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Temporal and spatial differences in species diversity in the intertidal region of south Mumbai

S. N. Datta, *S. K. Chakraborty, A. K. Jaiswar and K. Venkateshvaran

Fisheries Resource Management Division, Central Institute of Fisheries Education (Deemed University), ICAR, Versova, Andheri (West), Mumbai-400061, India.
**E-mail: sushanta.c@rediffmail.com*

Abstract

A study was carried out to examine the biodiversity and ecological health status of the intertidal region of rocky shores of NCPA (National Centre for Performing Art), Nariman Point, Mumbai. A total of 49 intertidal species was recorded of which *Euchelus asper* was the most dominant with density of 200/m^2 and biomass of 179.4 g/m^2 in November. Analysis of Variance (ANOVA) revealed that organisms did not vary according to transects though the variation was seen in different months and quadrates. Shannon's diversity index, Simpson's diversity index, Margalef richness index and Pielou's index indicated ecological variations in different months. Dendrogram from Bray – Curtis similarity matrix and Non metric Multi – Diamentional Scaling (MDS) indicated maximum similarity and closeness between *Nerita oryzarum* and *Tectarius malaccanus.* Abundance/biomass comparison (ABC) curve revealed moderately polluted status of the shore. However, in spite of such condition, this shore still supports a rich intertidal faunal biodiversity that must be conserved.

Keywords: Diversity indices, abundance, molluscs, intertidal, rocky shore, biomass

Introduction

The intertidal ecosystem is rich in biodiversity and plenty of data is available on biodiversity of intertidal ecosystem in India (Gopalkrishnan, 1970; Parulekar 1973; Goswami, 1992). The earlier investigators have recorded disturbances in biodiversity due to degrading of ecosystem, and hence it is concluded that biodiversity essentially reflects ecological quality of the habitats (Vladica and Snezana, 1999).

The present work was conducted with the objectives to assess the biodiversity and ecological status of the NCPA beach of Mumbai, India. Mumbai being a highly urbanised and industrialised city in India, discharges up to 230 million litres of industrial waste per day (MLD) and domestic wastes of around 2,200 MLD into the coastal ecosystem, of which, 1800 MLD are untreated (Zingde and Govindan, 2000). These anthropogenic discharges had their impacts on the biodiversity of all the intertidal areas of Mumbai. The intertidal organisms are not only important to the ecosystems, but are also of commercial importance (edible, ornamental). In the past, many investigations were conducted on the degrading water quality of coastal ecosystem around Mumbai Thakur *et al.*, 2002; Jaiswar 1999). However, the impact of environmental deterioration on the intertidal fauna has not been studied in detail. Hence the present investigation assumes importance in this respect and the results may be of use in conservation and management of the intertidal biodiversity of Mumbai.

Materials and methods

The shore area near the NCPA (National Centre for Performing Art) building is the end of Nariman

Point, situated in south Mumbai. The study site is a part of Queen's Necklace area in the form of a small bay. It is a semi - open type of rocky shore. On the shore three transects (T1, T2, T3) were marked perpendicular to the shore line keeping a distance of 70m between two transects and from each transect 15 quadrates of 0.1m^2 were sampled at the interval of 1m between two quadrates. The transects were fixed starting from spring high tide mark to spring low tide mark. Sampling of the intertidal organisms in the rocky zone of NCPA was done during low tide from the surface of the exposed areas. A metal frame of 0.1m^2 was used to sample a quadrate. Thus, the total number of quadrates sampled over the stretch of three transects was 45 and the total area sampled was about 4.5 m^2/month from December 2006 to November 2007.

Density (abundance) is presented as numbers/ m^2 and biomass as g/m^2. The average weight of each species was taken by weighing 10 deshelled individuals of different sizes of one species. The average weight was multiplied with the total number of organisms of different species in 1 m^2 to estimate the biomass. The organisms were identified following the publications of Crichton (1941), Hornell (1949), Menon *et al*. (1951), Subramanyam *et al.* (1949,1951,1952), Bhatt (1959), Fernando and Fernando (2002) and Chhapgar (2005). Specimens of doubtful identity were sent to the laboratory of Zoological Survey of India, Kolkata for confirmation.

