

A comparative study of macrobenthic community from harbours along the central west coast of India.

Ingole* B, S. Sivadas, M. Nanajkar, S. Sautya, & A. Nag
Biological Oceanography Division,
National Institute of Oceanography, Dona Paula, Goa-403004, INDIA.
*email:baban@nio.org
Tel No. 91- (0) 0832-2450242; Fax No. 91-(0) 0832-2450606

Abstract

Harbours are heavily stressed coastal habitats characterised by high concentration of contaminant and low diversity of benthic community. The west coast of India harbours most of the major harbours compared to the east coast. Very few studies have compared the macrobenthic community between different Indian harbours. The present study was therefore conducted in three important harbour (Ratnagiri, Goa, Karwar) along the central west coast of India. The paper discusses the health status of the three harbours diagnosed using various biotic indices. Sediment samples were collected using van Veen grab (0.11 m²) on board *CRV Sagar Sukti*.

A total of 55 macrobenthic taxa were identified and were numerically dominated by polychaete. Biomass was high (0.14- 145.7 g m⁻²) and was made largely by echinurans (>80%). Overall, polychaete dominated the macrobenthic diversity. Opportunistic *P.pinnata*, *Notomastus* sp. and *Mediomastus* sp., dominated the macrobenthic community responding to the increased in the harbour. Biotic indices (Polychaete:Amphipod ratio, ABC curve and geometric class abundance) and the dominance of opportunistic species indicate that, the three harbours are under stress from anthropogenic activities.

Key words: macrobenthos, polychaetes, harbour pollution, west coast, India.

1. Introduction

Harbours are the lifeline of a country's economy as bulk of the trade takes place through them. However, from the environmental point of view they are the most altered coastal habitats and

cause considerable pollution of water, air and land. Further, several other activities like fisheries, industries and tourism occurs in and around the area that may have an impact on the environment. The harbours are characterised by reduced dissolved oxygen level and higher concentration of pollutants in water and sediment (Danulat et al. 2002; Rivero et al. 2005).

In general, levels of pollution along the Indian coast are increasing and the west coast perhaps, is more polluted compared to the east coast (Sengupta et al. 1989; Zingde, 2002). This may be because most of the major harbour and harbours are located along the west coast resulting in higher movement of transport vessels. In fact, two of the major oil routes of the world pass through the Indian water and 70% of the world's oil is transported through this route (Anon, 2003). In addition, over 53,684 mechanised trawlers and about 2, 25862 traditional fishing vehicles operate along the coastal waters of India (Somvanshi, 2003). Further, the west coast of India is recognized as biodiversity hotspot and contributes to >70% of the countries marine capture fishery.

Assessment of coastal ecosystem change can be effectively monitored using benthic fauna, as pollutant from any source will ultimately ends in the seabed. The benthic communities play an important role in the transfer of materials from primary production through the detrital pool into higher trophic levels, including commercially exploitable fish (Bryan and Langston, 1992; Ingole, 2006). The relation between the benthic standing stock and demersal fish resources has been very well documented for Indian waters (Harkantra, 2004). Further, majority of the benthic fauna are sedentary and sessile and thus, cannot avoid any environmental perturbation (Danulat et al. 2002), hence are considered sensitive indicator of changes in the environment caused by natural and anthropogenic disturbances.

Mormugao is a major commercial port whereas; Karwar and Ratnagiri are minor ports along the central west coast of India. However, in recent years the commercial activities are on an increase in all the three harbours. In view of this, the respective state governments have considered the expansion. Further, the coastal waters between Ratnagiri and Karwar are recognized as active fishing zone (Madhupratap et al. 2001; Ingole et al. 2002). Due to their strategic location along the central west coast of India, the importance of all the three harbours is considered to further increase in years to come. Thus, the coastal areas along the central west coast of India are a suitable ecosystem to observe the impact of harbour activities by studying the macrobenthic community.

Although studies have been performed along Mormugao, Karwar and Ratnagiri coast, few biological studies corresponding specifically to the macrobenthic community of the harbour have been carried out. Thus, the present study aims to contribute to the knowledge of the macrobenthos and its potential use as diagnostic tool for assessing the environmental health status the harbour.

2. Methods

2.1 Study area

Field sampling was conducted at Mormugao, Karwar and Ratnagiri (Fig.1). The Mormugao harbour is situated near the historic city of Vasco-da-Gama (15°27'48" N; 73°38'64"E) along the Goa coast. Mormugao port, with a fine natural harbour is one of the oldest major ports on the west coast of India. The port accounts for about 39% of India's iron ore exported and ranks within the first ten leading iron ore exporting ports of the world. During the financial year 2003-2004, the port handled 8% of the total traffic handled by all the twelve major port of India. Ratnagiri harbour is situated (17°00'38" N and 73°15'34"E) in the Mirya Bay along the Maharashtra coast. Karwar port is situated in north Karnataka (14° 50' 36" N and 73° 54' 55" E) in the mouth of Kali estuary. The Karwar Harbour is one of the best natural all weather harbour. It has a 355 m long quay for accommodating simultaneous berthing of two ocean-going ships. The harbour is used for loading and unloading of all types of commodities including petroleum products. The water depth in the study area varies from 5-40 m. The sediment in the inner harbour was generally dominated by silt and clay whereas; outer harbour has higher content of fine sand.

2.2 Sample Collection

Sediment samples were collected on board *CRV Sagar Sukti* (SASU-105) in January 2006 using van Veen grab (0.11 m²). Sub sampling was done with a quadrant (225 cm²). Two stations were sampled in each harbour. Five grab were collected from each station at Ratnagiri (Rat 1 and Rat 2) and Kavar (Kar 1 and Kar 2) and triplicate samples from Goa (Goa 1 and Goa 2). Reference station was not taken as the sediment outside the harbour was dominated by sand in all the three harbours. All the samples were sieved on board through a 0.5mm mesh, and the materials retained were preserved in 5% buffered formalin Rose-bengal solution. In the

laboratory, macrofauna was sorted, counted and identified to the lowest possible taxonomic level. Group-wise biomass was measured by wet weight method.

