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Impact of Natural and Manmade Disturbances on Intertidal Biodiversity of Selected Shores of Mumbai, India

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Abstract

A study was carried out to examine the biodiversity status of TIFR, Bandstand and NCPA rocky beaches in Mumbai, India. A total of 50 species of intertidal organisms were recorded from these shores. Kruskal Wallis ANOVA revealed the variation in occurrence of organisms in different months and quadrates. However, there was no variation in occurrence of organisms in different transects of a shore that indicates uniform distribution of organisms along the length of these shores. Bray–Curtis similarity matrix showed highest similarity in the pattern of occurrence of *Nerita oryzarum* (TIFR), *Planaxis sulcatus* (Bandstand), and *N. oryzarum* and *Tectarius malaccanus* (NCPA) shore. Shepard diagram from different sites indicates stressed condition of these shores. Abundance / biomass comparison (ABC) curve also pointed towards the polluted status of these shores. Thus the study concludes that though these beaches are disturbed, they still support a rich biodiversity which needs immediate attention for protection and conservation.
Key words : Intertidal biodiversity, Natural and manmade disturbances, Shores of Mumbai.

The aquatic ecosystem is degrading as a result of human interference and the biodiversity which has been regarded as a central quality of life from the time of Aristotle (384—322 BC) has already been affected due to ecological degradation of this ecosystem. The Intertidal ecosystem of sea is one of the most dynamic zones being the interface between sea and terrestrial environment. The tides influence the life and activities of organisms of the intertidal zone by regulating duration of exposure. The intertidal ecosystem around Mumbai, India was environmentally clean and rich in faunal composition (Rai 1931, Subramanyam et al. 1949, 1951, 1952), but it has been disturbed and imbalanced (Govindan and Desai 1980, Sabnis 1984, Jaiswar 1999) as coastal waters of Mumbai receives industrial discharges up to 230 million liters per day (MLD) and domestic wastes of around 2,200 MLD of which, 1800 MLD are untreated (Zingde and Govindan 2000). Therefore, in view of degraded coastal ecosystem, the present investigation was undertaken to assess the present status of intertidal biodiversity of TIFR, Bandstand and NCPA beaches of Mumbai, India.

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Methods

Mumbai, the Island city is situated on west coast of India (between lat. 18°54′to 19°09′ N and long. 72°47′ to 72°56′ E). The intertidal areas different parts of Mumbai are exposed to varied width depending upon the slope of the shore. In the present study, three rocky shores, TIFR (Tata Institute of Fundamental Research), Bandstand (Bandra) and NCPA (National Center for Performing Arts) were selected. Three transects (T_1, T_2, T_3) were marked at the shores, and 15 quadrates with 0.1 m^2 area at interval of 5 m were sampled every month from each transects from December 2006 to November 2007 during low tide. Thus 45 quadrates (4.5 m^2 area) were sampled each month over the stretch of three

Table 1. Month-wise biodiversity indices for the intertidal fauna of TIFR (T), Bandstand (B) and NCPA (N) shores. S—No. of species, d-Margalef's richness index, J–Pilou's evenness index, H'–Shannon's diversity index, 1– λ'- Simpson's diversity index. N_1, N_2, Ninf–Hill numbers.

	T	B Dec	N	T	B Jan	N	T	B Feb	N
S	38	29	40	42	21	34	32	26	33
d	5.17	3.74	5.19	5.72	3.06	4.23	4.07	3.5	4.57
J'	0.82	0.75	0.76	0.8	0.81	0.73	0.67	0.8	0.81
Brillouin	2.92	2.48	2.76	2.93	2.39	2.54	2.3	2.56	2.77
H'	2.99	2.51	2.81	2.99	2.45	2.57	2.34	2.61	2.83
1-λ'	0.93	0.86	0.92	0.93	0.88	0.89	0.85	0.9	0.92
N_1	19.8	12.34	16.53	19.97	11.62	13.01	10.35	13.58	16.97
N_2	14.38	7.34	11.85	14.8	8.11	9.29	6.55	9.65	11.94
Ninf	6.69	3.24	6.8	9.63	4.64	4.84	3.41	5.77	5.95

Table 1. Continued.

