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Distribution and abundance of macrobenthic polychaetes along the South Indian coast

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Abstract Macrobenthic polychaetes play a significant role in marine benthic food chain. A study was carried out to observe the abundance and diversity of soft bottom macrobenthic polychaetes along the South Indian coast, along with observations on sediment characteristics. The present study indicated an increase in the polychaete diversity as compared to earlier reports. Sixty-three different forms of polychaetes were identified along the coast, which constitute the bulk of the macrobenthic fauna. Thirty-eight species of polychaetes showed higher abundance along the west coast, whereas 25 species showed higher abundance along the east coast. Seabed composition showed a spatial variation in its composition along the coast. Occurrence of *Prionospio pinnata* and *Capitella capitata* the deposit feeders and indicators of organic pollution suggesting the sampled area is organically rich. Polychaete abundance was found to be higher along the west coast and was attributed to loose texture of sediment due to high sand and sandy-silt resulting in higher interstitial space for organisms to harbor. Canonical correspondence analysis indicated that majority of polychaete species preferred low organic carbon, sandy silt, or sandy-clay substratum. The lower polychaete abundance at high organic carbon and high silt and clay areas can be attributed to avoidance of organisms to rich organic matter and suboxic levels, being a possible indication that these characteristics adversely affects the polychaete abundance and distribution.

Keywords Polychaete · Macrobenthos · Indian coast · Pollution indicator · Organic carbon

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Introduction

Soft bottom macrobenthic communities are key components in the functioning of coastal and marine ecosystems (Lu 2005). These bring about considerable changes in physical and chemical composition of sediments, especially in the water–sediment interface (Gaudencio and Cabral 2007; Shou et al. 2009). Macrofauna in marine sediments play an important role in ecosystem processes such as nutrient cycling, pollutant metabolism, dispersion and burial, and secondary production (Snelgrove 1998). Macrobenthos are residents of sediment surface with abundant oxygen and organic carbon. Among macrobenthos, polychaetes are one of the important organisms.

Polychaetes are bristle-bearing segmented worms belonging to phylum Annelida, class Polychaeta. Polychaetes being the most dominant

groups in benthic infaunal communities contribute about 80% to the total macrobenthic community and their diet include microbial (bacteria, microalgae, protists, and fungi), meiobial, and organic substance (Shou et al. 2009). In the trophic system, benthic fauna plays a significant role as they exploit all forms of food available in the sediment and form an important link in the energy transfer (Crisp 1971; Shou et al. 2009). Polychaetes form an important component in the marine food chain especially for bottom fish and some mammals as they form an important source of food for demersal fish (Parulekar et al. 1982; Herman et al. 2000).

Polychaetes are also being used for biomonitoring program as organic pollution indicators to check the health of the marine environment (Remani et al. 1983; Warwick and Ruswahyuni 1987; Jayaraj et al. 2007). It was only after 1970 that the work on marine soft bottom macrobenthos along the Indian coast has been carried out by several workers (Parulekar and Wagh 1975; Ansari 1977; Harkantra et al. 1980; Jayaraj et al. 2007).

Sediment parameters like grain size, organic content, and food availability are among the important factors affecting benthic community structure (Sanders 1958; Kari 2002). The present study was conducted to determine the diversity and distribution of the soft bottom polychaetes along the southeast and west coast of India. Observations were also made on macrobenthos belonging to other groups. Sediment characteristics were evaluated to understand their influence on macrobenthos.

Materials and methods

Sampling was carried out during December 2006 to January 2007 from 13 different locations viz. Mormugao, Karwar, Mangalore, Cannanore, Calicut, Kochi, Trivandrum along the west coast and Pondicherry, Chennai, Nellore, Nizamapatnam, Machilipatnam, and Kakinada along the east coast of India (Fig. 1). The samples were collected onboard CRV-*Sagar Sukti*. Sediment samples were collected in triplicate ($n = 3$) by operating van Veen grab (0.04 m^2). The sampling depth ranged from 26–28 m. The samples were washed separately through 500 μm nylon mesh at sea, transferred to plastic containers

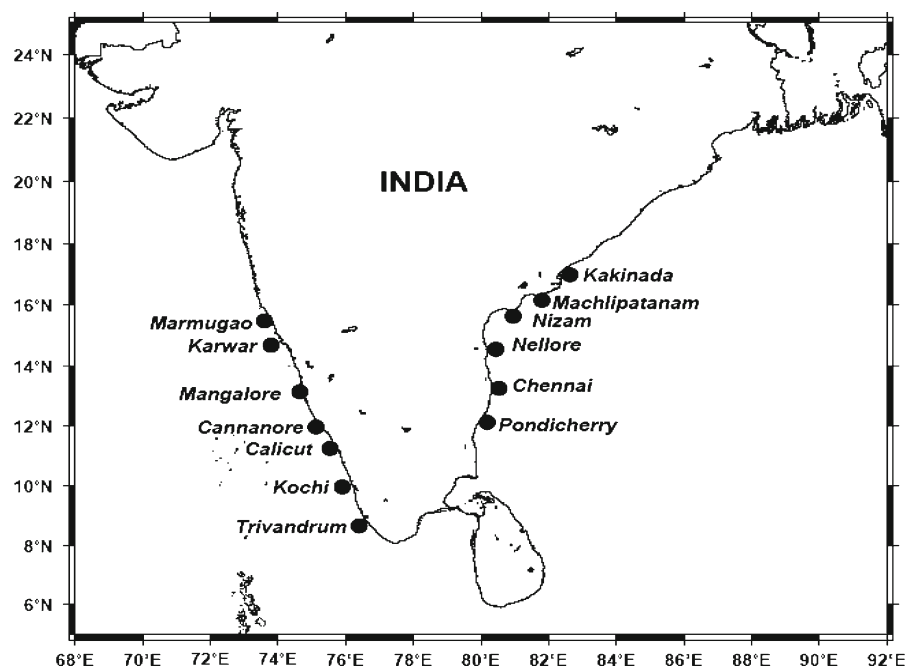

Fig. 1 Map showing sampling stations along the Indian coast

and preserved in 5% formaldehyde in seawater containing rose Bengal stain and were transferred to laboratory. Macrobenthic polychaetes were identified up to species level while other fauna such as crustaceans, mollusks, echinoderms, oligochaetes, nemertines, sipuncula, and fish larvae were recorded. The identification was done with the help of stereo zoom microscope following available identification keys (Day 1967; Gosner 1971). Numerical abundance of each species was recorded and expressed as number of species per square meter (no.m^{-2}). Organic carbon and percentage composition of sediment (sand, silt, and clay) was determined by standard titration method and pipette analysis, respectively (Wakeel and Riley 1956; Buchanan 1984). Organic carbon was expressed as percentage of sediment dry weight.

