

Benthic polychaetes as good indicators of anthropogenic impact

S Sivadas, *B Ingole & M Nanajkar

Biological Oceanography Division, National Institute of Oceanography, Council of Scientific and Industrial Research,
Dona Paula, Goa-403004, India

*[E-mail: baban@nio.org]

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Seven stations were sampled within the Mormugao harbour area for benthos and environmental variables from September 2003 to July 2004. A total of 71 polychaete taxa were identified from the area. Polychaete abundance, biomass and species number was highest during post monsoon, mainly due to new recruitment. Pre monsoon is the most stable period for community development when, the fauna was dominated by opportunistic deposit feeding polychaete species. Average abundance ranged from 652-4096 ind m⁻² reported at channel and harbour station respectively. Harbour station was dominated by *P. pinnata*, *Magelona* sp., *Tharyx* sp. and *Cossura* sp. Univariate and multivariate analyses showed clear demarcation of outer harbour, inner harbour and channel stations. Correlation of physico-chemical and biotic parameters did not show a significant correlation. Dominance of opportunistic deposit feeding species and low polychaete diversity in the inner harbour indicate negative impact of harbour activities on the species composition.

[**Keywords:** Harbour activities, Polychaete, Diversity, Opportunistic species, Goa, West coast of India].

Introduction

Macrofauna forms the dominant biomass in marine sediment and play an important role in ecosystem processes such as secondary production, nutrient recycling and pollutant metabolism¹. Polychaetes are an important component of macrobenthic community as they often dominate in terms of abundance, biomass and species. As a result, they play an important role in the stability and functioning of the benthic community and the ecology in general²⁻³. They are extremely diverse taxa, with wide range of reproductive strategies and feeding guilds². Since the taxon contains both sensitive and tolerant species, they have been identified world wide as group that responds quickly to environmental disturbance⁴⁻⁶. Potency of the use of polychaetes in marine environmental assessment are (1) they are the most abundant macrobenthic group, readily available and easy to sample (2) they include a great diversity of trophic guilds and reproductive strategies that could be the reason of their success in many environments; (3) they respond to disturbance induced by different kinds of pollution exhibiting quantifiable changes in the community structure.

Mormugao is one of the oldest and major port on the west coast of India. It accounts for \approx 40% of India's iron ore export and ranks within the first ten leading iron ore exporting ports of the world. In 2007,

it accounted to 7% of the total traffic handled by all the twelve major ports of India. In the vicinity of the harbour, several maritime activities like boat building, fishing, dry docking and other related activities are carried out which further impacts the marine environment. Besides this, urban effluents from nearby establishments also flow into the harbour⁷. Contaminants in the Mormugao harbour are derived from the shipping activities, from the river runoff, urban effluent, fishing activities, transportation of ores and mining effluents/rejects. Benthic study in the area is restricted to the spatial and temporal variation of macrofauna from the Zuari estuary⁸⁻¹¹. Present study was performed with the objective of studying the environmental quality of the harbour using benthic polychaete as an assessment tool.

Material and methods

Mormugao harbour (15°25' N and 73° 47'E) located on the southern bank of the Zuari river mouth (Fig. 1). A breakwater of 522.40 meters long protects the harbour from the SW monsoon. Harbour is dominated by periodic tidal exchange of oceanic and estuarine water¹² with strong bottom currents (1.5 m s⁻¹).

Field sampling for the present study was carried out monthly from September 2003 to July 2004. Sampling in August 2004 was not possible due to