At each station, sediment sample was also taken with acrylic core (\varnothing 4.5 cm) for the analysis of sediment chlorophyll, phaeopigment and organic carbon. Chlorophyll *a* (Chl *a*) and phaeopigment were analysed by acetone extraction method (Holm-Hansen, 1978) and organic carbon was estimated with CO₂ Coulometer after acidification of sediment to remove the inorganic carbon.

2.3 Data Analysis

Faunal data was processed using univariate and multivariate methods. Species richness, Shannon-Weiner diversity (*H'*), Peilou's evenness (*J'*), Margalef's species richness were calculated using PRIMER (Clarke and Warwick, 1994). Multidimensional Scaling (MDS) and Bray- Curtis similarity index was constructed based on macrofauna counts after log transformation. Following the division into groups from results of cluster analysis, the species having the greatest contribution to this division were determined using similarity percentage program SIMPER. Geometric class and Abundance biomass comparison curve (ABC curve) and the benthic opportunistic polychaete amphipod index (BOPA; Dauvin and Ruellet, 2007) were used to determine the environmental status of the study area. The significance of variation of benthic data was tested by analysis of variance (ANOVA). The normality of the data was verified using the Kolmogorov-Smirnov test and the homogeneity of variances using the Levens' test using STATISTICA 6. When data did not satisfy the assumptions of the parametric tests, the data was log transformed to achieve normality.

3. Results and Discussion

The sediment chl-*a* values ranged from 0.18- 0.35 $\mu\text{g g}^{-1}$ with highest values recorded in Mormugao and lowest at Ratnagiri harbour. Sediment organic carbon ranged from 1.4-3.5% with highest values in Goa. Since all the three harbours are located in close proximity of highly populated towns, the organic loading in the area may be mainly from the inflow of domestic waste and fishing activities (Ansari et al. 1994; Anon, 1996). Moreover, the harbours are located near the mouth region of the estuary, which brings significant amount of organic material from the upper reaches and deposit in the estuary. River flow is considered to be another major source of organic load in harbours (Webber and Kelly, 2003).

The macrofaunal community in the present study was comprised of 55 taxa belonging to 6 phyla (Table 1). Although, the ecological setting as well as water depth in all the three harbour were similar (varying from 5-30m) macrofauna showed significant variation in composition and abundance. The macrobenthic abundance ranged from 1214 -15407 ind m⁻² (6135±5045.8; Fig 2). Stations in Ratnagiri recorded the highest abundance and lowest values were in Goa. The macrobenthic abundance did not show significant variation within the harbour (p>0.05) but differed significantly between the harbours (p<0.001). Biomass (wet wt.) also showed greater variability between the stations and ranged from 0.14 (Goa) to 145.77 g m⁻² (Karwar). The higher biomass was largely due to the occurrence of bigger sized echiurids, accounting to 85 % of the macrofaunal biomass at Karwar. Biomass value shows significant variation within stations (p<0.03), however biomass did not show significant variation between the harbours (p>0.05).

Polychaetes were numerically dominant accounting for 96% of the total macrofauna. Dominance of polychaete worms was as expected for harbour area and compares well with other harbour studies (Raman, 1995; Belan, 2003; Guerra-García & García-Gómez, 2004; Rivero et al. 2005). The density data was subjected to Bray-Curtis cluster analysis and detected three groups (Fig. 3a). Group I consisted of Ratnagiri stations with 66.36% similarity. Goa 1 and Goa 2 (Group II) clustered at 69.73% and third group comprised of Karwar stations (80.24%). MDS ordination confirmed the results of cluster, and detected the same three groups (Fig. 3b). The community data was subjected to SIMPER analysis to find the species which contributed to the similarity within each group. Accordingly, Ratnagiri was dominated by *Mediomastus* sp. (42.35%), *Prionospio pinnata* (24.76%), *Cossura* sp.; Group II (Goa)- *P.pinnata* (30.88%), *Eunice* sp. (17.65), *Aricidea* sp. (8.82%) ; Group III (Karwar) - *P. pinnata* (53.6%), *Notomastus* sp. (21.58), *Mediomastus* sp. (12 %). The species, which resulted in the dissimilarity in the three harbours, are listed in Table 2.

The species composition showed that, the macrobenthic community was represented by fewer species which contributed to >60% of the total abundance (Table 3). *P.pinnata*, *Mediomastus* sp., *Notomastus* sp. of the family Spionidae and Capitellidae dominated. Species belonging to the above families are largely opportunistic and proliferate in sediments with high organic enrichment (Pearson and Rosenberg, 1978; Glémarec and Hilly, 1981). Further, Spionidae and Capitellidae contributed to 20% of the total polychaete species (Table 1). High organic content in sediment can promote the abundance of some tolerant species and reduce sensitive species (Pearson and Rosenberg, 1978). *P.pinnata* was the most dominant species at Goa and Karwar, which also showed the highest organic carbon values. *P. pinnata* is a cosmopolitan species

occurring in organically rich sediment and in areas subjected to continuous disturbance (Pearson and Rosenberg, 1978). In Ratnagiri, *Mediomastus* sp. contributed to 36% of the macrofaunal abundance. *Mediomastus* sp. is reported to dominate in areas of moderate disturbance and high energy environment (Rivero et al. 2005). In fact, species belonging to the genus *Mediomastus* sp. flourish in habitat with moderate amount of organic matter with total absence in area of high organic pollution (Pearson and Rosenberg, 1978).