Polychaetes reflect the ecological and environmental status and were calculated in terms of number of individuals or specimens (N), number of species (S), total abundance (A), Margalef species richness (d), Pielou's eveness (J'), Shannon index (H') at each site (Clarke and Gorley 2001). Bray Curtis similarity for species diversity for all the species belonging to macrobenthic polychaetes was determined analytically by PRIMER-v5. One-way ANOVA was carried out to see the variation in the abundance of polychaete macrobenthos at different stations. Canonical correspondence analysis (CCA) was performed to evaluate the relationship between sediment characteristics (sand, silt, clay, and OC) and macrobenthic polychaetes and for the species belonging to genus *Prionospio* (ter Braak 1995) using the multi-variate statistical package version 3.1 (Kovach 1998).

Results

Sediment texture and organic carbon

Sediment texture analyses indicated a diverse nature of substratum along the entire sampled area. The percentage of sand was more than silt and clay along the west coast of India, at Mormugao, Kochi, and Trivandrum. In the rest of the west coast stations sediment texture is sandy-silt except at Calicut where silty-clay sediment was observed (Fig. 2). Along the east coast of India, southern stations (Pondicherry, Chennai, and Nellore) dominated by sand while northern stations (Nizamapatnam, Machilipatnam, and Kakinada) showed silt–clay substratum (Fig. 2).

The organic carbon for sediment ranged from 0.11% to 3% along the west coast of India. The minimum organic carbon was recorded at Cannanore and maximum at Calicut. Along the

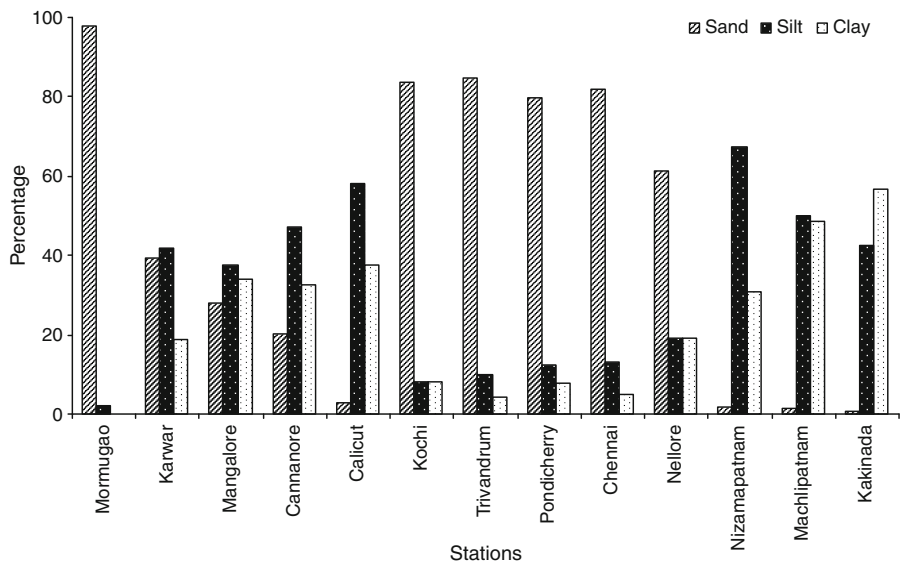

Fig. 2 Spatial variation in the sediment texture (percentage) along the coast

east coast it ranged from 0.59% at Nellore to 1.3% at Machilipatnam (Fig. 3).

Polychaete abundance and diversity

A significant variation ($p < 0.009$; one-way ANOVA) in the abundance of polychaetes was observed in different stations. In general the abundance was more along the west coast compared to east coast. The maximum abundance of polychaetes was observed at Kochi (4,475 no.m^{-2}) followed by Trivandrum (2,675 no.m^{-2}), and Calicut (2,550 no.m^{-2}) (Fig. 4a). At Mormugao and Cannanore, 1,675 and 1,050 no.m^{-2} polychaetes were recorded, respectively. The polychaete abundance at Karwar was minimal (200 no.m^{-2}). Along the east coast maximum abundance of polychaetes was observed at Pondicherry (1,650 no.m^{-2}). Rest of the stations showed comparatively lower abundance of polychaetes and minimum was at Chennai (125 no.m^{-2}; Fig. 4a).

Altogether 63 forms of polychaetes were identified during the study. Species belonging to genus *Prionospio*, *Magelona*, *Capitella*, and *Lumbrenerries* were widely distributed along the coast along with *Diopatra neapolitana*. Polychaetes belonging to genus *Magelona* are most dominant at Kochi (3,100 no.m^{-2}) compared to the other stations while *Glycera* sp. (425 no.m^{-2}), *Nephtys* sp. (200 no.m^{-2}), and *Cirratulus* sp. (350 no.m^{-2}) were abundant at Trivandrum (Table 1). It was observed that some macrobenthic polychaete species were found restricted to the west coast. The dominant among them are *Ancistrosyllis constricta*, *Cirratulus cirratus*, *Aricidea assimilis*, *Nephtys polybranchia*, *Lumbriconeris notocirrata*, *Cossura coasta*, and *Polydora* sp. Similarly some species were restricted to the east coast namely *Amphiarete* sp., *Magelona* sp., *Nephtys capensis*, and *Glycera longipinis*; however, the abundance of these species were less (Table 1). The CCA biplot for macrobenthic polychaetes (Fig. 4b), the two axes explained 79.99% of the relationship between macrobenthic polychaetes and sediment variables. Silt, clay, and organic carbon were the most important sediment variables influencing macrobenthic polychaete species abundance. *Heteromastus filiformis*, *Dorvillea* sp., *Ninoe* sp., and *Notomastus aberans* preferred clayey substratum whereas *Ancistrosyllis constricta* preferred silt. *Prionospio* sp.1, *Glycera* sp., *Sternaspis scutata*, *Cirratulus* sp., *Nephtys* sp.2, and *Onuphis* sp. preferred higher organic carbon values. The results depicted that group II polychaete species were favored by high organic carbon and silt and group III polychaete species were favored by higher percentage of clay. This signifies that the species indicated in group I preferred low percentage of clay and those in group IV preferred lower organic carbon and silt. This indicates that majority of polychaete species (groups I and IV) preferred low organic carbon and preferred either sandy-silt or sandy-clay substratum.