	T	B Mar	N	T	B Apr	N	T	B May	N
S	26	34	36	27	29	36	29	27	30
d	3.35	4.63	4.81	3.7	4.08	5.13	3.95	3.8	4.19
J'	0.74	0.73	0.79	0.76	0.81	0.81	0.77	0.8	0.75
Brillouin	2.36	2.5	2.77	2.47	2.67	2.84	2.54	2.59	2.5
H'	2.4	2.56	2.82	2.52	2.73	2.92	2.59	2.65	2.56
1-λ'	0.86	0.85	0.91	0.89	0.92	0.93	0.89	0.91	0.89
N_1	11.02	12.94	16.81	12.41	15.38	18.51	13.3	14.11	12.88
N_2	7.23	6.76	11.2	9.43	11.94	13.43	9.02	11.13	9.39
Ninf	4.38	2.97	4.95	5.65	7.28	6.61	4.11	6.06	5.23

Table 1. Continued.

	T	B Jun	N	T	B Jul	N	T	B Aug	N
S	35	29	31	26	33	34	28	24	31
d	5	3.83	4.1	3.71	4.96	4.96	3.52	3.27	3.87
J'	0.74	0.63	0.74	0.83	0.81	0.78	0.63	0.67	0.58
Brillouin	2.56	2.08	2.5	2.65	2.72	2.67	2.07	2.1	1.95
H'	2.63	2.12	2.54	2.72	2.81	2.75	2.1	2.14	1.98
1-λ'	0.88	0.83	0.9	0.91	0.92	0.91	0.8	0.81	0.78
N_1	13.89	8.33	12.66	15.11	16.69	15.7	8.18	8.51	7.27
N_2	8.18	5.88	10	10.69	12.11	10.57	5.03	5.38	4.6
Ninf	3.72	3.49	6.41	5.25	6.57	6.18	2.82	3.39	3.18

Table 1. Continued.

	T	B Sep	N	T	B Oct	N	T	B Nov	N
S	37	26	38	24	28	29	23	26	28
d	4.9	3.38	4.99	3	3.59	3.68	2.94	3.34	3.46
J'	0.77	0.68	0.7	0.68	0.67	0.64	0.71	0.76	0.68
Brillouin	2.73	2.17	2.51	2.12	2.22	2.12	2.21	2.44	2.25
H'	2.78	2.21	2.56	2.15	2.25	2.15	2.24	2.47	2.28
1–λ'	0.9	0.83	0.87	0.81	0.85	0.79	0.83	0.87	0.82
N_1	16.16	9.11	12.89	8.55	9.46	8.59	9.37	11.87	9.74
N_2	10.13	5.97	7.56	5.36	6.57	4.73	5.8	7.74	5.58
Ninf	5.27	3.65	3.34	2.72	4.02	2.4	3.17	3.63	2.7

Table 2. Variation of physico-chemical parameters in the intertidal water at TIFR, Bandstand and NCPA.

Para-meters	TIFR Min	TIFR Max	TIFR Mean ±SE	TIFR SD	Bandra Min	Bandra Max	Bandra Mean ±SE	Bandra SD	NCPA Min	NCPA Max	NCPA Mean ±SE	NCPA SD
Air temperature	28.50	34.00	30.45 ±0.57	1.98	28.00	32.00	29.75 ±0.33	1.16	28.50	32.00	30.04 ±0.34	1.18
Water temperature	27.00	32.00	28.62 ±0.49	1.68	27.00	30.00	27.95 ±0.29	0.99	27.00	31.00	28.58 ±0.32	1.12
Salinity ‰	26.00	34.50	31.95 ±0.71	2.47	25.50	34.00	31.83 ±0.75	2.61	26.50	34.00	31.79 ±0.73	2.54
pH	7.30	8.35	7.77 ±0.08	0.27	7.30	8.20	7.75 ± 0.08	0.28	7.45	8.35	7.81 ± 0.08	0.27
DO (mg/l)	4.80	6.60	6.04 ±0.15	0.51	5.00	7.60	5.92 ± 0.20	0.70	5.40	6.80	6.06 ± 0.13	0.46
BOD (mg/l)	8.80	11.80	10.78 ±0.29	1.00	8.80	12.20	10.45 ± 0.27	0.92	9.60	11.80	10.96 ±0.22	0.75
NH_4-N (mg/l)	0.06	0.40	0.18 ±0.03	0.11	0.02	0.32	0.14 ± 0.03	0.10	0.14	0.37	3.32 ±3.06	10.6
NO_3-N (mg/l)	0.10	1.70	0.48 ±0.13	0.44	0.08	0.50	0.29 ± 0.05	0.19	0.19	1.30	0.54 ±0.09	0.30
NO_2-N (mg/l)	0.01	0.09	0.045 ±0.01	0.03	0.02	0.11	0.05 ± 0.01	0.03	0.04	0.12	0.07 ±0.01	0.03
PO_4-P (mg/l)	0.08	1.20	0.49 ±0.08	0.29	0.08	0.70	0.33 ± 0.06	0.22	0.37	1.20	0.679 ±0.08	0.28

