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Benthic polychaetes in the Ratnagiri bay, India : Influence of anthropogenic factors

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Abstract

Study of changes in macrobenthic community structure is an intrinsic part of many environmental monitoring programmes. Hence, it is pivotal to distinguish the effects of natural and anthropogenic factors on these sensitive organisms for accurate assessment and management of coastal environment. Polychaete species diversity of five stations in the Ratnagiri bay was investigated during premonsoon and postmonsoon months in 2007. Though no spatial trends in polychaete diversity vis-à-vis the pollution was visible, the polychaete univariate indices were uniformly better in premonsoon indicating clear seasonal trends. Shannon diversity values ranged from 1.4-2.4 during premonsoon and 0.6-1.6 during postmonsoon. Station 5, which was most impacted by anthropogenic wastes as demonstrated by the anoxic conditions coupled with higher nutrient load, had comparatively higher *H'* values (1.9 and 1.6) and better evenness values (0.9 and 0.7) during both seasons indicating that the polychaetes were not influenced by anthropogenic contamination. The study indicates that the polychaete distribution and diversity in the bay were governed primarily by variations in sediment texture rather than the anthropogenic disturbances.

Key words

Polychaete, Sediment, Anthropogenic factors, Macrobenthic community

Introduction

Besides the multiple anthropogenic stressors that impact the coastal ecology of burgeoning cities the world over, natural events (rain, floods, sealevel rise) also significantly impact the macrobenthic species assemblages (Norkko *et al.*, 2002). The benthic taxa are routinely studied in numerous environmental impact assessment studies as bioindicators of ecological disturbances (Murugesan *et al.,* 2009). Among the benthic fauna, polychaetes, by virtue of their numerical abundance and diversity, widespread presence, diversity of feeding modes, differential tolerance to environmental imbalances and limited motility, have been used in many studies as markers of environmental health (Tomassetti and Porrello, 2005; Chollet and Bone, 2007; Hughes *et al.*, 2009). Hence, it is pivotal to distinguish the effects of natural and anthropogenic factors on these sensitive organisms for accurate assessment and management of coastal environment (Cardoso *et al.*, 2008).

Ratnagiri bay, located along the Maharashtra coast, is one of the major marine fish landing centers in India. The bay has a thriving fishing harbour and a cement jetty for transportation of clinker for a cement plant. Apart from this, further anthropogenic pressures include the dumping of untreated sewage from Ratnagiri town, fish discard at the landing centre and waste water from the various fish processing units that dot the bay. Ratnagiri harbour has been designated as anthropogenically stressed by Nanajkar and Ingole (2010) while investigating the benthic environmental status of 3 harbours along central west coast of India. Considering the importance of the area and the multiple stressors affecting it, it was intriguing to examine whether these anthropogenic activities impacted