The dominance of few species was further confirmed from the geometric abundance curve (Fig. 4). In the geometric abundance curve, the number of species represented by a single individual are in class 1, 2-3 individuals in class 2, 4-7 (class 3), 8-15 (class 4) and so on. In unpolluted situation, the community is represented by rare species resulting in a smooth curve with its mode to the left. In polluted condition, the community is represented by few rare species and abundance of few species, so that higher geometric abundance classes are more strongly represented and the curve become irregular. In the present study, the geometric abundance curves are very irregular and extend from class 2 - 13 for Ratnagiri (Fig. 4 a) and class 2-10 in Mormugao (Fig. 4 b) and to class 2-12 in Karwar (Fig. 4c). Therefore, it can be concluded that the area under investigation was dominated by higher abundance of few species, perhaps resulting from stress conditions due to anthropogenic activities.

Most invertebrate species observed during this investigation were small in size. The possible explanation for the presence of small-sized polychaetes is that the area is frequently disturbed by natural and anthropogenic factors. All the three harbour are located towards the estuarine mouth, an area in the estuary with the strongest hydrodynamics. Further, to maintain required water depth in the harbours, the area is regularly dredged. This may have resulted in the dominance of small, opportunistic, tube-dwelling polychaetes, which are the first faunal components to colonize in disturbed areas (Rhoads and Boyer, 1982). A similar association of small sized polychaetes was observed in the northern shallow shelf of Chile and Peru affected by sewage discharge (Carrasco, 1997).

Crustaceans were the second dominant group and the community was represented by a total of 16 species (Table 1). The most dominant was the amphipod *Ampelisca* sp., with highest abundance recorded in Mormugao harbour (755 ind m⁻²). In fact, *Ampelisca* sp is known to dominant in muddy sediments and are well adapted to stress environment (Lowe and Thompson, 1997).

The number of species ranged from 21 species (Goa 2) to 36 species at Rat 2. Species richness (d) was also highest at Rat 1 (1.7) and lowest at Kar 1 (1.2; Fig 5). Species diversity (H') was lowest at Kar 1 (1.4.) and highest at Rat 1 (2.1). Generally, the estuarine communities are subjected to greater natural stress than those in non-polluted coastal waters and are expected to show lower macrobenthic diversity index. Wilhm and Dorris (1966) stated that values <1.0 for diversity index (H') in estuarine waters was common when heavy pollution occurred; values between 1.0 and 3.0 indicated moderate pollution; and values exceeding 3.0 characterized non-polluted water. Diversity value in the study area ranged from 1.6 to 2.4. Thus, clearly indicates that the harbours are polluted and the macrobenthic community is under stress due to natural and/ or anthropogenic factors. Evenness (J) was higher in Goa (0.8) and lower in Karwar and Rat 2 (0.61). The lower J values obtained at Karwar were due to the dominance of *P. pinnata*, *Notomastus* sp. and *Mediomastus* sp. accounting to 83% of the total abundance. *Mediomastus* sp., *P. pinnata*, *Prionospio* sp. and *Cossura* sp. together contributed to 91% of the total macrofaunal abundance at Rat 2. Two-way ANOVA showed significant differences in species number and evenness ($p<0.05$) between the harbours. Within the site, significant differences in species diversity ($p<0.05$) were however observed only at Ratnagiri.

Various biotic indices have been formulated to study the pollution status of the marine environment. The opportunistic polychaete/amphipod ratio (P: A) based on ecological groups was used in the present study (Dauvin and Ruellet, 2007). The P: A ratio ranged from 0.22 in Mormugao to 0.27 in Karwar. P: A values 0 indicate unpolluted condition and 0.3 indicates a grossly polluted condition. The abundance/ biomass comparison (ABC) approach is recommended by Warwick (1986) who stated that, the ABC is suitably an abbreviated descriptor of the state of marine pollution. In certain cases the ABC curve can give wrong picture and can be overcome by the use of partial dominance curve (Warwick & Clarke, 1994). In Goa, the abundance curve crossed the biomass curve at several points which was mainly due to the dominance of small sized polychaete species having high density but low biomass (Fig. 6 a). The ABC curve showed partial dominance of density over biomass at Ratnagiri (Fig. 6b) and at Karwar the biomass curve dominated over the density curve (Fig.6 c) with crossing at two points. The dominance of biomass curve at Karwar and Ratnagiri was due to the dominance of echinurans that accounted to $> 80\%$ of the total biomass. The ABC curve is based on the concept that polluted areas are dominated by small-sized species with low biomass. However, dominance of large sized bioindicators, as in the present study can give a “wrong” picture of the pollution status of an area. Echinurans are deposit feeders inhabiting fine-grained, organically

rich sediment. Stull (1986) observed that the echiuran worm, *Listriolobus pelodes* reduced the negative effects of wastewater discharge like reducing the pore water hydrogen sulphide and showed high diversity in the coastal shelf region of Palos Verdes, S. California. This was evident from decrease in diversity and increase in opportunistic species of polychaete (*Capitella capitella*) after the decline of the echiuran worm (Stull, 1986).

The use of biotic indices have often been criticised as many of the indices have given wrong interpretation in areas, which are naturally stressed. Therefore, the combination of indices gave been suggested. In the present study various univariate and multivariate indices were used to detect the degree of pollution. Though all the indices showed a polluted condition the degree of pollution differed. Species richness, abundance of stress tolerant/sensitive species and trophic function and composition were the most successful measurement in differentiating the diversity grade of pollution leading us to think that increase or decrease in the number of tolerant/sensitive species is one of the best disturbance indicator and therefore, essential when it comes to differentiate ecological states. Vincent et al. (2002) observed that the methods combining composition, abundance and sensitivity might be the most promising. Species richness was highest at Ratnagiri and was dominated by deposit feeding *Mediomastus* sp. The area also showed the lowest organic carbon content (1.4%). On the other hand, lowest species richness and highest organic carbon were seen at Goa (3.5%) and Karwar (2.8%). Moreover, opportunistic *P.pinnata* dominated the area. The high pollution at Goa and Karwar harbour are expected since the shipping activities are higher compared to Ratnagiri harbour.