Polychaetes belonging to the genus *Prionospio* were most abundant and widely distributed along the study area. This genus which is mostly

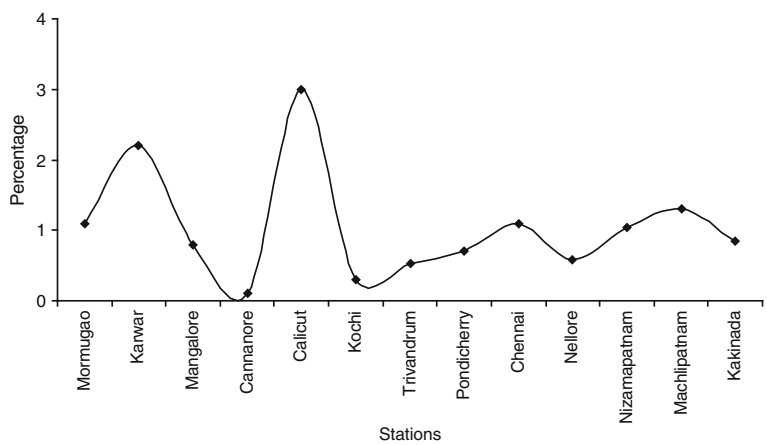

Fig. 3 Spatial variation in organic carbon (percentage) along the coast

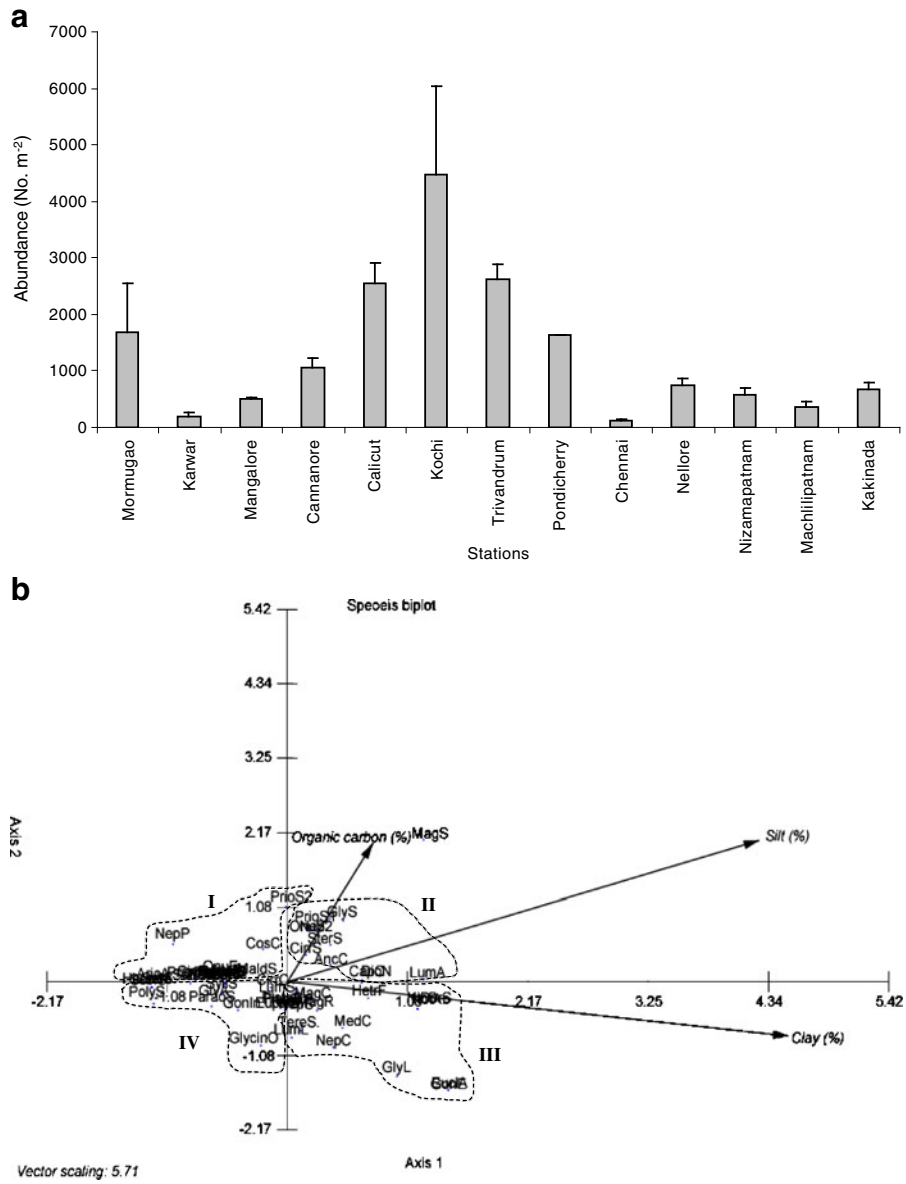

Fig. 4 **a** Spatial variation in the abundance of macrobenthic polychaete along the coast. **b** Canonical correspondence analysis showing polychaete species abundance and their relationship to sediment characteristics

represented by deposit feeders was the dominant genus in west and east coast except at Chennai and Machilipatnam and it was observed that their occurrence was not substratum specific and also they were found dominating both at low and high organic carbon areas (Fig. 5a). The results of the CCA biplot for abundant polychaete sp. Prionospip indicated, *Prionospio* sp.2 preferred higher organic carbon, silt, and clay whereas *Prionospio cirrifera* preferred lower values of organic carbon, silt, and clay (Fig. 5b).

On the basis of Bray Curtis similarity index which is applied for macrobenthic polychaete abundance, Cannanore and Calicut were grouped into one cluster and Nellore and Nizamapatnam as the second cluster at 50% similarity. The rest of the stations, Chennai, Mormugao, Kochi, Karwar, Mangalore, Trivandrum, Pondicherry, Machilipatnam, and Kakinada, were dissimilar at this level (Fig. 6).

The species diversity of polychaete was estimated based on Margalef species richness (*d*)

Table 1 Abundance of macrobenthic polychaete species in different stations

Species	Sps. code	Mormugao	Karwar	Mangalore	Cannanore	Calicut	Kochi	Trivandrum	Pondicherry	Chennai	Nellore	Nizamapatnam	Machilipatnam	Kakinada
Prionospio pinnata	PrioP	700	175	200	750	650	750	125	50					75
Prionospio cirrifera	PrioC	25						150	525					
Prionospio sp.1	PrioS1				75	1,175		600			25	25		
Prionospio sp.2	PrioS2					525		50	175			25		
Magelona cincta	MagC	150		25			2,900				100	25	25	25
Magelona rosea	MagR					25	200				25			25
Magelona sp.	MagS											50		
Glycera alba	GlyA	325		25			100	250			25			
Glycera longipinis	GlyL										25			25
Glycera sp.	GlyS				50	25		175			25	50		
Nephtys polybranchia	NepP	50	25					50						
Nephtys capensis	NepC								75					25
Nephtys sp.1	NepS			50				100	125				25	
Nephtys sp.2	Nep2							50			75	50		
Cirratulus cirratus	CirrC			25				200						
Cirratulus filiformis	CirrF							125	25					
Cirratulus sp.	CirrS					75		25	25	25	25	25		25
Ancistrosyllis constricta	AncC			100	150	50	150	25						
Ancistrosyllis parva	AncP								50					
Diopatra neopolitana	DioN	25						25			50	200	25	175
Capitella capitata	CapC				25			75	75		100	50	100	25
Lumbriconereis notocirrata	LumN	75												
Lumbriconereis latreilli	LumL						75		75					25
Lumbreneris aberrans	LumA										25	25		25
Lumbreneris sp.	LumS							25		25	100		25	
Orbinide	Orb							175	25					
Glycinde oligodon	GlycinO	150												25
Paraonide sp.	ParaoS						150		25					
Aricidea assimilis	AricA	50						100						
Mediomastus capensis	MedC							25	25				25	25