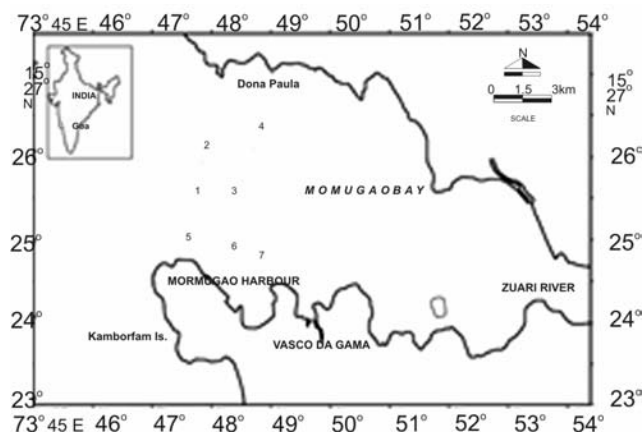


Fig. 1—Location of the study area

very rough weather conditions. Samples were collected from seven subtidal stations (Fig. 1), stn 1-4 located in the outer harbour, stn 5 in the navigation channel and stn 6-7 in the inner harbour. The depth in the study area ranged from 6–15 m. Sediment was collected with a modified (to avoid any spillage) van Veen grab (0.04 m²) in triplicates. Macrofauna were sieved on 0.5 mm mesh sieve and fixed in 5% formalin-rose Bengal solution. In the laboratory, samples were again washed, sorted, identified¹³⁻¹⁴ and counted. Biomass was determined by wet weight method.

At each station, sediment sample was taken for the analysis of chlorophyll *a* (chl *a*) and organic carbon. Chl *a* was analysed by acetone extraction method¹⁵ and organic carbon by wet oxidation method¹⁶. Water parameters (Dissolved oxygen, biological oxygen demand, nutrients, chl *a*, pH, temperature, salinity, petroleum hydrocarbon Cd, Pb and Hg), sediment metals (Cd, Pb, Hg) and granulometry were studied concurrently¹⁷ and used for correlation analysis with the biological parameters.

The data was divided into three seasons—monsoon (June–September), post monsoon (October–January) and pre monsoon (February–May). Significant variation of environmental and biological parameters was tested by analysis of variance (ANOVA) and Tukey's post hoc test. Correlation was carried out, in order to relate the environmental and biological data (Statistica 6). Shannon-Wiener diversity (*H'*), Pielou's evenness (*J'*), Margalef's species richness (*d*) was calculated using MDS ordination (Multi Dimensional Scaling) and Bray-Curtis similarity index was constructed based on polychaete abundance. Following the division into groups from

MDS analysis, the species having the greatest contribution to this division were determined using Similarity of Percentage (SIMPER). All these analysis were performed using Primer 6.

Results

Sediment chl *a* was highest at stn 5 (0.48 μg g⁻¹) and lowest was observed at stn 4 (0.17 μg g⁻¹). Generally, the values were high in post monsoon (0.51 μg g⁻¹) and low during pre monsoon (0.059 μg g⁻¹). Chl *a*, illustrated a significant seasonal variation (*p*<0.001). Average sediment OC was high at stn 5 (1.8%) and lower at stn 2 (1%). Seasonally, OC was highest during post monsoon at all the stations with average value of (1.86%) and lowest during monsoon (1.1 %). ANOVA demonstrated significant differences among the stations (*p*<0.05) and seasons (*p*<0.001). Tukey's post hoc test for multiple comparisons showed that OC was significantly low at stn 2 during monsoon and highest at stn 5 in post monsoon.

Survey of macrofaunal community in the Mormugao harbour revealed the total dominance of polychaete in terms of abundance (49%) and diversity (51%). Polychaete fauna of the area was represented by 71 species belonging to 30 families (Table 1). Average polychaete abundance was high at stn 6 (4096 ind m⁻²) and low at stn 5 (652 ind m⁻²; Fig. 2). Two-way ANOVA and post hoc test detected significant variation between stations (*p*<0.05) and maximum abundance was at stn 6.

Species composition and dominance varied significantly among the sampling locations. About 26% of the species identified were observed at all the stations. Ten species dominated the polychaete abundance in the area and together contributed to 55 - 88% of the total polychaete fauna (Table 2). *Mediomastus* sp. and *Paraprionospio pinnata* were the most dominant species and contributed to 14% each to the total polychaete abundance in the study area. Average abundance of *Mediomastus* sp. ranged from 77-453 ind m⁻² observed at stn 4 and stn 3, respectively. Abundance of *P. pinnata* was highest at stn 6 (1008 ind m⁻²) and lowest in stn 2 (58 ind m⁻²). Abundance of *Magelona* sp. was highest in the harbour station (846 ind m⁻²) and it contributed to 13% of the total polychaete abundance. Mean abundance of *Cossura* sp. ranged from 78-439 ind m⁻² with highest values observed in the channel (stn 5). *Terebellides stroemi* contributed to

Table 1—Diversity of polychaete fauna in the Mormugao harbour observed during Sep. 2003- July 2004. + present; - absent

