48"-15°15'57" N and Long. 80°20'56" -80°31'10" E. The River Krishna debouches in to the Bay of Bengal North of Singarayakonda. It empties sediment to the tune of (4, 110×10^3 t $year^{-1}$) in the Singarayakonda shelf region (Vaithiyanathan *et al*., 1988; Subramanian, 1993).

Collection of samples: Benthic samples were collected onboard FORV Sagar Sampada through Cruise No. 260 conducted on 15.12.2008. Samples were collected from various depths as 30, 50, 75, 100, 150 and 200 m using Smith-McIntyre grab having a bite area of 0.2 m^{-2}. From grab samples, sub-samples were taken from each depth for analyzing the sediment texture, organic carbon and heavy metals. Hydrographical data on temperature, pressure,

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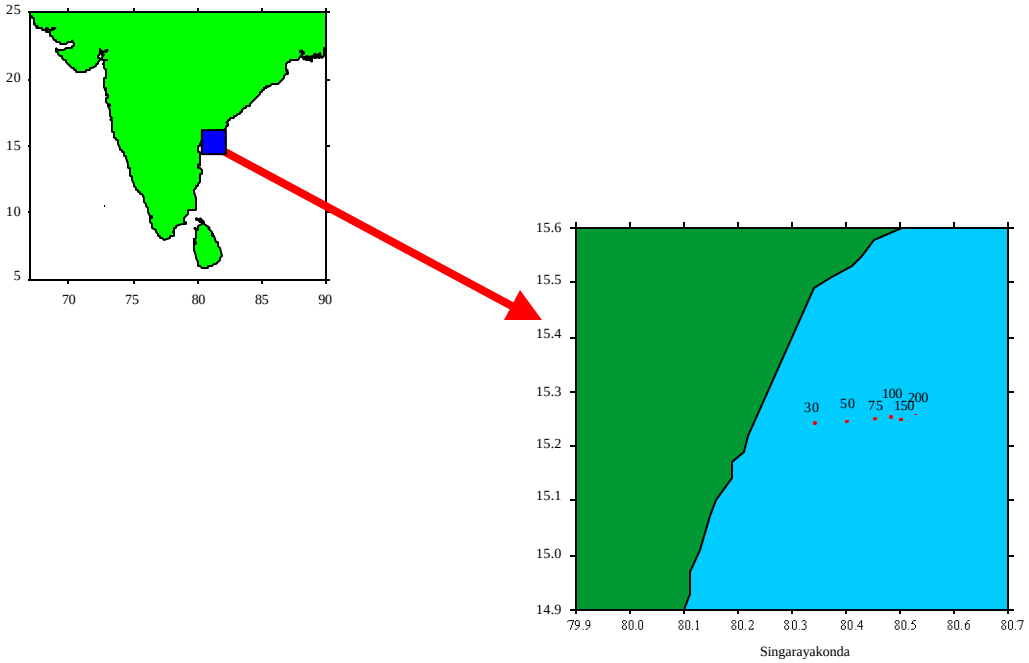

Fig. 1: Depths sampled in Singarayakonda shelf region

salinity and dissolved oxygen were collected from the CTD (Sea Bird 911 plus) available onboard Sagar sampada.

Sediment texture, organic matter and heavy metals were analysed following Folk and Ward (1957), Gaudette *et al*. (1974) and Walting (1981), respectively. The sediment samples were sieved using 0.5 mm sieve with copious sea water. After sieving, the organisms were carefully separated together with residual sediment if any, fixed in 5-7% formaldehyde containing Rose Bengal, labeled and stored for further examination. After identifying the benthos, the data were treated using PRIMER v6.

RESULTS

Environmental parameters: The temperature varied from 15.62°C (200 m) to 28.17°C (100 m). The concentration of dissolved oxygen decreased with increase in depth from 0.089 mL L^{-1} (200 m) to 4.21 mL L^{-1} (30 m). The salinity increased with increase in depth. It ranged between 27 psu (30 m) and 34.96 psu (150 m). The pressure just like salinity increased with increase in depth and fluctuated between 27.16 bar (30 m) and 197.21 bar (200 m). The median particle diameter decreased with increase in depth from 0.005 mm (75 m) to 0.471 mm (30 m). The nature of sediment was silty except at 30 m depth where it was sandy. The sand percentage ranged from 87% (30 m) to 58.12% (200 m), silt content from 12.25% (30 m) to 48.84% (50 m) and the clay percentage from 0.15% (30 m) to 4.22% (75 m). The TOM varied from 2.379% (75 m) to 6.542% (100 m) Table 1.