Mediomastus sp.	MedS								25					
Amphiarete sp.	AmphS								125					
Onuphis sp.	OnuS							50			25	25		
Euclymene annandalei	EuclA													100
Sternaspis scutata	SterS						25			25		25	25	
Syllis sp.	SyllS							50	25		25			
Sabella sp.	SabS						25	50		25				
Cossura coasta	CosC					25	50							
Maldane sarsi	MaldS			25				25		25				
Polydora sp.	PolyS.	50					25							
Terebellide sp.	TereS.							25	25					25
Amphiglena mediterranea	AmpM								50					
Dorvillea sp.	DorS												50	
Hesione pantherina	HesiP			25				25						
Onuphis eremita	OnuE							50						
Paralacydonia paradoxa	PrlP								50					
Pectinaria neopolitana	PectN							25						
Euphrasine myrtosa	EuphrMr										25			
Heteromastus filiformis	HetrF			25										
Notomastus aberans	NotAb												25	
Ninoe sp.	NinS												25	
Scoloplos sp.	ScolS	25												
Phyllodoce malmgreni	PhylM							25						
Goniada emerita	GonEr													25
Goniada incerta	GonIn						25							
Harmethoe imbricata	HarmIm	25												
Levensenia sp.	LevS								25					
Sabellides sp.	SabelS								25					
Pista sp.	PistaS.										25			
Terebellide stroemi	TerS										25			
Serpula sp.	SerS	25												
Flabelligera sp.	FlabS.										25			
Eurythoe sp.	EuryS								25					
Total		1,675	200	500	1,050	2,550	4,475	2,675	1,650	125	725	575	350	650

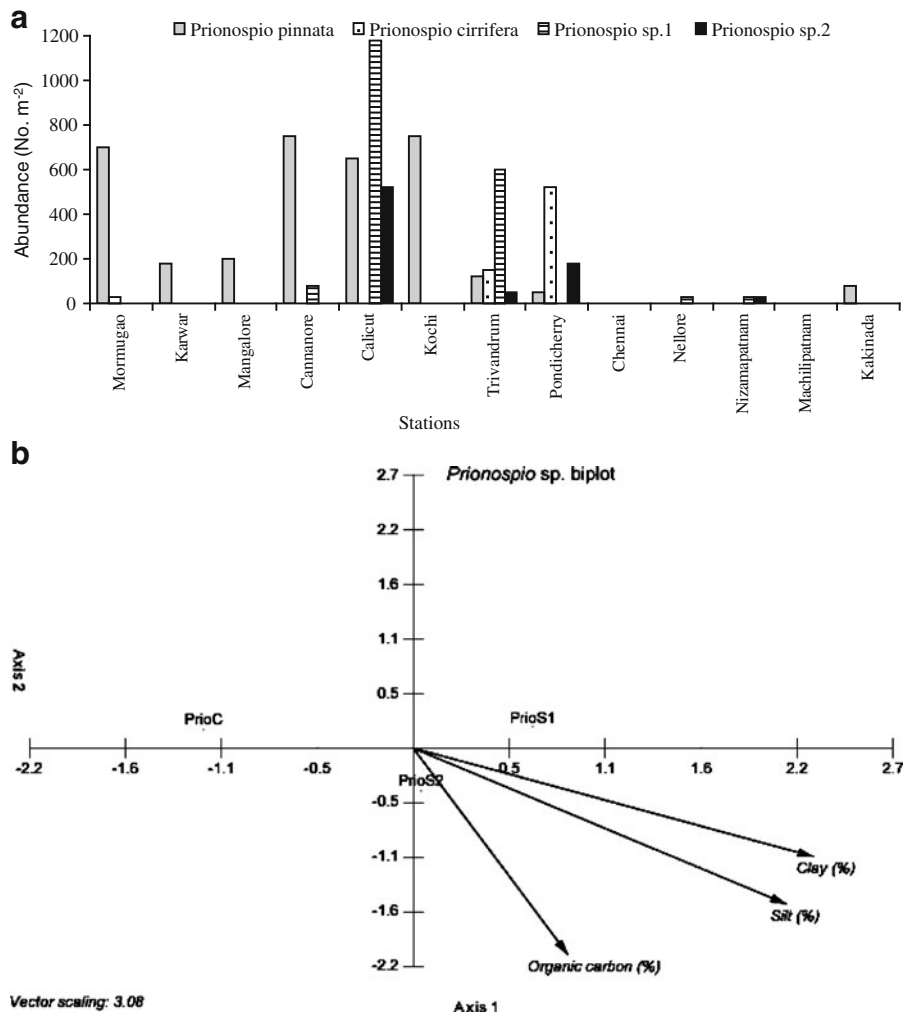

Fig. 5 **a** Distribution and abundance of species belonging to genus *Prionospio* along the coast. **b** Canonical correspondence analysis showing dominant polychaete (*Prionospio* sp.) and their relationship to sediment characteristics

and Shannon index (H'). Along the west coast species richness value ranged 0.188–3.421 (Karwar to Trivandrum), and along the east coast it was 0.828–2.56 at Chennai and Nellore, respectively. Shannon index (H') values ranged from 0.376 to 2.858 along the west coast from Karwar to Trivandrum and 1.609–2.690 at Chennai and Nellore, respectively, along the east coast (Table 2). In general the richness and diversity was higher in the region where the substratum was sandy followed by silty clay.