Species	Stn1	Stn 2	Stn 3	Stn 4	Stn 5	Stn 6	Stn 7
Family Phyllodoceidae							
<i>Phyllodoce</i> sp.	+	+	+	+	-	-	-
<i>P. malmgreni</i>	+	+	+	+	+	-	-
<i>P. madeirensis</i>	+	+	+	-	-	+	-
<i>Eteone</i> sp.	-	+	+	-	+	-	-
Family Aphroditidae							
<i>Sthenelais</i> sp.	-	-	-	+	-	-	-
<i>Harmothoë</i> sp.	-	+	+	+	-	+	+
Family Pisionidae							
<i>Pisione oerstedii</i>	+	+	+	+	-	-	-
Family Hesionidae							
<i>Podarke</i> sp.	-	-	+	+	-	+	-
<i>Hesione</i> sp.	-	-	+	-	-	-	-
Family Syllidae							
<i>Syllis cornuta</i>	-	-	-	-	-	+	-
<i>S. krohni</i>	+	+	+	-	+	-	-
<i>Syllis</i> sp.	+	+	+	+	+	-	-
<i>Sphaerosyllis</i> sp.	-	-	+	-	-	-	-
<i>Exogene</i> sp.	+	+	+	-	-	-	-
<i>Odontosyllis</i> sp.	-	-	+	-	-	-	-
Family Pilargiidae							
<i>Ancistrasyllis constricta</i>	+	+	+	+	+	+	+
<i>A. groenlandica</i>	+	+	+	+	-	+	+
Family Nephtyidae							
<i>Nephtys polybranchia</i>	+	+	+	+	+	+	+
Family Nereidae							
<i>Neries</i> sp.	+	+	+	+	-	+	-
<i>Drilonereis filum</i>	-	-	-	+	-	-	-
Family Glyceridae							
<i>Glycera alba</i>	+	+	+	+	-	+	+
<i>G. longipinnis</i>	+	+	+	+	+	+	+
Family Goniadidae							
<i>Gylcinde oligodon</i>	-	+	+	+	-	+	+
<i>Gylcinde</i> sp.	+	+	+	+	-	+	+
<i>Goniadides</i> sp.	+	+	+	+	+	-	-
<i>Goniada hexadentes</i>	+	+	+	+	-	+	-
<i>Goniada</i> sp.	-	-	-	+	-	-	-
Family Cirratulidae							
<i>Tharyx</i> sp.	+	+	+	+	+	+	+
<i>Chaetozone</i> sp. 1	+	+	+	+	+	+	+
<i>Chaetozone</i> sp. 2	+	+	+	+	+	+	+
Family Spionidae							
<i>Paraprionospio pinnata</i>	+	+	+	+	+	+	+
<i>Prionospio aucklandica</i>	-	+	+	-	-	+	-
<i>Polydora</i> sp.	+	-	-	-	-	+	-

Contd.—

Table 1—Diversity of polychaete fauna in the Mormugao harbour observed during Sep. 2003- July 2004. + present; - absent—*Contd.*

Species	Stn1	Stn 2	Stn 3	Stn 4	Stn 5	Stn 6	Stn 7
<i>P. ciliate</i>	+	+	+	+	-	+	+
<i>P. coeca</i>	+	+	+	+	+	+	+
<i>Pseudopolydora antennata</i>	+	+	+	+	-	+	-
<i>Pseudopolydora kempfi</i>	+	+	+	+	+	+	+
<i>Minuspio cirrifera</i>	+	+	+	+	+	+	+
Family Magelonidae							
<i>Magelona</i> sp.	+	+	+	+	+	+	+
Family Poecilochaetidae							
<i>Poecilochaetus johnsoni</i>	+	+	+	+	-	-	-
Family Chaetopteridae							
<i>Phyllochaetopterus</i> sp.	-	+	+	+	-	-	+
Family Disomidae							
<i>Trochochaeta orissae</i>	-	+	+	+	-	+	+
Family Maldanidae							
<i>Euclymene insecta</i>	+	+	+	+	-	+	+
<i>Axiothella obockensis</i>	+	+	+	+	+	+	-
Family Capitellidae							
<i>Mediomastus</i> sp.	+	+	+	+	+	+	+
<i>Heteromastus</i> sp.	-	-	-	+	-	-	-
<i>Neomediomastus</i> sp.	-	-	-	-	-	+	-
<i>Notomastus</i> sp.	+	+	+	+	-	+	+
<i>Dasybranchus</i> sp.	-	-	-	+	-	-	-
<i>Capitella</i> sp.	-	-	-	-	-	+	-
Unidentified Capitellidae	+	+	+	+	+	+	+
Family Dorvilleidae							
<i>Protodorvillea egena</i>	+	+	+	+	+	-	-
Family Lumbrineridae							
<i>Lumbrineris japonica</i>	+	+	+	+	+	+	-
Family Eunicidae							
<i>Eunice indica</i>	+	+	+	+	+	+	+
Family Onuphidae							
<i>Diopatra claparedii</i>	+	+	+	+	+	-	-
<i>Onuphis eremita</i>	+	+	+	+	+	+	-
<i>O. dibranchiata</i>	+	+	-	+	-	+	-
Family Sternaspidae							
<i>Sternaspis scutata</i>	+	+	+	+	+	+	+
Family Sabellariidae							
<i>Neosabellaria cementarium</i>	+	+	+	-	+	+	-
Family Terebellidae							
<i>Terebellides stroemi</i>	+	+	+	+	+	+	-
Family Sabellidae							
<i>Jasmineira</i> sp.	+	+	+	+	+	-	-
Family Saccocirridae							
<i>Saccocirrus</i> sp.	-	-	-	+	-	-	-
Family Orbiniidae							