Heavy metals: The concentration of cobalt ranged from 0.113 ppm (150 m) to 0.799 ppm (30 m). Copper varied between 0.198 ppm (150 m) and 2.693 ppm (30 m). The iron fluctuated from 189.1 ppm (30 m) to 679.6 ppm (75 m). The concentration of manganese ranged from 4.747 ppm (30 m) to 29.06 ppm (150 m). The nickel concentration was more (2.222 ppm) at 150 m depth and less (0.246 ppm) in 30 m depth. Lead varied between 0.346 ppm (30 m) and 0.774 ppm (150 m). The zinc differed from 2.368 ppm (30 m) to 57.51 ppm (50 m). Mercury was recorded only at 30 m depth (0.012 ppm) and at other depths it was not detected Table 2. The concentrations of Co, Cu, Fe, Mn, Ni and Pb concentration were higher at middle depths (75 and 150 m). Overall the zinc concentration increased with increase in depth.

Benthic biomass, species composition and abundance: The benthic biomass ranged from 0.2977 mg 0.2 m^{-2} (200 m) to 3.1091 mg 0.2 m^{-2} (30 m). Polychaetes constituted the dominant group by constituting 43% followed by molluscs (32%) and crustaceans (25%). Forty species of polychaetes were recorded. *Naineris laevigata*, *Scoloplos madagascariensis*,

Table 1: Variations in the environmental parameters at different depths of Singarayakonda shelf region

Depths (m)	Temperature (^{0}C)	DO (mL L^{-1})	Salinity (PSU)	Pressure (bar)	MPD (φ)	Nomenclature	TOM (%)
30	27.47	4.210	27.00	27.16	1.0860	Medium sand	4.996
50	27.71	4.190	32.21	45.26	7.3335	Fine silt	6.066
75	27.74	4.180	32.29	52.30	7.8306	Fine silt	2.379
100	28.17	3.800	33.43	91.54	5.2025	Coarse silt	6.542
150	17.61	0.210	34.96	141.36	7.0983	Fine silt	4.282
200	15.62	0.089	34.90	197.21	7.2161	Fine silt	5.353

Table 2: Variations in heavy metal concentrations at different depths of Singarayakonda shelf region

	Heavy metals (ppm)							
Depths (m)	Co	Cu	Fe	Mn	Ni	Pb	Zn	Hg
30	0.113	0.198	189.1	4.747	0.246	0.346	2.368	0.012
50	0.470	1.863	603.1	15.76	1.618	0.515	57.51	0.000
75	0.786	2.433	679.6	18.35	2.143	0.528	4.047	0.000
100	0.445	0.872	342.8	8.886	0.763	0.420	3.917	0.000
150	0.799	2.693	665.6	29.06	2.222	0.740	8.378	0.000
200	0.419	1.655	608.2	5.133	1.398	0.429	11.26	0.000

Table 3: Diversity of infauna recorded at various depths of Singarayakonda shelf region

Depths (m)	S	N	Fisher's alpha	Q statistics	H'(log2)	D	J'	Lambda'	Berger parker	Delta	Delta*	sPhi+
30	48	289	16.42	12.98	5.38	10.13	0.96	0.02	0.07	81.49	82.95	2520
50	26	108	10.87	9.01	4.58	6.43	0.97	0.03	0.18	84.46	86.68	1520
75	19	99	6.99	5.23	4.09	4.91	0.96	0.04	0.15	80.46	83.81	1220
100	18	125	5.77	6.39	3.92	4.61	0.94	0.06	0.30	78.10	82.66	1120
150	21	179	6.17	9.39	4.30	4.93	0.98	0.04	0.11	80.17	83.25	1140
200	12	58	4.60	3.61	3.43	3.47	0.96	0.06	0.28	77.28	82.41	800