Other macrobenthic fauna

Among the other macrobenthic fauna, crustaceans (crabs, amphipods, prawn larvae, cumacea, and tanaids), mollusks (gastropods and bivalves), echinoderms, oligochaetes, and fish larvae were recorded along with nemertine and sipuncula (Fig. 7a). The other macrobenthic fauna were more uniformly distributed along the east coast (Fig. 7a). It was observed that along the west coast except for Mormugao, rest of the regions showed dominance of macrobenthic polychaetes. However, along the east coast the abundance of other macrobenthic fauna was almost similar and in Machilipatnam and Kakinada other groups dominated the macrobenthic population (Table 3). Sipuncula were found at Kochi and Trivandrum in west coast while along the east coast they were reported from Nellore, Machilipatnam, and Kakinada. Oligochaetes and

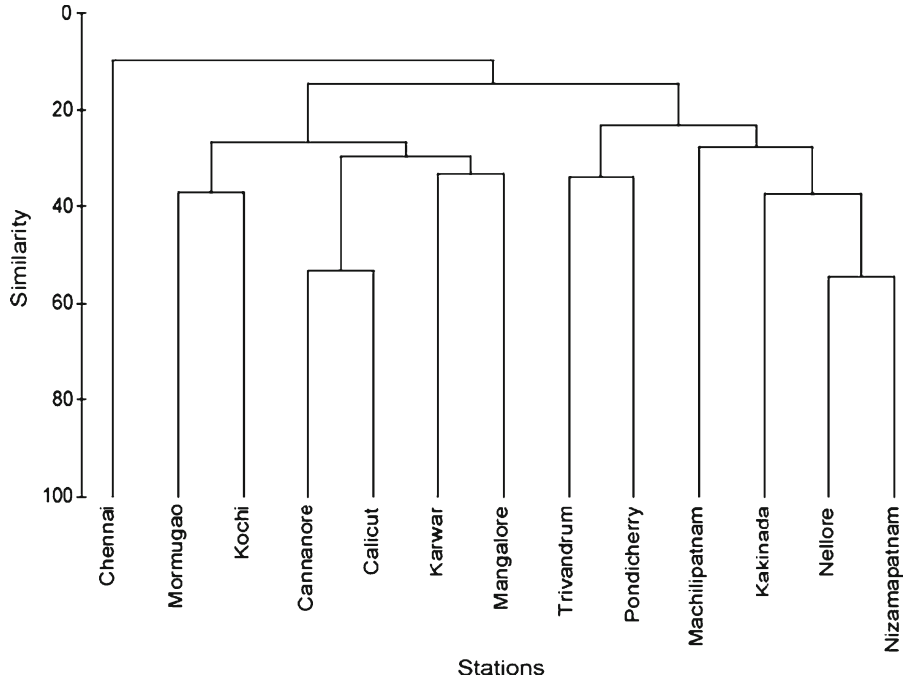

Fig. 6 Dendrogram for hierarchical clustering of macrobenthic polychaetes with Bray–Curtis similarity indices

fish larvae were encountered from Kakinada and Nizamapatnam (Fig. 7a). Bray Curtis similarity index showed two clusters and one single individual station. First cluster comprised Kochi, Mormugao, Trivandrum, Nizamapatnam, Pondicherry, Machilipatnam, Kakinada, Chennai, and Nellore whereas second cluster comprised of Mangalore, Cannanore, and Calicut. Karwar was dissimilar to the other stations (Fig. 7b).

Table 2 Number of species (S), number of specimens (N), Margalef species richness (d), Pielou's eveness (J'), and Shannon index (H) of macrobenthic polychaetes along the west and east coast of India

Stations	S	N	d	J'	H' (loge)
Mormugao (W)	13	1,675	1.61	0.73	1.88
Karwar	2	200	0.18	0.54	0.37
Mangalore	9	500	1.28	0.82	1.81
Cannanore	5	1,050	0.57	0.58	0.94
Calicut	8	2,550	0.89	0.64	1.34
Kochi	12	4,475	1.30	0.50	1.26
Trivandrum	28	2,675	3.42	0.85	2.85
Pondicherry (E)	22	1,650	2.8	0.82	2.53
Chennai	5	125	0.82	1	1.60
Nellore	18	750	2.56	0.93	2.69
Nizamapatnam	12	575	1.73	0.87	2.17
Machlipatnam	10	350	1.53	0.93	2.14
Kakinada	15	675	2.14	0.89	2.42

Discussion

The present study indicates higher polychaete diversity as compared to the earlier reports (Harkantra et al. 1982; Saraladevi et al. 1999). It was noticed that west coast of India is rich in polychaetes in terms of total abundance and diversity than the east coast. This was clear from Table 3, as west coast stations except Trivandrum showed higher percentage of polychaetes and at stations, Karwar, Mangalore, Cannanore, and Calicut their contribution to the total macrobenthos was more than 90%. From the results it has also been pointed out that 38 species of polychaetes showed higher abundance along the west coast compared to 25 species, showed higher abundance along east coast. Similar observations were made by earlier workers for the west coast (Parulekar and Wagh 1975; Harkantra et al. 1980; Ingole et al. 2002). A possible reason for this may be due to geo-physical process, i.e., southwest monsoon wind-driven upwelling leading to nutrient enrichment along the