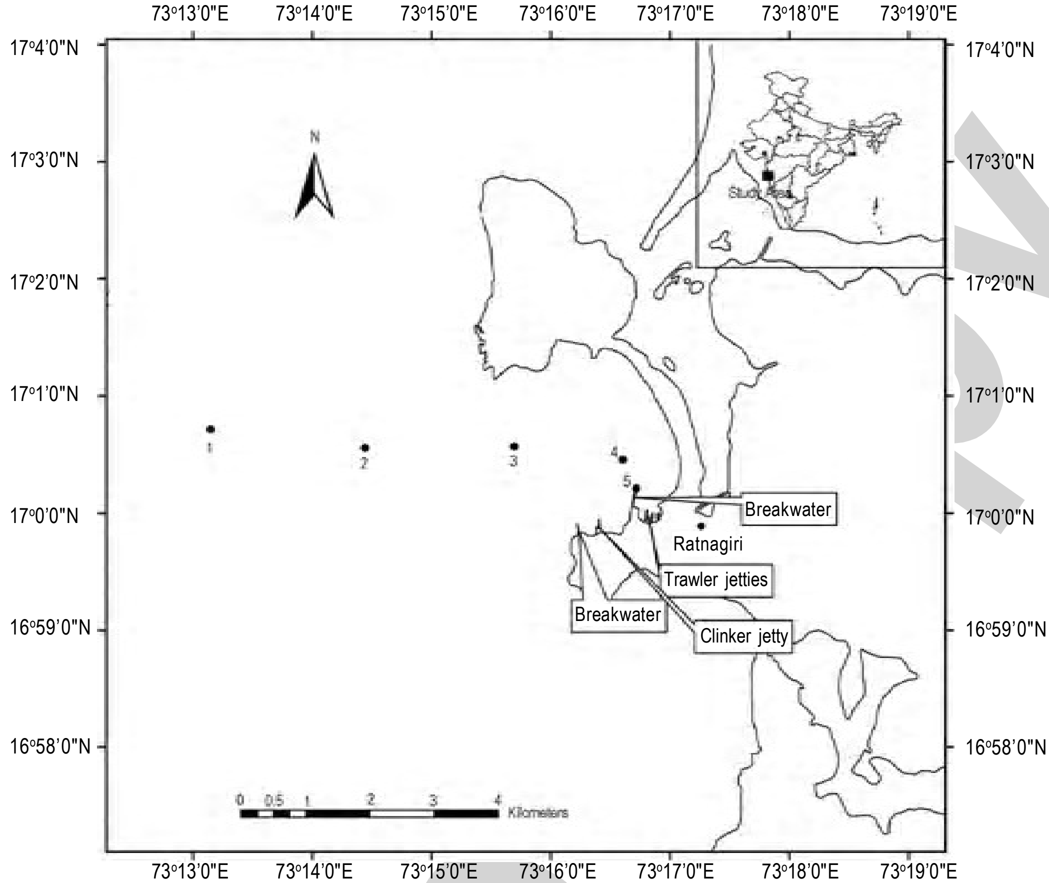

Fig. 1: Map showing the location of stations in Ratnagiri bay

the benthic fauna which are proven indicators of environmental disturbances, natural or man-made.

Though the polychaete diversity of the Ratnagiri coast have been studied by others (Parulekar, 1971; Gaikwad and Ranade, 1979; Rankhamb *et al.*, 2008; Ingole *et al.*, 2009) the specific factors governing their distribution patterns were never investigated. This work examines the polychaete species diversity over two months representing two seasons in order to discern whether the existing anthropogenic stressors or other natural factors were influencing the distribution of these sensitive fauna.

Materials and Methods

Study area: Ratnagiri bay is located at 17°00'38"N and 73°15'34"E along the Maharashtra coast, India. During the post monsoon, the bay experiences very strong winds sometimes reaching gale force and heavy rain in association with cyclonic storms which develop in the Arabian sea and move in close proximity to the coast. There is no river opening into the bay which excludes any freshwater input to the system. Barges carrying ore to the cement jetty and fishing vessels use the bay regularly. Both the jetty and the harbour have their own breakwaters (Fig. 1). The estimated quantity of domestic sewage from point and non-point sources is 3600 $m^3 d^{-1}$ and nearly 3028 $m^3 d^{-1}$ of industrial organic wastes are discharged in the bay. Besides there are trash fish disposals at the landing jetty.

Five stations (Fig. 1) were selected at increasing distances from the shore. Stations 1 to 3 were in the open coastal waters at a distance of about 3 km between each station with the farthest station at a distance of 8 km from the shore. Stations 4 and 5 were in the bay; the latter being adjacent to the fishery harbour in an area with limited flushing owing to the presence of breakwaters. The depth in the stations increased from station 5 (2.5 m) to station 1 (20 m). The stations were sampled during March, 2007 (premonsoon) and November, 2007 (postmonsoon).