transects. The intertidal organisms collected were identified by following the key of Crichton (1941), Hornell (1949), Menon et al. (1951), Subramanyam et al. (1949, 1951, 1952), Bhatt (1959), Rao (1982), Apte (1998) and Chhapgar (2005). Doubtful specimens were sent to the laboratory of Zoological Survey of India, Kolkata, for proper confirmation of the identification. To find out the variations in occurrence in different quadrates, transects and months, the Kruskal Wallis one way ANOVA ($P < 0.001$) was performed. Abundance / biomass comparison (ABC) method of determining level of disturbance (pollution induced or otherwise) described by Warwick et al. (1987) for macrofaunal organisms was attempted. To express the stress level on the intertidal organisms, the Shepard diagram method was applied. Physico-chemical parameters of water sample collected at low tide level were estimated by following standard method of APHA et al. (1998). All the statistical analyses of the collected data were performed by using software, PRIMER Ver. 6 (developed by Plymouth Research Laboratory, UK).

Results and Discussion

During the study a total 50 species of intertidal organisms (41 Gastropoda, 5 Pelecypoda, 1 Crustracea, 1 Anthozoa, 1 Cephalopoda and 1 Ophiuroidea) were recorded from these shores. All together, 48 species belonging to 21 family and 28 genera (43 Gastropoda, 3 Pelecypoda, 1 Crustracea, 1 Anthozoa) at TIFR shore ; 42 species from 17 family and 25 genera (37 Gastropoda, 3 Pelecypoda, 1 Crustracea, 1 Anthozoa) at Bandstand shore, and 49 species belonging to 22 family and 29 genera (41 Gastropoda, 4 Pelecypoda, 1 Crustracea, 1 Anthozoa, 1 Cephalopoda and 1 Ophiuroidea) from NCPA shore were observed. A variation in number of species and their composition was apparent at these sites.

Melvill and Abercrombie (1993) recorded 322 species, Hornell (1949) 414 species, Bhatt (1959) 93 species, Jaiswar (1999) 99 species of molluscs, which are numerically higher as compared to the present observation, where only 50 species of intertidal organisms including other groups were recorded. The reason may be many fold increase in anthropogenic activities in the coastal area that have lead to degradation of the coastal water. Decline of the biodiversity of benthic fauna along with change in the community structure under pollution stress has also been reported earlier (Bayne et al. 1982, Shetty 1982, Moore et al. 1997, Varshney 1988, Newey and Seed 1995, Simboura et al. 1995, Young et al. 1995). In addition, it was also observed that some intertidal areas where large numbers of organisms were recorded by earlier workers have become barren due to pollution stress. Secondly, the earlier investigators had recorded empty molluscan shells also, while in the present study, shells with live animals only were recorded.

The benthic population responds to pollutants or organic enrichment by undergoing detectable changes in population on a time scale of weeks to years. As the benthic biota consists of largely sessile organisms, they must tolerate the pollution or die. Also, these organisms are resident year round, naturally abundant, diverse and most are not fished or intentionally managed by man. Hence the benthic monitoring is sensitive, effective and reliable technique that can detect subtle changes that serve as an early indicator before more drastic environmental changes occur (Gray et al. 1992). Anthropogenic disturbances may affect the physiological state of the animals predicting to changes in growth rate, recruitment and mortality (Bryan et al. 1986, Tablado et al. 1994, Johnston and Keough 2000, 2002, Ng and Keough 2003). So the biodiversity essentially reflects ecological quality of the habitats (Vladica and Snezana 1999).