The data collected on numerical abundance, biomass of organisms and water quality parameters were subjected to statistical analysis in order to draw conclusions. One way ANOVA was performed to know the variation in the distribution of organisms with respect to different quadrates, transects and months. Various indices such as Shannon's diversity index (1949), Simpson's diversity index (1949), Margalef richness index (1958) and Pielou's evenness index (1975) were calculated to know the level of disturbances in the habitat. Multivariate analyses including hierarchical clustering and ordination of samples by non metric multi – dimensional scaling (MDS) were performed and abundance/ biomass comparison curve (ABC) was drawn for determining level of disturbance (pollution induced or otherwise) following Warwick (1986). Bray–Curtis similarity matrix of biological parameters (organisms/m^2 and biomass/m^2) for understanding closeness in occurrence among organisms was also performed. The data was log transformed as Log (X+1) (Clarke and Warwick, 2001) and statistical software PRIMER Ver.6 (Plymouth Research Lab. U.K.) was used for various types of analyses. Physico–chemical parameters of water samples collected at low tide level were estimated by following standard methods (APHA, 1995). Air and water temperature was measured using mercury thermometer, pH by pH meter (Eutech), salinity by refractometer, dissolved oxygen by Winkler's method and 5-Day BOD by incubation method, NH^3-N, NO^3-N, NO^2-N and PO^4-P were measured using spectrophoto-meter.

Results

During the present study, a total of 49 species of intertidal organisms (41 gastropods, 4 pelecypods, and of one each crustacean, anthozoan, cephalopod and ophiuroid) belonging to 22

Table 1. Monthwise biodiversity indices for the intertidal fauna of NCPA shore during 2006-2007

Index	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV
S	40	34	33	36	36	30	31	34	31	38	29	28
d	5.19	4.23	4.57	4.81	5.13	4.19	4.10	4.96	3.87	4.99	3.68	3.46
J'	0.76	0.73	0.81	0.79	0.81	0.75	0.74	0.78	0.58	0.70	0.64	0.68
H'	2.81	2.57	2.83	2.82	2.92	2.56	2.54	2.75	1.98	2.56	2.15	2.28
1- **â'**	0.92	0.89	0.92	0.91	0.93	0.89	0.90	0.91	0.78	0.87	0.79	0.82

S - Number of species, d - Margalef richness index (1958), J'- Pielou's evenness index (1975), H' - Shannon's diversity index (1949), 1- â'- Simpson's diversity index (1949)

Table 2. Sample name, sample statistics of non-metric MDS ordination and combination statistics of dendrogram from Bray – Curtis similarity matrix of NCPA intertidal species