For the study of benthic polychaetes, sediment samples were collected with a van Veen grab of 0.04 m^2 area, in quadruplicate at each station, and sieved on site using 500 µm mesh sieve. The polychaetes retained were preserved in 5% formalin- Rosebengal solution which were later sorted and calculated for their density (ind. m^{-2}). Taxonomic identification was done up to species level wherever possible using identification key developed by Day (1967). Sediment samples were also taken for analyses of sedimentological parameters like petroleum hydrocarbons (PHc), organic carbon (C_{org}) and sediment texture. At each station bottom water samples were collected for analyzing water quality parameters like pH, suspended solids (SS), salinity, dissolved oxygen (DO), dissolved inorganic phosphate (PO_4^{3-}-P), nitrate-nitrogen (NO_3^--N), nitrite-nitrogen (NO_2^--N) and ammonia (NH_4^+-N). pH was measured on a pH analyzer caliberated with standard buffers. Salinity, SS, DO and nutrients were analyzed using standard methods (Grasshoff, 1999). PHc (UNESCO, 1987) was estimated colorimetrically. Organic carbon (C_{org}) was analysed by titration method (Walkey and Black, 1934) and sediment texture by pipette method (Buchanan, 1984).

Data analyses using the statistical software, PRIMER (Clark and Warwick, 1994), included univariate techniques like: Shannon-Wiener diversity index, *H';* Margalef's index, *d*; and Pielou's evenness index, *J'*. The premonsoon stations were designated as R1 to R5 and the postmonsoon stations as R1' to R5' for the sake of analyses. Multivariate techniques included ordination of square root transformed polychaete data using Bray-Curtis similarities by non-metric multi-dimensional scaling (MDS) after which the species having the greatest contribution to the division of sites into groups were determined using the similarity percentages programme (SIMPER). Non-parametric Spearman rank coefficient was used to establish correlations between biological parameters and chemical characteristics using the software Statistica 7. BIO-ENV procedure was utilized for characterizing the impact of more than one ecological factor on the distribution and abundance of polychaetes. This calculates Spearman rank correlation coefficients between the similarity matrix underlying the biotic MDS and the Euclidean distance matrices for all combinations of environmental variables, thereby defining suites of environmental variables that best explain the measured biological structure. A paired t - test was used to detect significant differences in the *H'* values between seasons.

Results and Discussion

The bottom water temperature varied between 27-29°C during both seasons in the study area. The average values of hydro-sedimentological parameters during premonsoon and postmonsoon are given in Table 1. As expected, salinity was comparatively lesser during postmonsoon. DO showed marginal enhancement during postmonsoon .Though the DO levels generally remained good throughout the stations during both seasons, anoxic conditions were recorded in station R5 during premonsoon due to its proximity with the fishery harbour and poor flushing characteristics of that particular bay segment owing to the presence of the breakwaters. High values of PO_4^{3-}-P (17.3 μmol l^{-1}) and NH_4^+-N (5.9 μmol l^{-1}) recorded at the same station during the premonsoon was symptomatic of pollution associated with the harbour activities. In the outer stations (stations 1, 2 and 3), the sediment varied from sandy-silt during premonsoon to silty-sand during postmonsoon with low content of clay suggesting seasonal variability in sediment texture, while the stations in the bay *viz.* stations 4 and 5 had predominantly sandy texture during both sampling periods. The C_{org} values were generally low through out all stations except at station R1 (2.8% dry wt in premonsoon and 2.1% dry wt in postmonsoon). Relatively high content of C_{org} off Ratnagiri have also been reported by Jayaraj *et al.* (2007) which has been attributed to the combined influence of upwelling and primary productivity.

Thirty polychaete species belonging to 18 families were identified during premonsoon. Most abundant forms were *Parheteromastus tenuis* (28.6%), *Sabellides* sp. (19.6%),

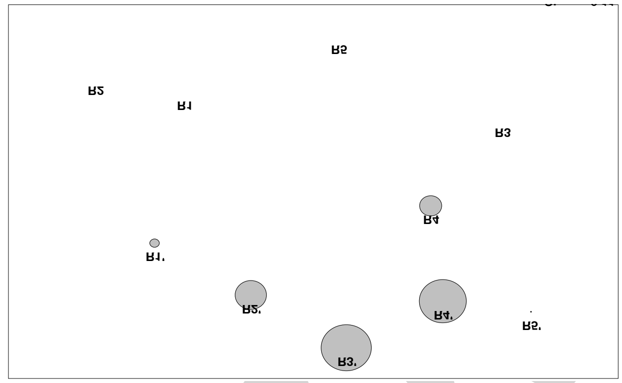

Fig. 2: Non-metric multidimensional scaling of polychaete species abundances from stations in the Ratnagiri bay during premonsoon (R1-R5) and postmonsoon (R1'-R5'). Abundance of *Paraprionospio pinnata* is superimposed as bubbles