Contd.—

Table 1—Diversity of polychaete fauna in the Mormugao harbour observed during Sep. 2003- July 2004. + present; - absent—*Contd.*

Species	Stn1	Stn 2	Stn 3	Stn 4	Stn 5	Stn 6	Stn 7
Family Orbiniidae							
<i>Scoloplos</i> sp.	+	+	+	+	+	+	-
Family Paraonidae							
<i>Aricidea catherinae</i>	+	+	+	+	+	+	+
<i>A. multiantennata</i>	-	-	-	-	-	-	+
<i>A. fauveli</i>	-	-	+	-	-	-	-
<i>Aricidea</i> sps.	-	-	-	-	-	+	-
<i>Paradoneis armata</i>	+	+	+	-	-	-	-
<i>Levinsenia</i> sp.	+	+	+	+	+	+	+
Family Cossuridae							
<i>Cossura</i> sp.	+	+	+	+	+	+	+
Family Opheliidae							
<i>Armandia lanceolata</i>	+	-	-	-	-	-	-

Table 2—Composition (%) of dominant species at the sampling location during the present study

Taxa	Stn.1	Stn.2	Stn.3	Stn.4	Stn.5	Stn.6	Stn.7
<i>Paraprionospio pinnata</i> (DF)	7	4	8	8	16	25	14
<i>Polydora coeca</i> (DF)	5	16	2	2	-	-	-
<i>Cossura</i> sp. (DF)	6	6	8	8	18	11	13
<i>Tharyx</i> sp. (DF)	2	1	4	2	2	15	19
<i>Nephtys polybranchia</i> (C)	5	5	6	2	8	2	4
<i>Mediomastus</i> sp.(DF)	14	19	21	26	11	7	12
Capitellidae (DF)	1	-	1	2	2	7	10
<i>Axiothella obockensis</i> (DF)	5	2	2	16	1	-	-
<i>Magelona</i> sp (DF)	2	12	18	3	1	21	11
<i>Terebellides stroemi</i> (FF)	8	2	4	1	6	0	0
Others	45	33	26	30	35	12	17

DF: Deposit feeders; C: Carnivorous; FF: Filter feeders

1-8% of the total polychaete abundance. *Tharyx* sp. (9%), *Nephtys polybranchia* (4%), *Minusprio cirrifera* (3%), *Aricidea catherinae* (2%), *Axiothella obockensis* (3%) were the other dominant species. Plate 1 represents some of the dominant species identified from the area.