	Best 2-d configuration (Stress: 0.126)				Combination of dendrogram
	Sample	1	2	%	
1	*Alpheus* sp.	0.14	-0.54	0.3	28+41 -> 50 at 93.77
2	*Aplysia benedicti*	1.63	0.34	4.8	6+11 -> 51 at 93.03
3	*Astrea semicostata*	0.4	0.7	2.9	1+51 -> 52 at 90.73
4	*A.stellata*	0.63	0.17	0.8	34+50 -> 53 at 90.43
5	*Bursa granularis*	-0.76	0.24	15.5	21+47 -> 54 at 90.38
6	*B.tuberculata*	0.17	-0.54	0.3	10+52 -> 55 at 89.71
7	*Cellana radiata*	0.2	-0.44	0.2	23+55 -> 56 at 87.14
8	*Cerithium morus*	0.22	-0.5	0.4	19+53 -> 57 at 86.32
9	*C. rubus*	0.6	-0.44	4	8+18 -> 58 at 86.25
10	*Clanculus ceylonicus*	0.17	-0.64	0.4	22+57 -> 59 at 85.93
11	*C. depictus*	0.18	-0.58	0.4	7+56 -> 60 at 85.77
12	*Conus figulinus*	0.16	0.63	3.1	43+44 -> 61 at 85.28
13	*Cyprea arabica*	1.79	0.7	4.9	54+60 -> 62 at 85.14
14	*C. pallida*	0.41	1.38	3.5	26+29 -> 63 at 81.88
15	*Diodora bombayana*	0.27	0.03	0.8	58+62 -> 64 at 81.85
16	*D. lima*	0.12	1.11	3.7	49+61 -> 65 at 80.93
17	*Drupa contracta*	0.08	-0.11	1.9	39+59 -> 66 at 79.61
18	*D. konkanensis*	0.27	-0.38	0.6	15+48 -> 67 at 79.59
19	*Euchelus asper*	0.18	-0.76	0.7	35+64 -> 68 at 79
20	*E. indicus*	0.93	0.81	1.9	37+63 -> 69 at 77.45
21	*Gafrarium divaricatum*	0.14	-0.39	0.3	30+32 -> 70 at 77.37
22	*Littorina intermedia*	0.28	-0.67	1.2	66+68 -> 71 at 76.97
23	*L. ventrucosa*	0.16	-0.46	0.3	67+69 -> 72 at 76.81
24	*Meretrix meretrix*	-0.97	1.19	2.8	36+40 -> 73 at 74.25
25	*Murex adustus*	-1.37	1.19	4.1	65+72 -> 74 at 72.62
26	*Nerita albicilla*	0.37	0.1	0.6	31+33 -> 75 at 71.2
27	*N. chameleon*	-0.02	1.51	4.5	2+13 -> 76 at 69.65
28	*N. oryzarum*	0.19	-0.74	0.7	42+45 -> 77 at 69.14
29	*N. polita*	0.26	-0.05	0.6	4+46 -> 78 at 69.05
30	*Octopus* sp.	-1.73	0.91	4.2	74+78 -> 79 at 64.96
31	*Onchidium* sp.	-0.23	0.52	1.7	3+20 -> 80 at 64.89
32	*Perna viridis*	-1.6	0.93	4.3	17+79 -> 81 at 63.72
33	*Placenta placenta*	-0.09	0.39	2.3	9+71 -> 82 at 61.97
34	*Planaxis sulcatus*	0.28	-0.76	1.6	25+70 -> 83 at 61.23
35	*P. similis*	0.08	-0.46	0.5	12+75 -> 84 at 60.1
36	Polychaete	-0.24	-0.56	1.8	81+84 -> 85 at 56.53
37	*Pyrene atrata*	0.37	-0.13	0.6	14+27 -> 86 at 55.35
38	*Scutus unguis*	-1.18	-0.19	2.8	73+82 -> 87 at 54.25
39	*Anthopleura midori*	0.07	-0.63	0.5	24+83 -> 88 at 49.49
40	*Ophiocnemus marmorata*	-0.49	-0.69	3.3	85+87 -> 89 at 49.33
41	*Tectarius malaccanus*	0.17	-0.78	0.8	16+86 -> 90 at 43.74
42	*Thais blanfordi*	-1.84	-0.87	3.3	5+76 -> 91 at 41.79
43	*T. bufo*	0.18	0.13	0.6	38+77 -> 92 at 38.32
44	*T. carinifera*	0.15	0.25	0.8	80+89 -> 93 at 34.14
45	*T. echinulata*	-1.98	-0.99	2.7	90+93 -> 94 at 23.39
46	*T. rudolphi*	0.56	0.32	1.1	91+94 -> 95 at 21.36
47	*T. tissoti*	0.15	-0.4	0.2	92+95 -> 96 at 12.16
48	*Trochus radiatus*	0.22	-0.22	0.4	88+96 -> 97 at 9.17
49	*Turbo brunneus*	0.3	0.34	0.7	

Table 3. Bray – Curtis similarity matrix of biological and physicochemical parameters [log (X+ 1) transformed] for the NCPA

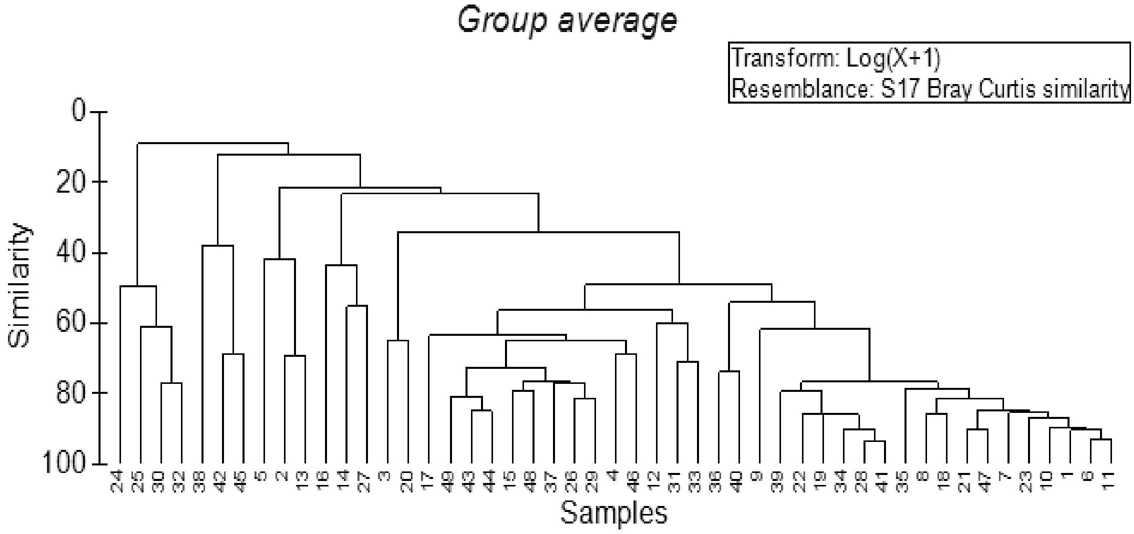
Parameters	Organisms/ month	Biomass/ month	Air temp (°C)	Water Temp (°C)	Salinity (ppt)	pH	DO (mg/l)	BOD (mg/l)	NH_4-N (mg/l)	NO_3-N (mg/l)	NO_2-N (mg/l)	PO_4 (mg/l)
Organisms/ month												
Biomass/ month	96.06											
Air temp(⁰C)	73.83	77.54										
Water temp (⁰C)	73.17	76.87	99.29									
Salinity (ppt)	74.54	78.26	98.83	98.28								
pH	54.09	57.26	77.56	78.23	76.84							
DO(mg/l)	49.94	52.96	72.51	73.16	71.81	94.62						
BOD(mg/l)	59.41	62.76	83.86	84.55	83.13	93.46	88.12					
NH^4-N (mg/l)	16.03	17.24	24.93	25.02	25.24	29.38	30.26	28.14				
NO^3-N (mg/l)	13.31	14.33	21.72	22.00	21.43	32.26	35.29	28.87	53.67			
NO^2-N (mg/l)	2.35	2.54	3.98	4.03	3.92	6.21	6.89	5.47	23.99	28.56		
PO^4 (mg/l)	15.87	17.06	25.68	25.99	25.34	37.73	41.14	33.88	46.94	81.58	24.23	