The benthic communities are strongly linked to higher trophic levels; therefore any alteration of their trophic structure potentially affects the fishery production of an area. Fisheries in estuarine regions depend more on taxa available at the sediment surface, such as amphipods, mysids, and surface deposit feeders (SDF) polychaetes, than on subsurface deposit feeders (SSDF) (Hines et al. 1990; Franz & Tanacredi, 1992). Demersal fish constitutes the major portion of the commercial fish landing (particularly the prawns) and any change or alteration in benthic standing stocks will reflect directly in the demersal fish production. Preliminary results of the recent coastal surveys also suggest increasing level of pollution at Ratnagiri, Goa and Karwar (Anon, 1996; Nanajkar and Ingole, 2007). This along with the increased fishing efforts, over-fishing, may be the main cause for decline in the fishery production of the area (Ansari, 2006). Although, macrofaunal abundance was relatively higher at Ratnagiri compared to Goa and Karwar, the fauna was largely comprised of the small-sized, opportunistic annelid species that did not contribute significantly to the benthic biomass.

Continuous assessments of areas under stress, such as harbour, are therefore needed to determine the temporal changes in the community. The long-term monitoring can be time-consuming and expensive. Therefore, the concept of bioindicator should be attempted to use their presence in an area to characterise a certain degree of community change or pollution effects. This approach has been widely applied to benthic monitoring studies and was successfully used in the present study to determine the impact of harbour activities on the marine environment along the central west coast of India.

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Table 1

Macrobenthic species list of the study area (+ present; - absent)

Stations	Rat 1	Rat 2	Goa1	Goa2	Kar 1	Kar 2
Echiurida	+	+	-	-	+	+
Sipuncula	-	+	+	-	-	-
Polychaeta						
Family Phyllodocidae						
<i>Phyllodoce</i> sp.	-	+	+	+	-	-
<i>Eteone</i> sp.	-	+	-	-	-	+
Family Aphroditidae						
<i>Sthenelais</i> sp.	-	-	-	+	-	-
Family Syllidae						
<i>Syllis cornuta</i>	-	-	-	+	-	-
Family Pilargiidae						
<i>Ancistrosyllis</i> sp.	+	+	+	-	-	+
<i>Cabira</i> sp.	+	+	-	-	+	+
Pilargidae	-	-	-	-	-	+
Family Nephtyidae						
<i>Nephtys</i> sp.	+	+	+	+	+	-
Family Nereidae						
<i>Nereis</i> sp.	+	+	+	-	-	+
Family Glyceridae						
<i>Glycera alba</i>	+	+	+	-	+	+
<i>Glycera</i> sp.	+	-	-	-	+	+
Family Goniadidae						
<i>Glycinde</i> sp.	-	+	-	-	+	-
Family Cirratulidae						
<i>Tharyx</i> sp.	+	+	+	+	-	-
Family Spionidae						
<i>Prionospio krusadensis</i>	+	-	-	-	-	-
<i>Prionospio pinnata</i>	+	+	+	+	+	+
<i>Prionospio</i> sp.	+	+	+	+	+	+
Family Magelonidae						
<i>Magelona</i> sp.	-	+	-	-	-	-
Family Capitellidae						
<i>Mediomastus</i> sp.	+	+	+	+	+	+
<i>Notomastus</i> sp.	-	+	+	+	+	+
Capitellidae	-	-	-	-	-	+
Family Dorvilleidae						
<i>Dorvillea</i> sp.	+	-	+	+	-	-

Table 1 Contd...

Stations	Rat 1	Rat 2	Goa1	Goa2	Kar 1	Kar 2
Family Lumbrineridae						
<i>Lumbriconereis latereilli</i>	+	+	+	+	+	+
Family Eunicidae						
<i>Eunice</i> sp.	+	-	+	+	-	-
Family Onuphidae						
<i>Onuphis</i> sp.	+	-	+	+	-	-
Family Sternaspidae						
<i>Sternaspis scutata</i>	+	-	-	+	-	-
Family Terebellidae						
<i>Terebella</i> sp	+	-	+	+	-	-
Family Sabellidae						
<i>Jasmineira</i> sp.	+	+	+	+	-	-
<i>Hypsicomus</i> sp.	-	+	-	-	-	-
Family Serpulidae						
<i>Hydroides</i> sp	-	+	+	+	+	+
Family Cossuridae						
<i>Cossura</i> sp.	+	+	+	+	+	+
Family Paraonidae						
<i>Aricidea</i> sp.	+	+	+	+	+	+
<i>Levinsenia</i> sp.	+	-	+	+	+	+
Amphipoda						
Family Ampeliscidae						
<i>Ampelisca</i> sp.	+	+	+	+	+	+
Family Hyalidae						
<i>Hyale</i> sp.	+	-	-	-	-	-
Family Haustoriidae						
<i>Urothoe</i> sp.	-	+	-	-	-	-
Family Oedicerotidae						
<i>Synchelidium</i> sp.	+	+	-	-	-	-
Family Liljeborgiidae						
<i>Liljeborgia</i> sp.1	+	+	-	-	+	-
<i>Liljeborgia</i> sp.2	+	+	+	-	-	+
Family Ampithoidae						
<i>Ampithoe</i> sp.	+	-	-	-	-	-
Family Isaeidae						
Isaeidae(Unidentified)	+	+	-	-	+	-

Table 1 Contd..