Amphicteis gunneri and *Terebellides stroemi* species were found to be more at 30 m depth; *Lumbrineris latreilli* and *Ancistrosyllils parva* at 50 m; *Eurythoe complanata*, *Onuphis geophiliformis* and *Amphicteis gunneri* at (75 m); *Terebellid* sp. at 150 m and *Prionospio* sp., at 200 m. Fourteen species of crustaceans, such as *Lysianassa* sp. and *Ampelisca* sp. (30 m); *Ampithoe* sp., *Isaea* sp. and *Lysianassa certaina* (50 m); *Amphithoe* sp., *Lysianassa* sp. and *Ampelisca* sp. (75 m); *Ampelisca* sp. and *Isaea* sp. (100 m); *Urothoe* sp., *Lysianassa* sp., *Isaea* sp., *Ichnopus spinicorni*, *Amphithoe rubricata*, *Ampelisca* sp. and *Isaea* sp. (150 m); *Ampithoe rubricata*, *Isaea* sp. and *Lysianassa* sp. (200 m) were found to be dominant. Among the 15 species of molluscs recorded *Donax scortum*, *Tellina virgata*, *Paphia* sp. and *Mactra leavis* were dominant (30 m) and only one gastropod species *Natica dydima* was found at 100 m depth.

The total number of organisms collected from the study area was 858. The abundance varied from 58 (200 m) to 289 nos. 0.2 m^{-2} (30 m). The total no of species varied between 12 (200 m) and 48 (30 m).

Diversity: The maximum value of Fisher's alpha index was recorded at 30 m (16.42) and minimum value at 200 m (4.6). Similar trend was noticed in Shannon diversity (5.38 at 30 m depth and 3.43 at 200 m depth) and Q statistics (12.98 at 30 m depth and 3.07 at 200 m depth. In species richness also, the Margalef's index showed the maximum (10.13) at 30 m depth. The minimum of 3.47 was recorded at 200 m depth. In evenness, the highest value (0.98) was recorded at 150 m depth and the lowest (0.94) at 100 m depth. The Berger Parker dominance index was high (0.30) at 100 m depth and low (0.07) at 30 m depth. With respect to the new diversity indices, taxonomic diversity was more (84.46) at 50 m depth and low (77.28) at 50 m depth. The taxonomic distinctness was more (86.68) at 50 m depth and 82.41 at 200 m depth). The maximum value (2520) of Total phylogenetic diversity index ($sPhi^+$) was recorded in 30 m depth and the minimum (800) at 200 m depth Table 3.

Species estimators: In the present study a total of 69 species was recorded. The likelihood of recording higher number of species with intense sampling was found out using various species estimators which showed the likelihood of the occurrence of 129 species (Fig. 2). While the maximum estimate (129) was given by Chao 1, the minimum estimate was given by MM. (67 species).

Similarity: The similarity percentage between all the depths ranged from 12.31 (30 and 200 m) to 53.4312% (50 and 75 m). The dendrogram (tree diagram) derived showed only one group formed by 50 and 75 m depths at 53.43% similarity to which 100, 150, 30 and 200 m depths joined, respectively at 46.12, 37.1, 35.41 and 21.36% similarities. Cluster done with SIMPROF (similarity profile) showed all the depths sampled except 200 m in red colour

indicating that diversity at 200 m depth differed significantly from all the other depths (Fig. 3). The Pi value (2.59) calculated comparing the similarity of 30 m with those of other depths(150, 100, 75 and 50 m) was not significant (7.6%). However the Pi value (3.78) calculated comparing the similarity of 200 m with the other depths (30, 150, 100, 75 and 50 m) was statistically significant (0.6%) (Fig. 4). The MDS done by superimposing cluster showed two groups at 30% similarity. As all the depths except 200 m were lying cluttered on the right hand side of MDS and 200 m depth fell on the left had side.

Relationship with environmental parameters: The LINKTREE (Linkage Tree) was employed to find out the influence of environmental parameters on the distribution of macrobenthos. The LINKTREE showed two major groups namely A and B. Group A was comprised of only one depth (200 m depth) while B all the other depths. This division having R (ANOSIM) of 1 took place at 100% of B (a dissimilarity measure) based on the differences among the environmental variables included in the calculation namely pressure, depth, temperature and dissolved oxygen. Group B was further divided in to two groups one having depths 1 and 5 (depths 30 and 150 m) and the other having 2-4 (50, 75 and 100 m). This division having R of 0.58 took place at 51.3% of B. This division was based on differences in temperature. In depths 30 m and 150 m the temperature was more than 27.5°C and in depths 50, 75 and 100 m the temperature less than 27.7°C Table 4.