Paraprionospio pinnata (14.3%) and *Cirriformia tentaculata* (11.9%). During the postmonsoon, 24 species (16 families) were identified of which *P. pinnata* (48.2%) was the most dominant species (Table 2). The species diversity (*H'*) values during premonsoon ranged from 1.4 to 2.4 whereas during postmonsoon they were 0.6 to 1.6 (Table 3). All stations consistently showed higher values of *H'* during premonsoon. The species richness (*d*) and evenness index (*J*) also followed the same trend (Table 3). Interestingly station 5 had comparatively healthier diversity values during both sampling episodes though it was located in a polluted zone.

The *H'* values did not show distinct spatial variations and minimum values were recorded at stations 2 and 3 during both the seasons. Seasonal variations in *H'* were significant (t test; $p< 0.05$). The stations were well demarcated season-wise in the MDS plot signifying that the composition of the polychaete community differed considerably between the seasons (Fig. 2). Similar observations

Table - 1: Season-wise average values of water and sediment parameters in Ratnagiri bay

Parameters	Pre-monsoon (March-07)	Post-monsoon (Nov-07)
pH	7.8±0.2	8.0±0.04
SS(mg l^{-1})	21.2±2.4	17.4±2.1
Salinity (ppt)	35.3±0.1	34.3±0.1
DO(ml l^{-1})	3.6±2	4.2±0.3
PO_4^{3-}-P (μmol l^{-1})	3.9±7.5	1.2±1.2
NO_3^--N (μmol l^{-1})	0.9±0.5	0.7±0.1
NO_2^--N (μmol l^{-1})	0.7±0.2	0.6±.5
NH_4^+-N(μmol l^{-1})	1.7±2.4	2.3±3.6
Sand (%)	45.4±36.9	77.5±14.3
Silt(%)	47.8±34.2	20.0±12.7
Clay(%)	6.9±2.8	2.4±1.9
C_{org} (%)	0.8±1.1	1.3±0.9
PHc (μg g^{-1})	0.9±1.1	1.6±2.3

SS = Suspended solids; DO = Dissolved oxygen; PO_4^{3-}-P = Dissolved inorganic phosphate; NO_3^--N = Nitrate-nitrogen; NO_2^--N = Nitrite-nitrogen; NH_4^+-N = ammonia nitrogen; C_{org}= Organic carbon; PHc = Petroleum hydrocarbons. Values are mean of replicates ± SD

Table - 2: Polychaetes at sampling stations in the Ratnagiri bay during March, 2007 and November, 2007

Species	March 2007 (Premonsoon)					November 2007 (Postmonsoon)				
	R1	R2	R3	R4	R5	R1'	R2'	R3'	R4'	R5'
Ancistrosyllis parva	+					+	+			
Boccardia polybranchia			+	+					+	+
Capitellidae	+	+	+	+	+	+	+	+	+	+
Cirratulidae					+					
Cirriformia tentaculata	+	+	+	+	+					
Cossura coasta	+	+				+	+			
Diopatra cuprea cuprea			+	+				+	+	
Eteone ornata				+			+	+	+	+
Fabricia bansei			+	+	+		+	+	+	+
Glycera longipinnis			+	+	+	+	+	+	+	+
Glycinde multidens		+			+					
Goniadella gracilis		+								
Hesionidae	+						+		+	
Isolda pulchella			+	+						
Leptonereis sp						+	+			
Lumbrineridae				+						
Lumbrineris brevicirra							+		+	
Magelona cincta	+	+	+	+		+	+		+	
Maldanidae		+	+		+	+	+			
Mediomastus	+									
Nephtys dibranchis	+	+	+	+				+	+	+
Nephtys lyrochaeta		+								
Nereidae	+	+							+	+
Ninoe sp	+	+	+							
Ninoe lagosiana							+	+		
Onuphis geophiliformis			+	+						
Paraprionospio cirratobranchia							+			+
Paraprionospio pinnata	+	+	+	+	+	+	+	+	+	+
Parheteromastus tenuis	+		+	+	+				+	
Phyllodocidae		+	+							
Poecilochaetus serpens							+			
Sabellastarte longa							+	+	+	+
Sabellides sp			+	+						
Scoloplos armiger			+	+					+	+
Spionidae		+		+						
Sthenelais boa									+	
Terebellides stroemi	+	+								