Stations	Rat 1	Rat 2	Goa1	Goa2	Kar 1	Kar 2
Family Caprellidae						
Caprellidae (Unidentified)	-	-	+	-	-	-
Family Podoceridae						
Podoceridae (Unidentified)	+	-	-	-	-	-
Unidentified Amphipoda	+	-	-	-	+	+
Cumacea	+	+	-	-	+	-
Family Squillidae						
<i>Squilla</i> sp.	+	+	-	-	-	-
Decapoda						
Family Grapsidae						
Varuninae	-	-	-	-	+	+
Brachyurans	-	-	-	-	+	-
Family Penaidae	-	-	+	-	-	-
Gastropoda						
Family Potamididae						
<i>Cerithidae</i> sp.	-	-	-	-	+	-
Bivalvia						
Family Nuculanidae						
<i>Nuculana</i> sp.	-	+	-	-	-	-
Family Lucinidae						
<i>Lucina</i> sp.	-	-	-	-	+	+
Family Tellinidae						
<i>Tellina</i> sp.	+	-	-	-	-	+
Family Veneridae						
Unidentified Bivalvia	+	+	-	-	-	-

Table 2

SIMPER analysis based on group obtained from cluster and MDS ordination showing the species that contributed to the differences among the groups.

Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
GROUP						
Avg. dissimilarity 78.7	Rat	Goa				
<i>Mediomastus</i> sp.	4386.72	81.4	30.07	3.71	38.17	38.17
<i>Cossura</i> sp.	1691.64	111	10.84	2.64	13.76	51.93
<i>Prionospio pinnata</i>	1900.32	740	8.37	1.64	10.62	62.55
Avg. dissimilarity 64.0	Rat	Kar				
<i>Mediomastus</i> sp.	4386.72	492.84	22.05	2.56	34.45	34.45
<i>Notomastus</i> sp.	4.44	1509.6	9.55	1.8	14.93	49.38
<i>Cossura</i> sp.	1691.64	279.72	7.86	1.92	12.28	61.66
Avg. dissimilarity 67.5	Goa	Kar				
<i>Prionospio pinnata</i>	740	2060.16	20.37	1.93	30.15	30.15
<i>Notomastus</i> sp.	74	1509.6	20.25	2.11	29.97	60.12
<i>Mediomastus</i> sp.	81.4	492.84	6.26	2.76	9.26	69.38

Table 3
Composition (%) of dominant species at various sampling location
observed during the present study

Stations	Rat 1	Rat 2	Goa 1	Goa 2	Kar 1	Kar 2
<i>Mediomastus</i> sp.	30.55	41.96	4.66	2.44	8.14	12.77
<i>Prionospio pinnata</i>	17.86	15.91	40.93	25.61	36.46	50.00
<i>Cossura</i> sp.	10.93	16.60	7.25	1.22	6.73	4.33
<i>Notomastus</i> sp.	0.00	0.06	4.66	1.22	38.65	20.13
<i>Aricidea</i> sp.	2.47	2.48	3.11	8.54	0.16	0.65
<i>Prionospio</i> sp.	1.76	16.71	2.07	6.10	1.41	1.95
<i>Eunice</i> sp.	0.47	0.00	6.22	20.73	0.00	0.00
<i>Ampelisca</i> sp.	0.47	0.23	9.33	2.44	0.16	0.22