Overall, inner harbour (stn 6 and 7) was dominated by *P.pinnata* (14-25%), *Magelona* sp. (11-21%), *Tharyx* sp. (15-19%) and *Cossura* sp. (11-13%). Other species occurring in the harbour were *M. cirrifera*, *A. catherinae*, *Sternaspis scutata*, *Chaetozone* sp.1 and 2 and unidentified Capitellidae. *Mediomastus* sp. was most dominant in the outer harbour, contributing to 14 – 26% of the total polychaete abundance. Other commonly occurring species were *Polydora coeca* (2-16%), *A. obockensis* (2-16%) and *Magelona* sp. (2-18%). The fauna in the

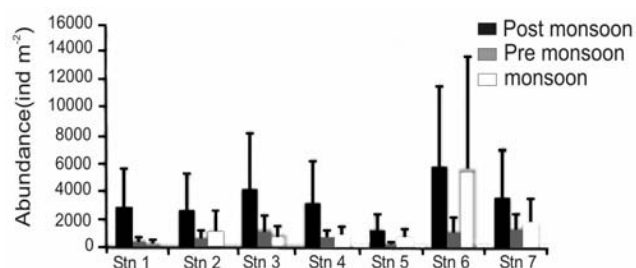


Fig. 2—Spatio-temporal variation of polychaete abundance in the study area

navigation channel was dominated by *Cossura* sp. (18%), *P.pinnata* (16%) and *Mediomastus* sp. (11%).

Species abundance was subjected to the cluster analysis and ordination (Fig. 3). The method detected two groups and reliability of the data was seen from the low stress value (0.01). Stns 1-4 clustered together with 74% similarity (Group I). Stn 6 and 7 with 79%



Plate 1 — Dominant polychaete species of MPT. *P.pinnata* (a), *Magelona* sp. (b), *Mediomastus* sp. (c), *Cossura* sp. (d), *Tharyx* sp. (e), Capitellidae (f), *M.cirrifera* (g), *T.stroemi* (h)

similarity formed the second group (Group II). The channel station (stn 5) did not cluster with the other stations. SIMPER analysis was performed based on the results of cluster analysis to find out the species, which accounted for the differences between the clustered groups (Table 3).

Polychaete abundance was highest in post monsoon (3362 ind m⁻²) which dropped drastically during pre monsoon (735 ind m⁻²; Fig. 2). During the study, polychaetes community showed a distinct seasonal pattern. Abundance of *P. pinnata* was highest in monsoon (533 ind m⁻²) and dropped during post monsoon. However, the minimum abundance (15 ind m⁻²) was in pre monsoon. Abundance of *Magelona* sp. increased from monsoon (58 ind m⁻²) to post monsoon (591 ind m⁻²) and like all other species the abundance showed sharp decrease during pre monsoon (36 ind m⁻²). Abundance of *Mediomastus* sp. also showed a similar trend to that of *Magelona* sp.

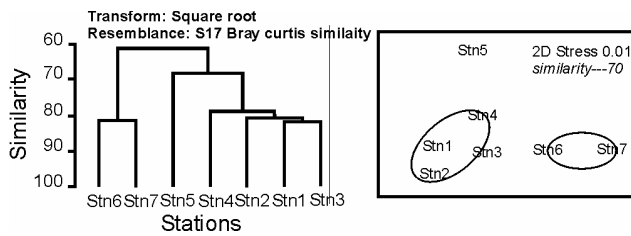


Fig. 3—Bray Curtis cluster (a) and MDS ordination (b) analysis based on species abundance.

The values increased from monsoon (122 ind m⁻²) to post monsoon (383 ind m⁻²) and declined in pre monsoon (127 ind m⁻²). Abundance of *Cossura* sp. was observed throughout the study period with high values in monsoon (210 ind m⁻²). The abundance of *Cossura* sp. showed a marginal decrease during post monsoon (180 ind m⁻²) and pre monsoon (187 ind m⁻²). Abundance of *Tharyx* sp. ranged from 48 – 272 ind m⁻². Highest abundance of *Tharyx* sp. was observed in monsoon and lowest value was in pre monsoon.

Polychaete biomass (wet wt) showed a similar trend to that of abundance with lower values being at stn 5 (0.9 g m⁻²) and higher at stn 6 (4.96 g m⁻²; Fig. 4). Seasonally highest biomass was during post monsoon at all the stations (Fig. 4). Biomass also showed significant variation between stations (p<0.05).