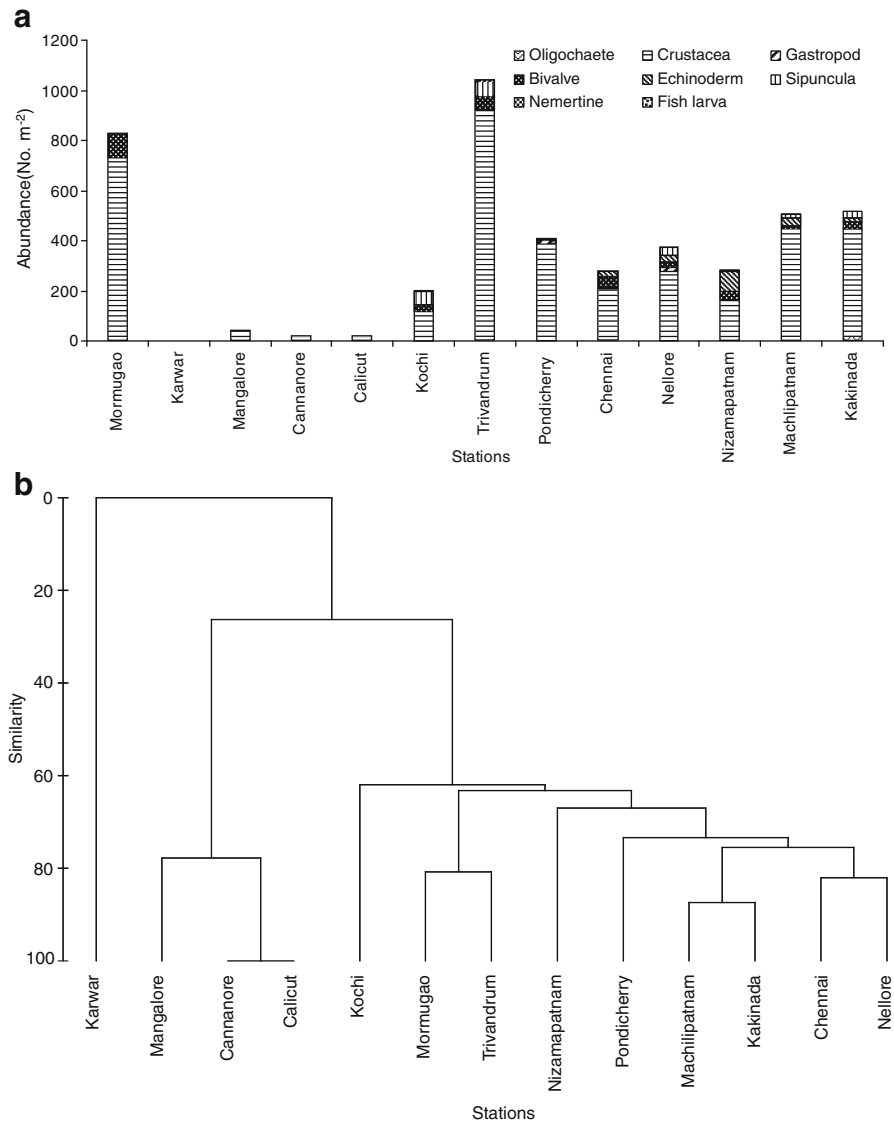

Fig. 7 **a** Abundance of other groups of macrobenthos reported from different stations along the coast. **b** Dendrogram for hierarchical clustering of other groups of macrobenthos with Bray–Curtis similarity indices

west coast (Goes et al. 1992), thus making Arabian sea along the west coast more productive than the Bay of Bengal. High abundance of polychaetes can also be attributed to high saline waters compared to east coast. Vizakat et al. (1991) while studying the ecology and community structure of soft bottom macrobenthos of Konkan, along west coast of India suggested recolonization of benthos when salinity increased indicating higher salinities positively influence the benthic population.

Sea bed composition (sand, silt, and clay) indicated a diverse nature of the benthic substratum along the study area. It was sandy at Mormugao, Kochi, and Trivandrum whereas Karwar, Mangalore, Cannanore, and Calicut showed a combination of silt and clay along the west coast of India. Pondicherry and Nellore, on the other hand, were sandier, and Nizamapatnam, Machilipatnam, and Kakinada were more silty and clayey along the east coast. Increased percentage of fine sediment may help to retain organic matter. The incidence of high species diversity and total abundance of polychaetes along the west coast might be attributed to loose texture of

Table 3 Percentage composition of polychaetes and other groups of macrobenthos along the west and east coast of India

Stations	Polychaete (%)	Other groups (%)
Mormugao	50.38	49.62
Karwar	100	0
Mangalore	91.78	8.22
Cannanore	96.5	3.5
Calicut	95.31	4.69
Kochi	68.14	31.86
Trivandrum	28.46	71.54
Pondicherry	50.78	49.22
Chennai	59.01	40.99
Nellore	52.13	47.87
Nizamapatnam	58.7	41.3
Machilipatnam	44.19	55.81
Kakinada	43.88	56.12

sediment character due to high content of sand. Similarly, Ansari (1977) reported high density and biomass of polychaetes are associated with sandy substrate. Generally, water content of the sediments reflects an increase in the fine particles (mud and clay) which can retain more water than coarse particles (sand and gravel). Such fine deposits or particles were commonly composed of decomposable organic constituents. As the organic content represents an important direct or indirect food source for benthic organisms, elevated organic matter may result in an enhancement of benthic metabolism (Gray 1981; Meksumpun and Meksumpun 1999). However, this metabolic increase causes a marked decline in sediment oxygen content (Pearson 1980) leading to anoxic conditions. Thus organically rich sediments may inhibit some benthic invertebrates. This may be the reason for the high abundance and diversity of polychaetes along the west coast, which constituted sand as the major composition in the sediment. Harkantra and Parulekar (1985) also observed that in clayey-sand and sandy substrate, faunal abundance is rich whereas only clay showed poor abundance. The specificity of fauna to the type of substratum largely depends upon the feeding habits. Fine particles of clay might result in clogging of the feeding apparatus of the filter feeders hence its avoidance of the fine particle size substrata although adequate supply of food is available (Harkantra 1982; Jayaraj et al. 2007). Palacin et al. (1991) also reported higher abundance of benthos in sandy sediment and low density in greater sedimentation area from Mediterranean Bay.

Some polychaete species were restricted to the west coast such as *Ancistrosyllis constricta*, *Cirratulus cirratus*, *Aricidea assimilis*, *Nephtys polybranchia*, *Lumbriconeris notocirrata*, *Cossura coasta* and *Polydora* sp. among these *Nephtys polybranchia* and *Lumbriconeris notocirrata* are carnivores and the rest are deposit feeding polychaetes. *Nephtys* sp. is an active predator mainly feed on the small crustaceans, mollusks, and other polychaetes. They possess jaws which could be used for seizing the prey (Pettibone 1963; Fauchald and Jumars 1979). It was reported that stable conditions allow many specialized species to be present in the areas, but competition for the sparse food is probably severe, which lead to low densities (Duineveld et al. 1991).

Despite from macrobenthic polychaetes, other macrobenthic forms which were dominant along the coast were crustaceans followed by mollusks, echinoderms, and sipuncula. It was also observed that the density of other macrobenthic forms was more along the east coast, except at Trivandrum and Mormugao where the density of crustaceans was high. Such observations were also reported from the west coast of India by Ingole et al. (2002) and Parulekar and Wagh (1975). A transition in the community structure was reported by Jayaraj et al. (2008) with a change in the sediment texture and depth. Other macrobenthic faunas especially crustaceans found dominant over the other macrobenthic groups along the east coast at Machilipatnam and Kakinada. Along the southwest coast of India demersal fisheries is more rich from the regions of 20–30 m. Higher biomass in higher depths of 15 to 30 m was reported (Kurian 1971). Parulekar et al. (1982) reported that areas around 30 m depth mainly supported high benthic production. Harkantra (1998) opined that as far as the demersal fishery recourses are concerned, the benthic biomass is more valid parameter in projecting the potential demersal fishery resources, which is also pointed out by Moiseev (1971). Godfriaux (1970) while studying the food of predatory demersal fish indicated that the fishes feed on some element of the benthic fauna; in general, crustaceans were the most important group.