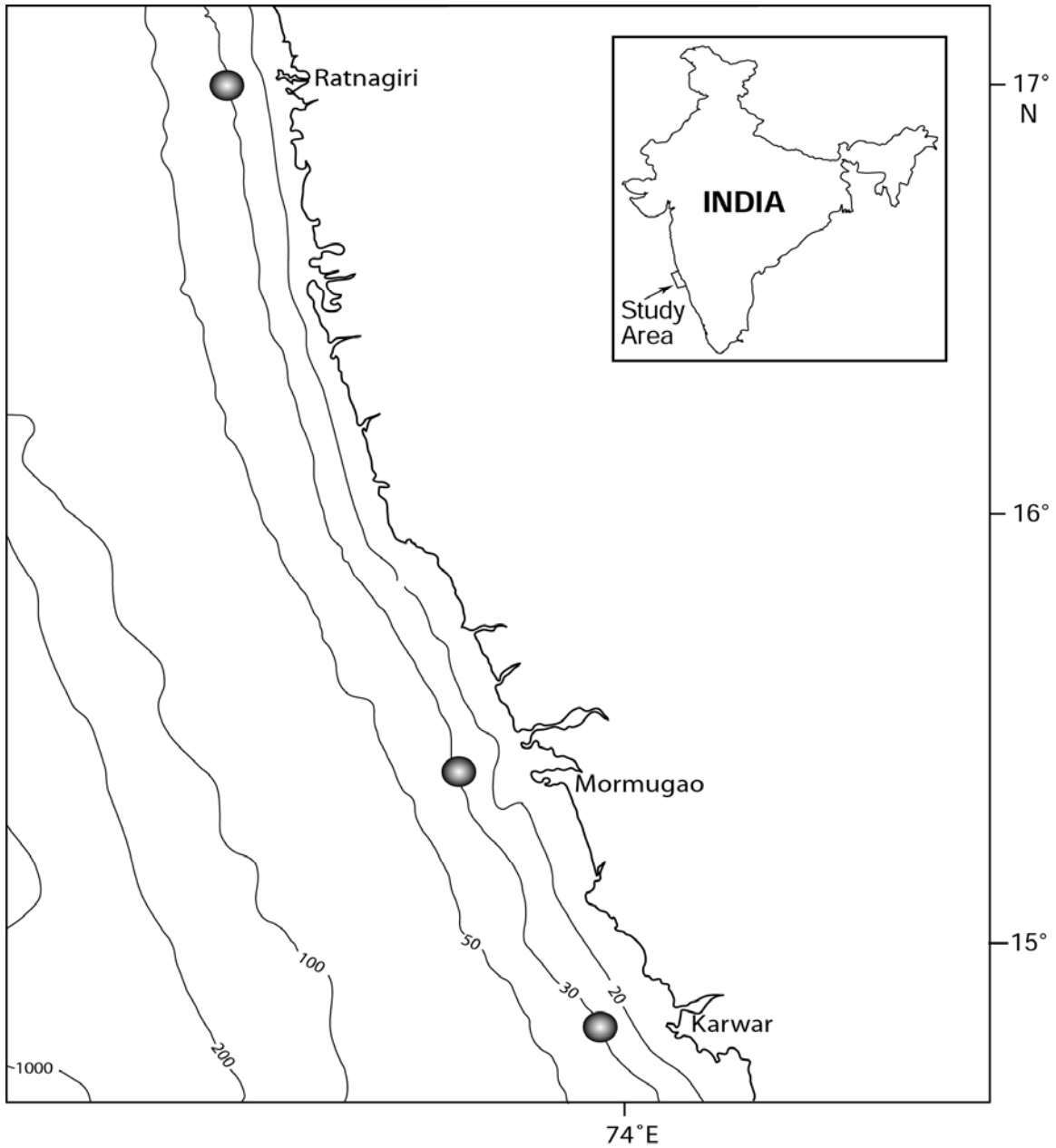


Fig. 1 Map showing the location of the sampling site

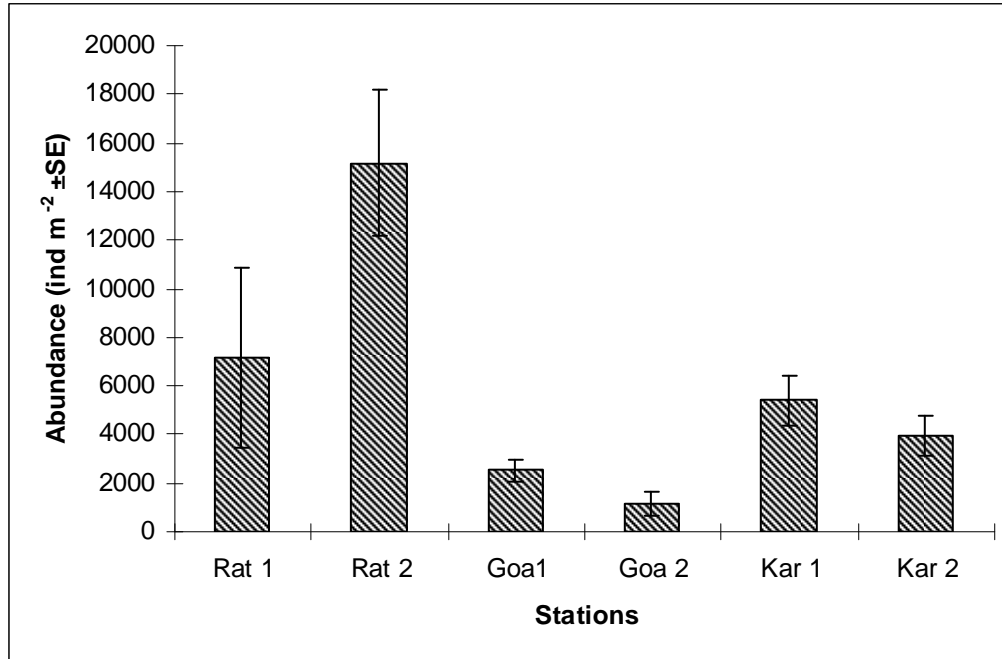


Fig. 2 Comparison of Macrofaunal abundance in the harbours