A scale of pollution in terms of Shannon's species diversity (3.0—4.5 slight, 2.0—3.0 light and 1.0—2.0 moderate and 0.1—1 heavy pollution) has been described by Staub et al. (1970). In present study, Shannon's index varied from 2.1 (August) to 2.99 (January) at TIFR, 2.14 (August) to 2.81 (July) at Bandra and 1.98 (August) to 2.91 (April) at NCPA. So, the values indicate light polluted nature of TIFR and Bandra shore whereas, light to moderate polluted nature of NCPA shore (Table 1). Overall low values of H' is indicator of stressful environment. The evenness index reveals the evenness of distribution of various species in a sample, and the Shannon index becomes maximum when all the species in a sample are equally abundant, decrease towards zero as the relative abundance of species diverse away from the evenness due to environmental disturbances (Ismael and Dorgham 2003). So, a community becomes more dissimilar as the stress increases and accordingly species diversity decreases with decreasing water quality. Hence community dominated by relatively few species would indicate environmental stress (Plafkin et al. 1989).

The data from different sites showed that all the pair wise distance between samples in the final ordination against the similarity in the resemblance matrix was not too much deviated from the best fitting increasing regression line except in the lower range. Variations in lower range of similarity axes indicate the stressed condition of these shores. The stress values recorded (0.13, 0.151, and 0.126 for TIFR, Bandstand and NCPA shore, respectively) are also pointing towards stressful conditions of these shores.

Warwick et al. (1987) and Clarke (1990) stated that the distribution of numbers of individuals among species and the distribution of biomass among species in marine macrobenthic communities show a differential response to pollution-induced disturbance. Such a response can be demonstrated by comparison of ABC curves for abundance and biomass. These curves, rank species in decreasing order of their abundance or total biomass on the x-axis (logarithmic scale) with the percentage of the total abundance of all species in the sample on the y-axis (cumulative scale). This curve is widely used for determining level of disturbance (pollution induced or otherwise) on macrobenthos (Warwick et al. 1987). The k-dominance curve for biomass lies above that for numbers. In moderately disturbed communities, both curves roughly coincide, and in grossly disturbed communities the numbers curve lies above the biomass curve. This method is based on the assumption that in the event of environmental disturbance, the distribution of numbers of individuals among species in macrobenthic assemblages behaves differently from the distribution of biomass.

In the present study, the ABC curves for both, the dominance and abundance curve roughly coincided for TIFR and Bandra indicating the moderately disturbed condition. Whereas, for NCPA beach the abundance curve lies above the biomass curve in some of the portion indicating grossly disturbed communities. The W statistics values observed for Bandra, TIFR and NCPA are 0.085, 0.019 and 0.001, respectively also indicated the very same situation of these shores. This polluted condition of these shores could be attributed to human interference and anthropogenic stress. The TIFR and NCPA beaches are is very near to the Mumbai port, which also contributes to some degree of oil pollution due to sea transport. However in Bandra, the disturbances could be attributed mainly to anthropogenic stress. Thus variations in the pollution on the three shores can be justified.

Khan et al. (2004), found the abundance curve to fall over the biomass curve throughout its length suggesting polluted nature of Uppanar estuary. He also found W values to fall on the negative side, ranging from –0.084 to –0.112, showing the highly disturbed nature. In the present study, the value of W ranged from 0.001—0.085, thus indicating moderate pollution level at all the three sites. Ismael and Dorgham (2003) observed the curve for numerical abundance to lie partially above the biomass curve for El-Dekhaila Harbor which he described as moderately polluted conditions.

The results on hydrological parameters of TIFR, Bandstand and NCPA shore indicated similarity in the physical parameters (temperatures, pH, and salinity) for three stations (Table 2). Air and water temperature from three sites varies between 28 to 34 C and 27 to 32 C, respectively. Salinity and pH varied between 25.5 to 34.5$\%_0$ and 7.3 to 8.35, respectively. Among other parameters DO (4.8 to 7.6 mg/liter) and BOD (8.8 to 12.2 mg/liter) revealed variations over the year from different stations. NH_4-N, NO_3-N, NO_2-N, PO_4-P ranged from 0.06—0.4 mg/liter, 0.08—1.7 mg/liter, 0.01—0.12 mg/liter, 0.08—1.2 mg/liter, respectively. Dhargalkar and Komarpant (2003) recorded similar physical parameters from Colaba, but they observed comparatively lower range level of nutrients and higher range of BOD similar to the present study. This situation indicates increase in pollution (Zingde et al. 1979, Zingde and Desai 1980, Zingde and Sabnis 1994). However, the overall results on physico-chemical parameters also revealed stressful ecological conditions of these intertidal areas.

So the present study indicate the occurrence of pollution on the selected shores that have affected the intertidal biodiversity of the region. However, some of the shores of Mumbai, a metropolitan city, still harbor varied intertidal biodiversity that need immediate attention.

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