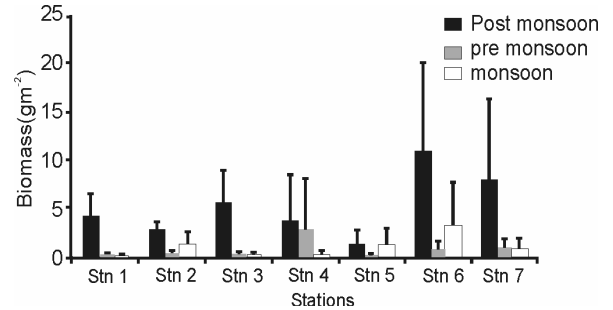


Fig. 4—Spatio-temporal variation of polychaete biomass in the study area

Table 3—SIMPER analysis based on group obtained from cluster showing the species that contributed to the differences among the groups. Av. Abund: average abundance; Av. Diss: Average dissimilarity; Contrib: Contribution

Species	Av. Abund	Av. Abund	Av. Diss	Diss/SD	Contrib%	Cum. %
Average dissimilarity 49.90	Group I	Group III				
<i>Mediomastus</i> sp.	331.02	77.41	10.44	2.51	20.93	20.93
<i>Magelona</i> sp.	154.38	7.03	5.74	1.02	11.5	32.43
<i>Polydora coeca</i>	90.4	3.01	3.93	0.89	7.87	40.3
<i>Axiiothella obockensis</i>	97.55	8.03	3.87	0.87	7.76	48.06
<i>Cossura</i> sp.	114.98	132.54	1.59	1.62	3.19	51.25
Average dissimilarity 60.05	Group I	Group II				
<i>Paraprionospio pinnata</i>	112.57	656.78	10.65	1.78	17.74	17.74
<i>Tharyx</i> sp.	39.25	503.04	9.92	7.56	16.51	34.25
<i>Magelona</i> sp.	154.38	545.38	8.34	1.61	13.89	48.14
<i>Cossura</i> sp.	114.98	356.01	5.07	3.52	8.44	56.58
Capitellidae	18.56	246	4.94	7.97	8.22	64.8
Average dissimilarity 71.62	Group III	Group II				
<i>Magelona</i> sp.	7.03	545.38	13.06	1.93	18.23	18.23
<i>Tharyx</i> sp.	15.06	503.04	12.96	33.22	18.09	36.32
<i>Paraprionospio pinnata</i>	118.48	656.78	12.71	1.45	17.75	54.07
Capitellidae	13.05	246	6.3	7.39	8.8	62.87
<i>Cossura</i> sp.	132.54	356.01	5.7	4.87	7.96	70.83

Average values of species richness, evenness and Shannon-Wiener diversity are shown in figure 5. Species number and richness was low at stn 7 (31 and 3.9) and high at stn 3 (59 and 7.5). Species richness ranged from 1.24 to 2.49 observed during post monsoon and monsoon respectively. Species richness showed significant differences between stations ($p < 0.001$). Evenness varied between 0.6-0.8 observed at stn 6 and 1, respectively and was statistically significant ($p < 0.05$). Species evenness showed significant temporal ($p < 0.01$) variation and mean species evenness value was significantly highest during pre monsoon (0.79). Shannon-Wiener diversity was higher at Stn1 (3.2) and lower (2.0) at stn 6. Shannon-Wiener diversity showed significant differences between stations ($p < 0.001$). Species diversity ranged from 1.59 – 2.10 recorded during monsoon and post monsoon respectively. Shannon-Wiener diversity showed significant seasonal difference ($p < 0.001$). The mean diversity value during post monsoon was significantly high.

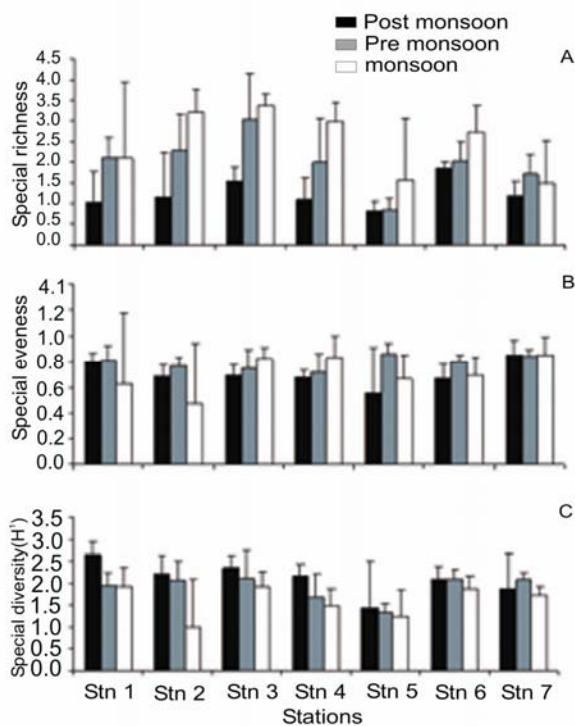


Fig. 5—Mean (\pm SD) of species richness (a), evenness (b) and diversity (c) for the seven stations during the study area.