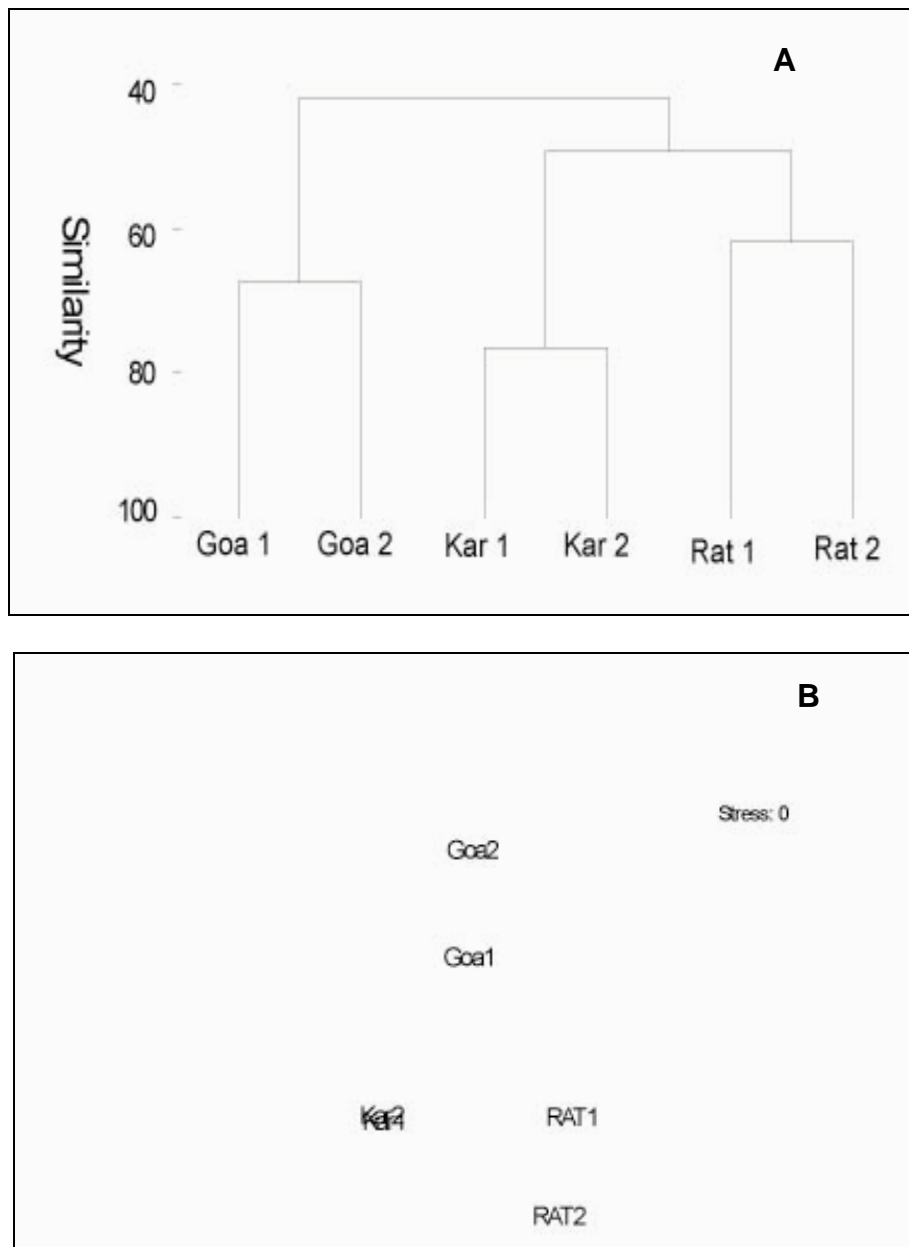


Fig. 3 Cluster and MDS based on macrofaunal abundance

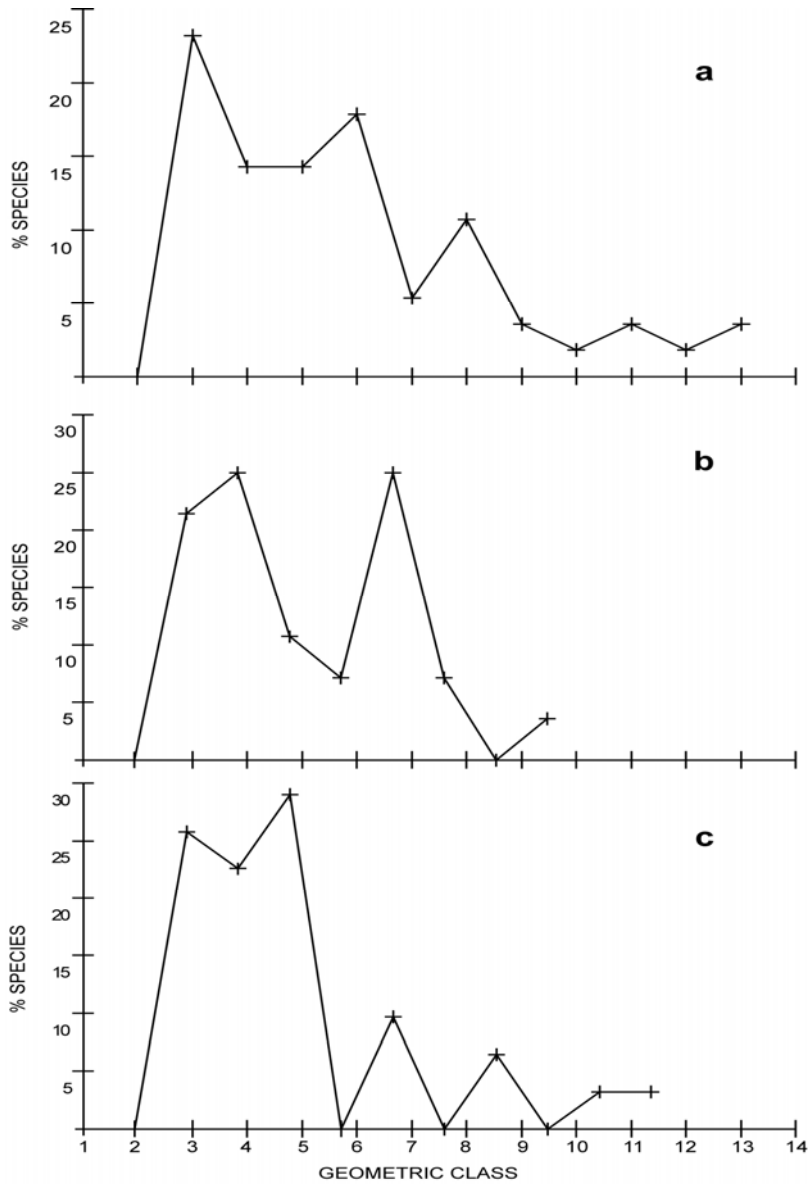


Fig. 4 Geometric class abundance for Ratnagiri (a), Mormugao (b) and Karwar (c).