In the BIO-ENV procedure, employed to measure the agreement between the biological (Bray-Curtis similarity) and environmental (Euclidean distance) matrices, ten environmental variables were allowed to match the biota. They were depth (m), temperature (°C), salinity (PSU), dissolved oxygen (mL L^{-1}), pressure (bar), mean particle diameter (mm), total organic matter (%), mercury (ppm), Zinc (ppm) and copper (ppm).

Table 4: Results of LINKTREE (Linkage Tree) showing splitting up of depths sampled in. Singarayakonda shelf region based on environmental variables

Groups	Environmental variables
A	->(6), B
	R: 1 B%: 100
	Pres. >197 (<141)
	Depth in m >200 (<150)
	Temp. <15.6 (>17.6)
	Do< 0.09 (>0.21)
B	B->(1, 5), (2-4)
	R: 0.58 B%: 51.3
	Temp. >27.7°C (<27.7°C)

(R-ANOSIM statistic, B%-an absolute measure of group difference (depths sampled: 1-30, 2-50, 3-75, 4-100, 5-150,6-200 m)

The maximum correlation found was 0.757 showing good match between the biotic and dissolved oxygen.

The serial change in species composition with increase in depth was studied using the tool RELATE. The Spearman rank correlation (Rho) value obtained was 0.513 (Fig. 5) having the sample statistic of 1.1% indicating significant changes in species composition with increase in depth.

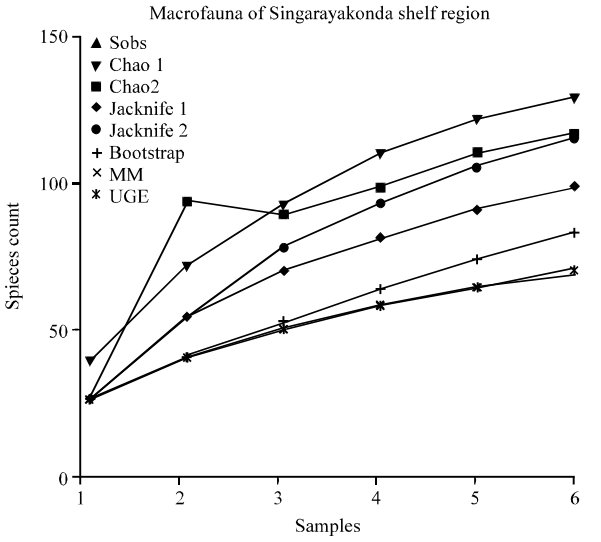

Fig. 2: Species estimators for all the depths sampled in Singarayakonda shelf region (1-30, 2-50, 3-75, 4-100, 5-150, 6-200 m)

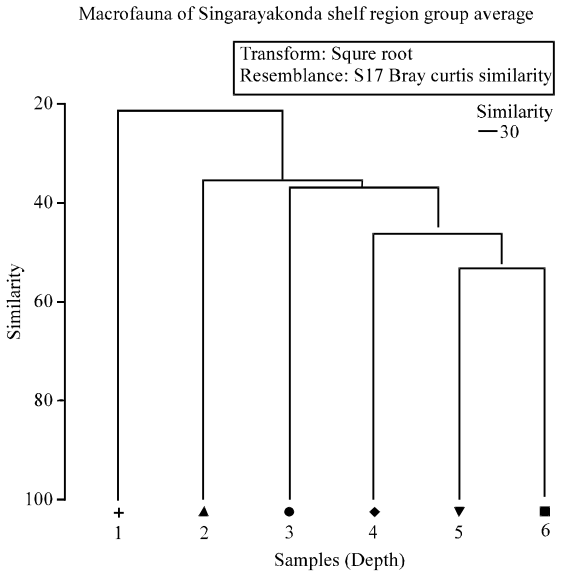

Fig. 3: Dendrogram done using SIMPROF for samples collected at various depths in Singarayakonda shelf region