The polychaete abundance, biomass and species diversity indices were correlated with abiotic

parameter. The abundance value correlated positively with DO ($r=0.7$, $p=0.05$) and showed negative correlation with BOD. A similar relation was observed between polychaete biomass and DO ($r=0.7$, $p=0.05$). Correlation with sediment texture showed similar pattern observed in most area i.e positive with silt ($p=0.05$) and negative with sand ($p=0.05$). Species number showed a significant negative correlation with BOD ($r=0.8$, $p < 0.01$). The correlation between polychaete community and contaminants (water and sediment PHC, Cd, Hg, Pb) were not significant.

Discussions

Polychaete abundance and biomass was lowest at stn. 5 (Figs 2 and 4). Stn. 5 was located in the navigation channel. Continuous disturbance by vessel movements and the annual maintenance dredging carried out to deepen the channel after the monsoon affect the fauna. Quantity of the maintenance dredging carried out annually along the navigational channel and harbour basin is about $3.7 \times 10^6 \text{ m}^3$ (17). Community in the outer harbour was represented by *Mediomastus* sp., *P.coeca* and *A. obockensis*. *Mediomastus* sp. is known to dominate moderately disturbed high energy environment¹⁸. *T. stroemi* was observed with highest abundance in the outer stations and are known to have large ecological flexibility essential for adapting under stress conditions¹⁹. Further, compared to the inner harbour, species sensitive to pollution occurred in some of the outer harbour stations. Inner harbour was dominated by opportunistic species like *P.pinnata*, *Tharyx* sp., *Magelona* sp. and *Cossura* sp. Generally, the benthic community in an unstable environment is typically dominated by r-selected species, characterised by higher reproduction rate and genetic variation, and is therefore more stress tolerant²⁰. These dominant species in the inner harbour (*P.pinnata*, *Tharyx* sp., *Magelona* sp. and *Cossura* sp.) are surface or subsurface feeders, and are established as pollution indicators^{21,4}. Results of the present study agreed with other harbour fauna that was also dominated by few opportunistic polychaete species.

Although the polychaete abundance was highest in the inner harbour, species number, richness, evenness and diversity was highest in the outer harbour (Fig. 5). Low diversity and evenness in the inner harbour was largely due to the dominance of few opportunistic species that together contributed to > 80% of the total polychaete abundance. Cluster and MDS ordination

was also able to discriminate between inner and outer harbour stations indicating a clear difference in polychaete community in the two areas. SIMPER, further confirmed the results that the variations observed between the outer and inner harbour were due to the dominance of different species. High OC may have contributed to the higher abundance of opportunistic species in the inner harbour⁴. But the low diversity in inner harbour reflects the negative effect of increase organic levels. Present finding agrees well with other studies where maximum diversity is observed in an area with moderate values of OC and values decreased with increase in OC²².

There are very few studies that relate seasonal variations of fauna with the environmental variables and thus making it difficult to differentiate between natural and man-made changes. In the present study polychaetes showed significant seasonal variability. Abundance, biomass and species diversity peaked during post monsoon and showed a decline during pre monsoon. Seasonal variability was influenced by recruitment as juveniles were responsible for the high abundance observed during post monsoon. Majority of the polychaete in pre monsoon were adults and microscopic inspection of random specimens indicated presence of eggs in majority of specimens. In the tropical estuaries, increased salinity during pre monsoon triggers the reproduction in most of the benthic fauna followed by recolonization in post monsoon²³.

However the polychaetes in Mormugao harbor did not follow the general pattern normally observed in tropical estuaries of increase in abundance from monsoon to post monsoon and pre monsoon⁸. Polychaete abundance showed a decline during pre monsoon which may due to the harbour activities which increased after the monsoon and peaks during pre monsoon. During monsoon, harbour activities are reduced due to the rough weather conditions. Increased harbour activities after monsoon also increase the sediment load and contaminants (hydrocarbons and metals). Increased harbour activities along with extreme environmental conditions can cause considerable stress to the organisms and only highly tolerant species survive the stressed conditions. Most dominant species during pre monsoon season was *Cossura* sp. Other dominant species were *Tharyx* sp., *M.cirrifer*, *Nephtys polybranchia* and unidentified Capitellidae. The adults and larvae of polychaete species (Spionid,

Cirratulids, Cossurids, Capitellids) are know to have remarkable tolerance of hydrocarbon and other pollutants that are toxic to most other fauna²⁴⁻²⁵. Their dominance in contaminated sediments is due to higher per capita rates of recruitment and adult survival than more sensitive taxa²⁴.