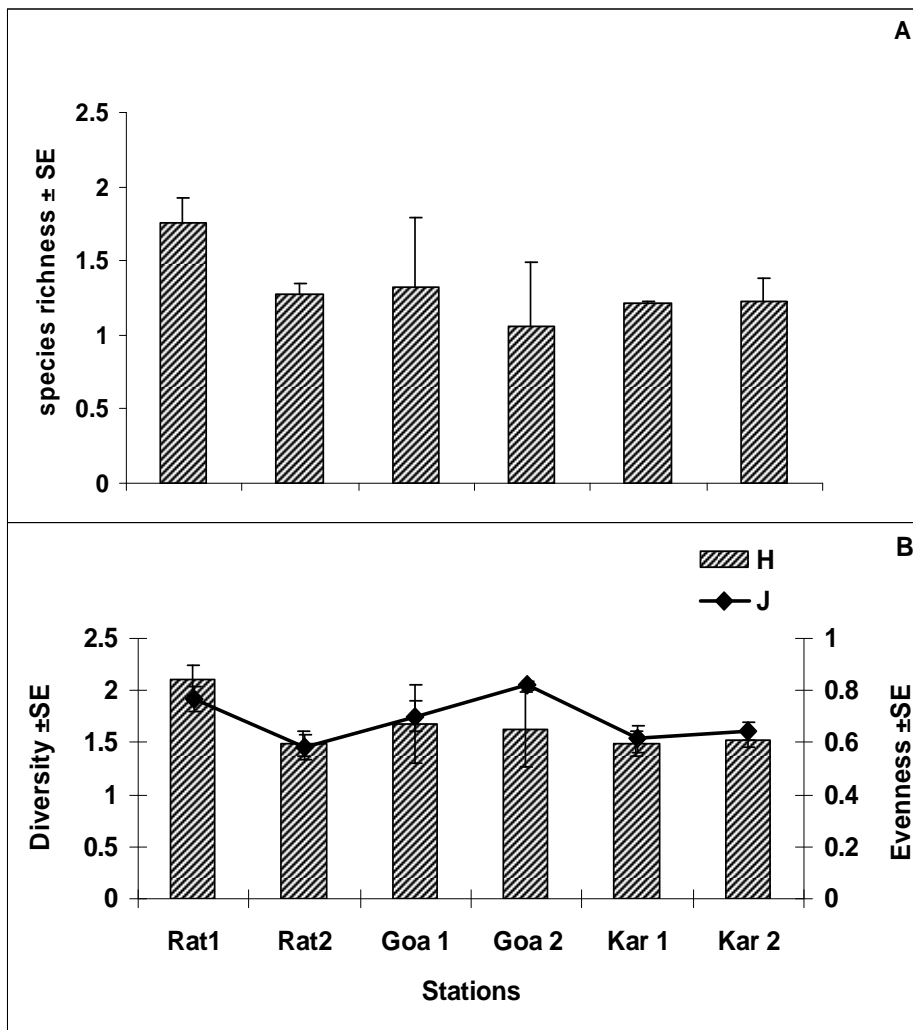


Fig. 5 Comparison of species richness (A), evenness and diversity (B) between the harbours

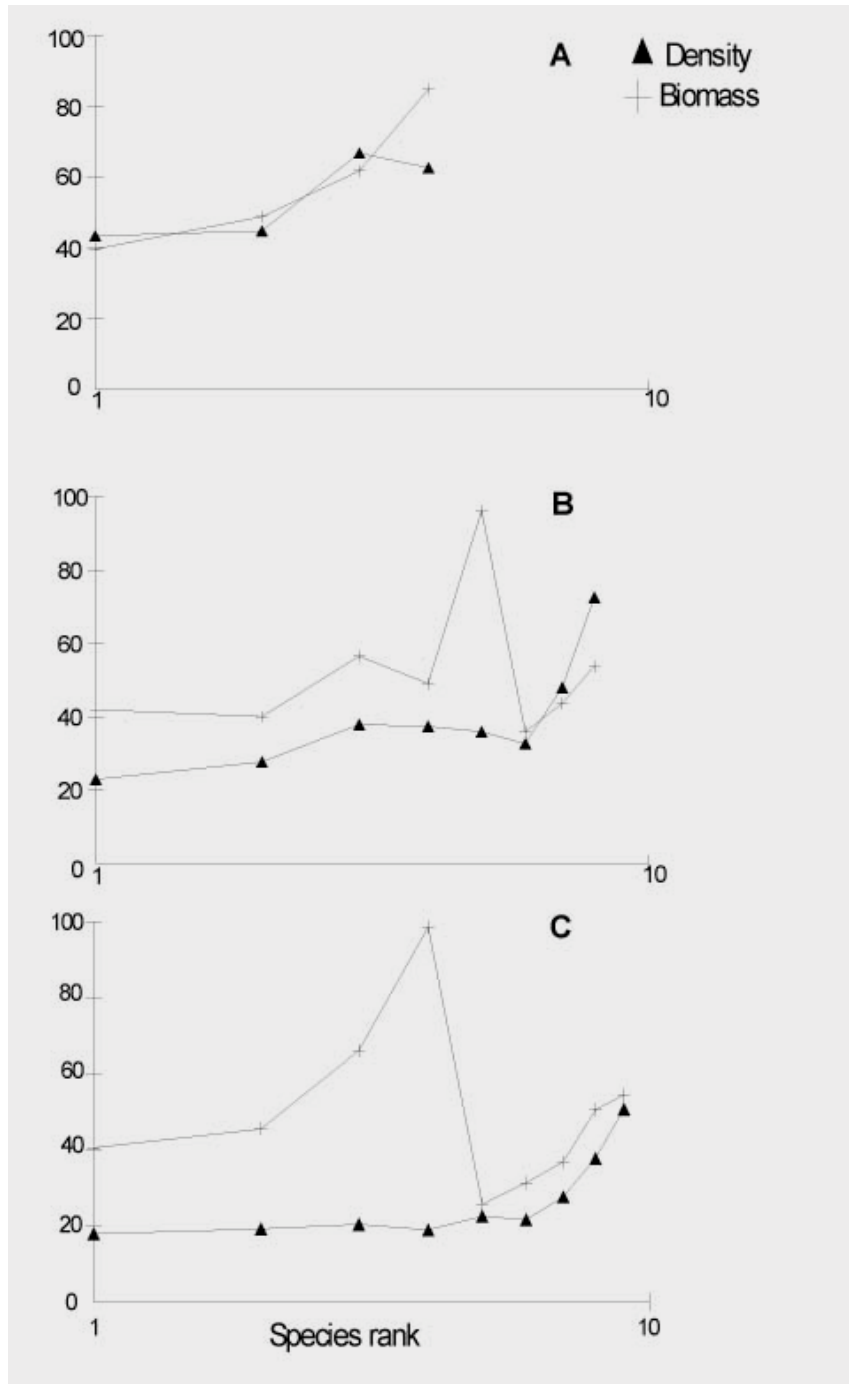


Fig. 6: ABC curve of Goa (A), Ratnagiri (B) and Karwar (C)