+ = Present

were made by Parulekar *et al.* (1980) in Goa estuaries and Patnaik (1971) in Chilka lake.

Though station 5 was the most impacted by anthropogenic wastes as demonstrated by the anoxic conditions as well as higher nutrient load, the polychaetes were not influenced by it as evident from their comparatively higher *H'* values (1.9 and 1.6) and better evenness values (0.9 and 0.7) during both seasons. On the other hand R2 and R3, the stations with the least *H'* and evenness values were away from all the sources of pollution as corroborated by the hydro-sedimentological values. Obviously, there were other factors other than of anthropogenic origin which were influencing the polychaete distribution patterns.

The Spearman rank correlation between environmental variables and the univariate indices showed significant positive correlation of *H'* with clay (r=0.64, $p< 0.05$) while *d* was significantly positively correlated with silt (r=0.69, $p< 0.05$) and clay (r=0.77, $p< 0.05$) and negatively correlated with sand (r= -0.71, $p< 0.05$) (Table 4). Individual polychaete species were not related to any of the chemical parameters separately, probably because in a multifarious ecology a set of ecological factors may be responsible for the polychaete assemblage patterns (Jayraj *et al.*, 2008) which in this study was determined through BIO-ENV analysis. The BIO-ENV analysis between single environmental variable and polychaetes for all stations showed that silt content of sediments had the highest correlation with species composition (ρ=0.48). The combination of environmental parameters which best explained the polychaete distribution patterns were sand and silt (ρ=0.52) (Table 5). The above statistical analysis revealed that sediment texture majorly influenced the polychaete distribution. Many authors have reported

Table - 3: Polychaete statistics of the stations in Ratnagiri bay during premonsoon (R1-R5) and postmonsoon (R1'-R5')

Station	Number of species (S)	Total number (no)	Margalef richness (*d*)	Pielou's evenness index (*J'*)	Shannon diversity (*H'*)
R1	13	207	2.3	0.9	2.4
R2	15	766	2.1	0.6	1.5
R3	17	2263	2.1	0.5	1.4
R4	17	3076	2.0	0.7	2.0
R5	9	208	1.5	0.9	1.9
R1'	8	657	1.1	0.7	1.4
R2'	16	1527	2.0	0.4	1.0
R3'	9	2169	1.0	0.3	0.6
R4'	16	4677	1.8	0.6	1.6
R5'	11	2039	1.3	0.7	1.6

Table - 4: Pairwise Spearman rank correlations between environmental variables and univariate indices

Environmental variable	Shannon diversity (*H'*)	Margalef richness (*d*)	Pielou's evenness index (*J'*)
pH	-0.38	-0.02	-0.52
SS	0.51	0.57	0.38
DO	-0.18	-0.30	-0.39
PO_4^{3-}-P	0.26	-0.23	0.47
NO_3^--N	-0.03	0.49	-0.25
NO_2^--N	-0.37	-0.18	-0.25
NH_4^+-N	0.15	-0.38	-0.31
sand	-0.50	-0.71*	-0.31
silt	0.48	0.69*	0.29
clay	0.64*	0.77*	0.44
C_{org}	0.21	0.24	0.19
PHc	0.16	-0.32	0.30

*significant at $p< 0.05$

Table - 5: Results of BIO-ENV analyses for all stations

No. of variables	Variables	Spearman correlation (ρ)
1	Silt	0.481
2*	Sand, silt	0.487
3	Salinity ,sand, silt	0.485
4	pH, DO, sand, silt	0.464

* shows highest correlation

sediment texture as the principle abiotic factor influencing polychaete distribution (Arasaki *et al.*, 2004; Jayaraj *et al.*, 2008). It was also observed that the diversity indices did not give any significant correlation with pH, DO, nutrients, C_{org} or PHc.