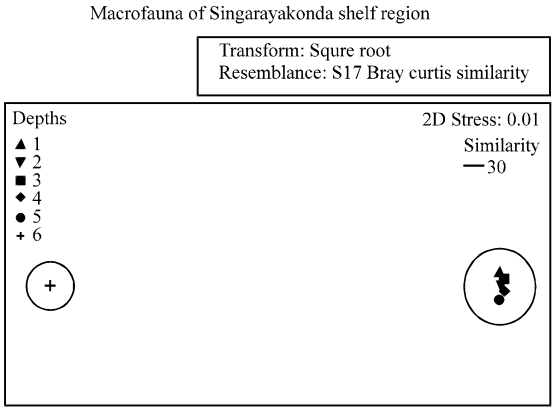

Fig. 4: MDS of infauna collected at various depths in Singarayakonda shelf region showing differences in species composition between 200 m depth (6) and all other depths (1-5), (1-30, 2-50, 3-75, 4-100, 5-150 and 6-200 m)

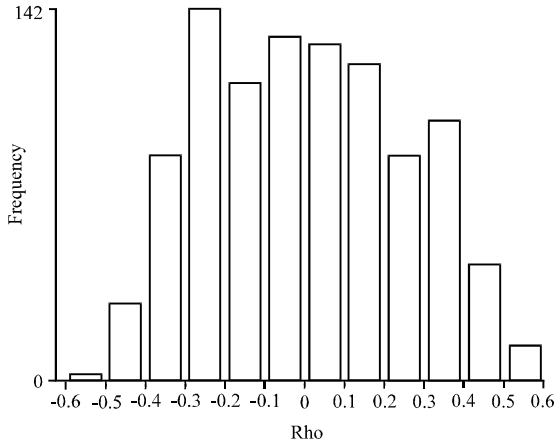

Fig. 5: Histogram showing serial changes in macrofaunal diversity in Singarayakonda shelf region

DISCUSSION

In Indian waters, Day (1967), Neyman (1969), besides Parulekar and Ansari (1981) observed high abundance and diversity of benthos in muddy bottom. Ansari and Parulekar (1998) studied the relation between particle size and benthic fauna off Goa and pointed out a significant relation between abundance and sediment size. The median particle diameter decreased with increase in depth and was found negatively correlated with salinity, pressure, depth and positively with temperature and dissolved oxygen.

The presence of organic matter, reported as total organic carbon in marine sediments, affects the geotechnical properties, including water content, porosity and wet bulk density (Bush and Keller, 1981; Bennett *et al*., 1985; Booth and Dahl, 1986). In the present study total organic carbon was found to be high in 100 m depth and low in 75 m depth.

As per the permissible limits prescribed by the CPCB (Central Pollution Control Board-www.cpcb.nic.in), the concentrations of Co, Cu, Ni and Pb were below the permissible limits (permissible limits for the above metals are 2.0, 3.0, 5.0 and 2.0 ppm, respectively). The concentration of Fe (permissible limit 3.0 ppm) in all the depths was found exceedingly above the permissible limit prescribed. The Zn concentration was also above the permissible limit of 15 ppm. The manganese concentration was also above the permissible level of 2.0 ppm. The concentration of mercury (0.012) was found to be marginally above the permissible limit (0.01 ppm).

Rae (1997) reported that heavy metals vary significantly in the shelf sediment of east and west coasts of India. Finer sediments with abundant clay minerals, iron/manganese oxides as well as organic matter tend to show higher metal concentrations.

Joydas and Damodaran (2009) found the infaunal biomass to vary from 13.8 g m^{-2} (30 m) to 0.05 g m^{-2} (200 m). Jayaraj *et al*. (2008) reported total biomass of macrofauna in the range of 0.02-17.51 g mg^{-2}. The biomass observed in the present study was found to be lower than the above. The abundance varied from 58 to 289 nos. 0.2 m^{-2}. While the maximum number of organisms was found at 30 m depth, the minimum was found at 200 m depth. Ganesh (2003) found polychaetes Cossurid *Cossura coasta* (Kitamori, 1960) and Cirratulids (Carus, 1863) both deposit feeders to be relatively abundant at Divipoint and Kakinada where the Rivers Krishna and Godavari open into the sea, respectively. In the present study *Amphicteis gunneri* (Ampharetidae) besides bivalves *Tellina virgata* and *Donax scortum* were found dominant at Singarayakonda.