Sediment composition is most important to the marine benthic organisms (Sanders 1958; Ingole et al. 1998) which provides shelter and food in the form of organic matter (Gray 1981). However, higher organic carbon is reported to cause a decline in species diversity, abundance, and biomass, possibly due to the oxygen depletion and build up of toxic by-products such as ammonia and sulfide (Jørgensen 1977; Revsbech and Jørgensen 1986; Snelgrove and Butman 1994; Hyland et al. 2005). Low diversity in shallow area can also be attributed to the depletion of oxygen by organic matter in the upwelling areas (Sanders 1968). The density of polychaetes was generally less at high organic carbon area except few species (Fig. 4b) providing a possible indication that high organic content adversely affect some of the polychaete species abundance and distribution. Jayaraj et al. (2007) reported that benthos especially polychaetes were low in high organic matter (>3%) areas. Harkantra et al. (1982) reported that organic matter beyond 4% adversely affected the macrobenthic organisms. In conditions of high organic carbon, diversity of the polychaetes is expected to be low. However, in the present study some species (Group II; Fig. 4b) could withstand high organic carbon associated with silt. Similarly, results from all the study site is observed to be true except Calicut which shows both high organic content (3%) and comparatively higher abundance of polychaetes (2,550 no.m^{-2}) with dominance of deposit feeders belonging to genus *Prionospio*, indicating that these species can withstand high organic carbon area and can be indicators of organically enriched area. Harkantra (1982) made a similar observation in which he stated that low and high value of organic content shows poor fauna and median values show rich fauna.

From the present study, Trivandrum in west coast has highest diversity index followed by Pondicherry and Nellore in east coast, indicating these areas to be ideal and environment is healthy for different species of polychaetes to thrive. This observation is also supported by the Shannon index (H') and species richness (d) values which are in the range of 2.5–3.5. For healthy environment H' and d are considered to be in the range of 2.5 to 3.5 (Magurran 1988). Along the remaining stations H' and d values are below 2.5 signifying the unhealthy status of the prevailing environment, while Karwar has the lowest value of H' and d (0.37 and 0.1, respectively) supported by very low abundance of macrobenthos. On the other hand, members of the family Spionidae (*Prionospio* sp.) and Capitellidae (*Capitella capitata*) were widely distributed along the southwest coast and east coast, respectively. While member of Eunicidae (*D. neapolitana*) occurred in Mormugao and Trivandrum along the west coast and they were also found widely distributed along northern east coast (from Nellore to Kakinada). Jayaraj et al. (2008) also made a similar report on the high occurrence of *Prionospio* sp. from the southwest coast. The incidence of these species indicates these areas are organically polluted. Remani et al. (1983) reported two species belonging to the genus *Prionospio* (*Prionospio polybranchiata* and*Prionospio pinnata*) in the Cochin backwaters at a municipal discharge point and suggested that these deposit feeding polychaetes to be favored by the organic enrichment. It can be pointed out here that CCA biplot indicated *Prionospio* sp2 preferred higher organic carbon. Elias et al. (2005) also indicated *Prionospio* sp. as an indicator of organic enrichment in subtidal areas. *C. capitata* has been regarded as an excellent indicator of pollution or environmental disturbance (Eagle and Rees 1973; Halcrow et al. 1973; Grassle and Grassle 1974, 1976). These observations suggest that the sampled area is organically enriched. Higher abundance of polychaete along the west coast can be attributed to loose texture of sediment due to high sand with higher interstitial space for polychaetes to harbor. Less abundance of polychaetes at high organic carbon areas is attributed to avoidance of these organisms to organic matter, being a possible indication that high organic matter adversely affects the abundance and distribution of macrobenthos.

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References

Ansari, Z. A. (1977). Macrobenthos of the Cochin backwater. *Mahasagar-Bulletin of the National Institute of Oceanography, 10*(3 & 4), 169–171.

Buchanan, J. B. (1984). Sediment analysis. In N. A. Holme & A. D. McIntyre (Eds.), *Methods for the study of marine benthos* (p. 41e645). Oxford: Blackwell Scientific Publications.

Clarke, K. R., & Gorley, R. N. (2001). *PRIMER v5: User manual/Tutorial* (p. 91). Plymouth: PRIMER-E Ltd.

Crisp, D. J. (1971). Energy flow measurements. In N. A. Holme & A. D. Mcintyre (Eds.), *Methods for the study of marine benthos. IBP Handbook 16* (pp. 197–279). Oxford: Blackwell Scientific Publications.

Day, J. H. (1967). *A monograph on the polychaete of Southern Africa Part-I and II, trustees of The British museum* (Natural history). London.

Duineveld, G. C. A., Kunitzer, A., Niermann, U., Dewilde, P. A. W. J., & Gray, J. S. (1991). The macrobenthos of the North Sea. *Netherlands Journal of Sea Research, 28*(1/2), 53–65.

Eagle, R. A., & Rees, E. I. S. (1973). Indicator species—A case for caution. *Marine Pollution Bulletin, 4*, 25.

Elias, R., Palacios, J. R., Rivero, M. S., & Vallarino, E. A. (2005). Short term responses to sewage discharge and storms of subtidal sand-bottom macrozoobenthic assemblages off Mar del Plata City, Argentina (SW Atlantic). *Journal of Sea Research, 53*, 231–242.

Fauchald, K., & Jumars, P. A. (1979). The diet of worms: A study of polychaete feeding guilds. *Oceanography and Marine Biology Annual Review, 17*, 193–284.

Gaudencio, M. J., & Cabral, H. N. (2007). Trophic structure of macrobenthos in the Tagus estuary and adjacent coastal shelf. *Hydrobiologia, 587*, 241–251.

Godfriaux, B. L. (1970). Food of predatory demersal fish in Hauraki Gulf. *New Zealand Journal of Marine and Freshwater Research, 4*(3), 248–266.

Goes, J. I., Gomes, H., Kumar, A., Gouveia, A. D., Devassy, V. P., Parulekar, A. H., et al. (1992). Satellite and ship studies of phytoplankton along the west coast of India. In B. N. Desai, (Ed.), *Oceanography of the Indian Ocean* (pp. 67–80). New Delhi: Oxford & IBH.

Gosner, K. L. (1971). *Guide to identification of marine and estuarine invertebrates XIX: 693.*

Grassle, J. F., & Grassle, J. P. (1974). Opportunistic life histories and genetic systems in marine benthic polychaetes. *Journal of Marine Research, 32*, 253–284.

Grassle, J. F., & Grassle, J. P. (1976). Sibling species in the marine pollution indicator *Capitella* (Polychaeta). *Science, 192*, 567–569.

Gray, J. S. (1981). The ecology of marine sediments. An introduction to the structure and function of benthic communities. In: *Cambridge studies in modern biology* (p. 185). Cambridge University Press.

Halcrow, W. D., Mackay, D. W., & Thorson, J. (1973). The distribution of trace metals and fauna in the firth of cycle in relation to the disposal of sewage sludge. *Journal of the Marine Biological Association of the United Kingdom, 53*(3), 721–739.

Harkantra, S. N. (1982). Studies on sublittoral macrobenthic fauna of the inner Swansea bay. *Indian Journal of marine Sciences, 11*, 75–78.

Harkantra, S. N. (1998). Benthos and demersal fishery resources assessment in the shelf region of Indian coast. Exploration and exploitation for sustainable development and conservation of fish stocks. In V. S. Somvanshi. (Ed.), *International symposium on large marine ecosystems, Kochi, India* (pp. 54–58). Fishery Survey of India.