Biotic parameters showed a weak correlation with environmental parameters. Polychaete community did not show significant relation with sediment and water contaminants. Chemical concentration in environmental parameters is not always an accurate predictor of biological and ecological effects²⁶. Hence, the use of benthos in environmental monitoring has an advantage as it can integrate conditions over a period of time rather than reflecting condition during the time of sampling. Lack of any significant relationship between the biotic and abiotic parameters may be due to the low bioavailability of the contaminants. Bioavailability of contaminants depends on bioturbation, salinity, temperature, redox, pH²⁷⁻²⁸. On the other hand, organic matter is also known to be an important factor controlling the abundance of trace metals²⁹. Further, iron and manganese oxides (oxyhydroxides) are strong scavengers of metals, affecting trace metal mobilization, as they precipitate under oxic condition and dissolve in anoxic environment. Since, Fe and Mn are the main ore exported from the harbour, the values of these metals were also higher in the study area. Iron concentration in the Zuari water ranged from 0-20 mg l⁻¹ and 1- 16 mg l⁻¹ in the sediment³⁰.

An attempt was made to evaluate the change in the polychaete community in the area by examining previous data. However, comparison with previous data had its limitations because, studies were often based on short investigation; sampling location and limitations to the species identified were not fully presented. Earlier studies revealed that the polychaete as the most diverse and abundant group and was true for the present study. However, notable change was observed in the community composition. Carnivorous, *D. neapolitana* and *G.alba* were replaced and dominated by opportunistic, *P.pinnata*. A similar shift was observed by Raman³¹ in the Visakhapatnam harbour. Carnivorous *D. neapolitana* and *Nereis glandicineta* were replaced by the opportunistic, *Capitella capitata*. Ansari et al.⁷ reported that Nereidae dominated the harbour community. Further, carnivorous species belonging to the family Glyceridae, Goniadidae, Eunicidae, Nereidae were

recorded in low abundance and mostly in the outer station. Out of the 71 identified polychaete species, 62 are reported for the first time from the area. Moreover, 43% of the species were deposit feeders and dominated in terms of abundance. *Mediomastus* sp., which dominated the polychaete community of the area, was not reported from the area previously. Other species which dominated the area and not reported earlier are *Tharyx* sp., *A. obockensis*, *A. catherina*, *Polydora coeca*, *Pseudopolydora kemp*, *Jasmineria* sp. Therefore, the increase in deposit feeding polychaete in the area may be the result of increase organic load as average organic carbon value also showed an increase from 1%⁸ to 2% during the present study and highest values were in the harbour stations. *D. neapolitana* feeds on algae, sponges, bryozoans and crustaceans and *G. alba* prefers motile preys, such as small polychaetes and amphipods compared to sessile and tube dwelling forms³². Crustaceans were the second dominant group during earlier studies, however were replaced by bivalves³³. Further, crustaceans, specially the amphipods show high sensitivity to pollution and disappear from highly polluted habitats⁴. Moreover, the polychaetes of the present study were dominated by tube dwelling species. Change in food availability must have resulted in decrease in the population of carnivorous forms. Therefore, it clearly indicates that the changes in the benthic community favoured opportunistic polychaete species.

Conclusions

The use of polychaete taxon for assessing the health of marine environment has been widely accepted and was successfully demonstrated in the present study. Polychaete community was able to clearly demarcate the outer and inner harbour stations. Pre monsoon is considered to be most stable period and during this time the fauna in the area is dominated by opportunistic deposit feeding polychaete species. Comparison with earlier data, showed a shift from carnivores to deposit feeding polychaete species. It can be concluded that, the increasing harbour activities may perhaps have contributed for structuring the polychaete community of the Mormugao harbour. However compared to many other harbours around the world, the Mormugao harbour did not show complete defaunation of the area, which can be attributed to the dynamic nature of the Zuari estuary.

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