Tselepides *et al*. (2000) observed a decrease in abundance and diversity with increase in depth in the continental shelf of Crete, South Aegean Sea. Harkantra *et al*. (1980) and Harkantra and Parulekar (1987) found a progressive decrease in benthic faunal abundance with depth. In the present study also such a trend was noticed. Joydas and Damodaran (2009) noticed maximum richness (d) value of 4.85 (124 m), evenness (J') of 0.96 (91 m) and Shannon diversity of 4.64 (124 m) in the continental shelf area of the west coast of India. Ganesh and Raman (2007) reported Shannon diversity in the range of 0.64-3, Margalef richness in the range of 0.37-7.7 and evenness 0.59-0.99 in the continental shelf of the northern part of Bay of Bengal. In the present study

higher diversity (5.38) and richness (10.13) were noticed in the area covered presently (situated quite close to the study area of Ganesh and Raman (2007). This trend was also found in Fisher's alpha diversity, Q statistic and in total phylogenetic diversity index besides the Margalef's richness index. The values declined with increase in depth from 30 to 150 m, increased at 150 m depth and again decreased at 200 m depth. The rise in diversity at this depth is attributed to increase in the number of species of crustaceans in particular the amphipods. As Q statistic, Alpha diversity, Berger Parker Dominance, Taxonomic diversity, Taxonomic distinctness and phylogenetic diversity were not used in Indian waters, the results of the present study could not be compared with other works.

Several factors like locality, depth, distance from the shore, river proximity and local oceanographic features such as bottom currents, nature of substratum etc., appeared important in determining the pattern of distribution of benthos. Off Visakhapatnam, sediments within 30 m typically represented 'sand' and differed markedly from other localities with relatively soft substrata. This is attributable to significant river inflows in the study areas (Divi Point, Kakinada, Barua and Paradip) where heavy sediment loads (rich in silt and clay) enter the sea through the Rivers Krishna, Godavari, Vamsadhara and Mahanadi systems. Below 150 m sediments along the northeast shelf are clayey silt, between 50 and 150 m, mostly silt and from 30 to 50 m, sand, silt and clay, as reported earlier (Rao, 1964). In the present study, only 30 m depth was found to be sandy (medium) and all the other depths silty in nature.

In the present study, Shannon diversity was more at 30 m (5.3762) and less at 200 m (3.4335) depth. Higher diversity of macrobenthos was found at 30 m depth where the nature of the sediment was medium sand. In Indian waters, many investigators reported higher abundance and diversity in the sandy substratum (Harkantra *et al*., 1982). Gray (1974) reported that diversity within shelf habitats is lowest in mud, higher in sand and highest in mixed mud and sands-sediments with a median particle diameter of about 200 μm. Ingole *et al*. (2010) reported that the macrofaunal abundance was much higher at the deeper stations on the shelf (mean values~2900-3722 ind. m^{-2}) region having sandy substratum. Thomas *et al*. (2006) reported that the polychaetes showed a preference for sandy areas (> 40 m depth) and exhibited high abundance in this zone with an average of 2500 nos. m^{-2}. Few have also found high abundance and diversity of benthos in muddy bottom (Day, 1967; Neyman, 1969; Parulekar and Ansari, 1981). The maximum values of taxonomic diversity and taxonomic distinctness were observed at 50 m depth where only 26 species were recorded and not at 30 m depth where 48 species were recorded. Warwick and Clarke (1995) who introduced these indices pointed out that these indices vouch for the taxonomic breadth of diversity in areas sampled. Somerfield *et al*. (2008) pointed out that these indices are weakly related to species richness. To interpret the results of these indices and to understand their variations, taxonomic ratios which vouch for the taxonomic breadth were calculated (Table 5 and 6). The taxonomic ratios at all the levels except S/G were on the lower side indicating higher taxonomic breadth at this depth. That is why these indices were on the higher side at this depth.