The sediment texture varied from sandy silt (predominant silt) during premonsoon to silty sand (predominant sand) in postmonsoon (Table 1). This can be mainly attributed to the southwest monsoon (June-September) the principle rainy season of west coast of India, accounting for about 73% of the total rainfall. Similar changes have been reported by Kumar *et al* (2004) at Panambur, west coast of India. The average species dissimilarity between the two seasons was 64.69% (as calculated by SIMPER). At least 9 polychaete species which were present in the premonsoon samples were absent in the postmonsoon samples, the prominent ones being *Cirriformia tentaculata* (av 155 ind m^{-2}), *Sabellides* sp. (av 256 ind m^{-2}), *Isolda pulchella* sp. (av 25 ind m^{-2}) and *Onuphis* sp (av 11 ind m^{-2}). Their ecological niches were probably taken over by dominant polychaetes like *Paraprionospio pinnata* (av 1066 ind m^{-2}), *Fabricia bansei* (av 275 ind m^{-2}), *Boccardia polybranchia* (av 175 ind m^{-2}) and Capitellidae (218 av ind m^{-2}) in the post monsoon scenario. *P. pinnata* is a widely distributed (Yokoyama, 1990), cosmopolitan species occurring in areas subjected to continuous disturbances (Pearson and Rosenberg, 1978). The pronounced change in sediment texture between the two seasons probably influenced the polychaete assemblage patterns and led to lower H' values and J' values. The role of sediment stability as an important variable controlling the distribution and abundance of polychaete species is well documented (Wildish *et al.*, 1979).

It is universally accepted that when the benthic biota is exposed to severe disturbance the benthic communities become increasingly dominated by one or two species resulting in low evenness (Murugesan *et al.*, 2009). In this case, the polychaete *P. pinnata* which was relatively lower in the premonsoon samples (av. 186 ind m^{-2}) was predominant in the postmonsoon samples (av. 1066 ind m^{-2}) as depicted in the MDS graph (Fig. 2). An increase in the density of opportunistic species after flood events have been reported by other workers (Salen-Picard *et al.*, 2003).

The significant pollution load in the bay did not seem to create any imbalance in the polychaete community structure as exemplified by the absence of dominant polychaetes in the station (R5) nearest to the source of pollution, the semienclosed fishery harbour. The study indicates that in Ratnagiri bay, the polychaete distribution and diversity were probably governed primarily by variations in sediment texture brought about by the monsoon that falls in the period intervening between the two sampling episodes rather than the anthropogenic disturbances. Chollet and Bone (2007) have observed that in marine coastal systems heavy rainfall may act as disturbing agent that alter the system structure and promote species responses. Levin (1984) has reported an increase of abundance above previous levels in some species and temporary changes of dominance in most benthic polychaetes species due to unusual rainstorms. Likewise, Hylleberg and Nateewathana (1991) described reduction of polychaete diversity and species richness on the west coast of India due to heavy rains.

The results show that though the anthropogenic factors were present in the domain of study, natural physicochemical variables majorly influenced the distribution of these sensitive fauna. Ingole *et al.* (2009) have suggested that while usage of biotic indices has become rampant in many monitoring programmes, it may lead to wrong conjecture in areas which are naturally stressed. Therefore in the light of this study, we suggest that while evaluating the ecological health of any coastal system by studying the polychaete characteristics, it may be prudent to ascertain whether any apparent changes in polychaete community structure were due to natural factors or anthropogenic stressors to arrive at a more accurate assessment of the environment under study. An understanding of the coastal ecosystem with a comprehensive baseline polychaete data will be one way to prevent erroneous conclusions.

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