Harkantra, S. N., & Parulekar, A. H. (1985). Community structure of sand-dwelling macrofauna of an estuarine beach in Goa, India. *Marine Ecology Progress Series, 30*, 291–294.

Harkantra, S. N., Nair, A., Ansari, Z. A., & Parulekar, A. H. (1980). Benthos of the shelf region along the west coast of India. *Indian Journal of Marine Sciences, 9*, 106–110.

Harkantra, S. N., Rodrigues, C. L., & Parulekar, A. H. (1982). Macrobenthos of the shelf off northeastern Bay of Bengal. *Indian Journal of marine Sciences, 11*, 115–121.

Herman, P. M. J., Middelburg, J. J., Widdows, J., Lucas, C. H., & Heip, C. H. R. (2000). Stable isotopes as trophic tracers: Combining field sampling and manipulative labeling of food resources for macrobenthos. *Marine Ecology Progress Series, 204*, 79–92.

Hyland, J., Balthis, L., Karakassis, I., Magni, P., Petrov, A., Shine, J., et al. (2005). Organic carbon content of sediments as an indicator of stress in the marine benthos. *Marine Ecology Progress Series, 295*, 91–103.

Ingole, B. S., Ansari, Z. A., & Parulekar, A. H. (1998). Spatial variation in meiofaunal abundance of some coralline beaches of Mauritius. *Tropical Ecology, 39*(1), 103–108.

Ingole, B. S., Rodrigues, N., & Ansari, Z. A. (2002). Macrobenthic communities of the coastal waters of Dabhol, west coast of India. *Indian Journal of Marine Sciences, 31*(2), 93–99.

Jayaraj, K. A., Jayalakshmi, K. V., & Saraladevi, K. (2007). Influence of environmental properties on macrobenthos in the northwest Indian shelf. *Environmental Monitoring and Assessment, 127*, 459–475.

Jayaraj, K. A., Jocob, J., & Dineshkumar, P. K. (2008). Infaunal macrobenthic community of soft bottom sediment in a tropical shelf. *Journal of coastal research, 24*(3), 708-718.

Jørgensen, B. B. (1977). The sulfur cycle of a coastal marine sediment (Limfjorden, Denmark). *Limnology and Oceanography, 22*, 814–832.

Kari, E. (2002). Soft sediment benthic biodiversity on the continental shelf in relation to environmental variability. *Marine Ecology Progress Series, 232*, 15–27.

Kovach, W. (1998). *Multi-variate statistical package*. Ver. 3.01, Pentraeth.

Kurian, C. V. (1971). Distribution of benthos on the Southwest coast of India. In J. D. Costlow Jr. (Ed.), *Fertility of the sea* (Vol. I, pp. 225–239). New York: Gordon and Breach Scientific Publication.

Lu, L. (2005). The relationship between soft bottom macrobenthic communities and environmental variables in Singaporean waters. *Marine Pollution Bulletin, 51*, 1034–1040.

Magurran, A. E. (1988). *Ecological diversity and its measurement*. Princeton: Princeton University Press.

Meksumpun, C., & Meksumpun, S. (1999). Polychaete–sediment relations in Rayong, Thailand. *Environmental Pollution, 105*, 447–456.

Moiseev, P. A. (1971). *The living resources of the world oceans* (p. 34). Jerusalem: Israel Prgramme for Scientific Translation.

Palacin, C., Martin, D., & Gili, J. M. (1991). Features of spatial distribution of benthic infauna in a Mediterranean shallow water Bay. *Marine Biology, 110*, 315–321.

Parulekar, A. H., Harkantra, S. N., & Ansari, Z. A. (1982). Benthic production and the assessment of demersal fishery resources of the Indian sea. *Indian Journal of Marine Sciences, 11*, 107–114.

Parulekar, A. H., & Wagh, A. B. (1975). Quantitative studies on benthic macrofauna of north-eastern Arabian Sea shelf. *Indian Journal of Marine Sciences, 4*, 174–176.

Pearson, T. H. (1980). Marine pollution effects of pulp and paper industry wastes. *Helgolander wiss Meersunters, 33*, 340–365.

Pettibone, M. H. (1963). Marine polychaetes worms of the New England region I. Aphroditidae through Trochochaetidae. *Bulletin of the United States National Museum, 227*(Pt. I), 1–356.

Remani, K. N., Devi, K. S., Venugopal, P., & Unnithan, R. V. (1983). Indicator organisms of pollution in Cochin backwaters. *Mahasagar, 16*(2), 199–207.

Revsbech, N. P., & Jørgensen, B. B. (1986). Microelectrodes: Their use in microbial ecology. *Advances in Microbial Ecology, 9*, 293–352.

Sanders, H. L. (1958). Benthic studies in Buzzards Bay. Animal–sediment relationships. *Limnology and Oceanography, 3*, 245–258.

Sanders, H. L. (1968). Marine benthic diversity: A comparative study. *American Naturalist, 102*(925), 243–282.

Saraladevi, K., Sheeba, P., Balasubramanian T., Venugopal, P., & Sankaranarayanan V. N. (1999). Benthic fauna of southwest and southeast coasts of India. In *The fourth Indian fisheries forum proceedings, 24–28 November, Kochi* (p. 9–12).

Shou, L., Huang, Y., Zeng, J., Gao, A., Liao, Y., & Chen, Q. (2009). Seasonal changes of macrobenthos distribution and diversity in Zhoushan sea area. *Aquatic Ecosystem Health & Management, 12*(1), 110–115.

Snelgrove, P. V. R. (1998). The biodiversity of macrofaunal organisms in marine sediments. *Biodiversity and Conservation, 7*, 1123–1132.

Snelgrove, P. V. R., & Butman, C. A. (1994). Animal–sediment relationships revisited: Cause versus effect. *Oceanography and Marine Biology Annual Review, 32*, 111–177.

ter Braak, C. J. F. (1995). Ordination. In R. H. G. Jongman, C. J. F. ter Braak, & O. F. R. Van Tongeren (Eds.), *Data analysis in community and landscape ecology* (pp. 91–173). Cambridge: Cambridge University Press.

Vizakat, L., Harkantra, S. N., & Parulekar, A. H. (1991). Population ecology and community structure of subtidal soft sediment dwelling macro-invertebrates of Konkan, west coast of India. *Indian Journal of Marine Sciences, 20*(1), 40–42.

Wakeel, S. K., & Riley, J. P. (1956). Determination of organic carbon in marine muds. *Journal of Du. Conseil International Exploration, 22*, 180–183.

Warwick, R. M., & Ruswahyuni (1987) Comparative study of the structure of some tropical and temperate marine soft bottom macrobenthic communities. *Marine Biology, 95*, 641–649.