Table 5: Taxonomic details of macrobenthos collected from various depths of Singarayakonda shelf region

Taxonomic level	30 m	50 m	75 m	100 m	150 m	200 m
Species	48	26	19	18	21	12
Genus	45	24	19	17	16	11
Family	29	20	17	14	14	11
Order	18	13	9	9	6	5
Class	3	3	3	4	3	3
Phylum	3	3	3	3	3	3

Table 6: Taxonomic ratios of macrobenthos collected from various depths of Singarayakonda shelf region

Taxonomic ratios	30 m	50 m	75 m	100 m	150 m	200 m
S/G	1.07	1.08	1.00	1.06	1.31	1.09
S/F	1.70	1.30	1.11	1.29	1.50	1.09
S/O	2.70	2.00	2.11	2.00	3.50	2.40
S/C	16.00	8.70	6.33	4.50	7.00	4.00
S/P	16.00	8.70	6.33	6.00	7.00	4.00

S: Species, G: Genus, F: Family, O: Order, C: Class, P: Phylum

Species estimators: The extent of diversity is often inferred from the richness levels at local scales. In places where sampling is limited and collection of more number of samples at spatial and temporal scales involves higher expenses, species richness can be estimated through extrapolation. A variety of methods are available for estimating the richness through extrapolation. The estimate is based on the ratio of singletons and doubletons either with quantitative data or qualitative data (presence/absence). The species richness increases with the increase in the number of singletons (Magurran, 2004). In the present study a total of 69 species was recorded. The likelihood of recording higher number of species with intense sampling was found out using a number of species estimators. The various extrapolators showed the likelihood of the occurrence of 67 to 129 species Fig. 2. While the maximum estimate was given by Chao 1, the minimum estimate was given by MM. Intensive sampling is required to collect all the 129 species.

LINKTREE

The LINKTREE (Linkage Tree) takes the subset of abiotic variables identified by the BIO-ENV and uses them to describe how best the samples are split into groups, by successive binary division. Each division is characterized by a threshold on a single environmental variable (Clarke and Gorley, 2006). The separation of 200 m depth (A) from others depths (B) had an absolute measure of group difference (B%) of 100. Incidentally it also showed the maximum ANOSIM statistic of 1. The separation of other depths into 2 groups (30 and 150 m depths and 50, 75 and 100 m depths) had a B% value of 51.3 and ANOSIM R value of 0.58. While high B% values corresponded to higher dissimilarity between depths with respect to the environmental variables, low values of B% correspond to samples which are rather close together on the MDS plot.

The BIO-ENV procedure is a method to measure the agreement between the rank correlation of biological (Bray-Curtis similarity) and environmental (Euclidean distance) matrices (Mackie *et al*., 1997). The extent to which these two patterns match reflects the degree to which the chosen abiotic data explains the biotic pattern. It searches for a high rank correlation between a fixed similarity matrix of species assemblage and resemblance matrix generated from environmental variables. Joydas and Damodaran (2009) found depth, temperature, dissolved oxygen and sand forming the "best combination" in explaining the distribution of the polychaetes in the BIO-ENV analysis. In the present study BIO-ENV showed high Spearman rank correlation (0.757) indicating good match between the biotic entities and dissolved oxygen. Sen Gupta *et al*. (1976) and Qasim (1982) pointed out that depletion of oxygen in the shelf edge of northern latitude in India may be due to the presence of oxygen minimum layer. Limited mixing, high organic production and sinking besides decomposition of large amount of organic matter were cited as the causes for oxygen depletion. Neyman (1969) found the benthos to be sparse in the northern shelf of western India at depths of 75-200 m and attributed this to the impact of waters with a minimum of oxygen content. Joydas and Damodaran (2009) reported that the decrease of dissolved oxygen with increase in depth was found to be analogous to the decrease in the abundance and biomass of benthic fauna.

Clear-cut zonation patterns in the form of a serial change in community structure with increasing water depth are a striking feature of shallow water benthic communities on both hard and soft substrata. The causes of zonation patterns are varied and may differ according to circumstances, but include environmental gradients such as depth, light or wave energy, competition and predation. Elimination of a particular predator may affect the patterns which are due to differential mortality of species caused by that predator (Clarke and Warwick, 2001). The serial change in species composition with increase in depth was studied in the present study. The Spearman rank correlation (Rho) value obtained was (0.513) having the sample statistic of 1.1% indicating significant changes in species composition with increase in depth.

CONCLUSION

Intense sampling should be done in future to record all the species as shown by the species estimators (129 species against 69 observed in the present study). The shelf productivity off all the other rivers in the east coast of India should be studied in relation to the sedimentary load and nutrient discharge to understand the contribution of rivers to benthic productivity. The role of other environmental factors including the nature of the sediment should also be found out.

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