families and 29 genera were recorded from the NCPA shore. Among the recorded organisms *Euchelus asper* was present in highest density (200/ m^2) in November. However, *Planaxis sulcatus* , *P. similis*, *Cerithium morus, Littorina intermedia, L. ventricosa*, *Tectarius malaccanus*, *Cellana radiata*, *Clanculus ceylonicus*, *C. depictus*, *Nerita oryzarum*, *Thais bufo*, *T. tissoti*, *Trochus radiatus* and *Alpheus* sp. were also represented in considerable quantities throughout the study period. The maximum biomass was exhibited by *E. asper* in November (179.4 g / m^2) and the lowest by *L. ventricosa* (0.022 g / m^2) in May.

ANOVA ($p<0.05$) performed to know the distribution of organisms with respect to different quadrates, transects and months revealed significant variations in different months (H = 9.034) and quadrates (H = 49.91) but non-significant (H = 0.8567) with respect to transects. This indicated variation in the abundance and biomass of organisms in different quadrates and months. However, non significant variation between transects points towards the uniform distribution of organisms throughout the length of the shore.

The highest value of Margalef richness index was found in December (5.18) and the lowest in November (3.46). Maximum value of Pielou's evenness index was recorded in February and April (0.81) and minimum in August (0.57). As the Shannon's diversity index is dependent on evenness of distribution, it was also highest in April (2.91) and minimum in August (1.98). Simpson's diversity index (1949) (1- ®′) also depicted same pattern being highest in April (0.93) and lowest in August (0.78) (Table 1). The results of all the indices indicated stressful ecological conditions during the monsoon. However, the low values of H' and 1- â' are indicators of poor health of this shore throughout the year.

Dendrogram from Bray – Curtis similarity matrix of intertidal species revealed the highest similarity of *Nerita oryzarum* and *Tectarius malacanus* (similarity value 93.77) (Fig. 1). Uniformity in the N - MDS ordination of Bray – Curtis similarity matrix of species abundance data also indicated highest closeness of *N. oryzarum* and *T. malacanus* as both the species are placed very close to each other in MDS plot (Fig. 2) and ordination values are very close (0.19, -0.74; 0.17,



1. *Alpheus* sp.
2. *Aplysia benedicti*
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4. *A. stellata*
5. *Bursa granularis*
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17. *Drupa contracta*
18. *D. konkanensis*
19. *Euchelus asper*
20. *E. indicus*
21. *Gafrarium divaricatum*
22. *Littorina intermedia*
23. *L. ventricosa*
24. *Meretrix meretrix*
25. *Murex adustus*
26. *Nerita albicilla*
27. *N. chameleon*
28. *N. oryzarum*
29. *N. polita*
30. *Octopus* sp.
31. *Onchidium* sp.
32. *Perna viridis*
33. *Placenta placenta*
34. *Planaxis sulcatus*
35. *P. similis*
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38. *Scutus unguis*
39. *Anthopleura midori*
40. *Ophiocnemus marmorata*
41. *Tectarius malaccanus*
42. *Thais blanfordi*
43. *T. bufo*
44. *T. carinifera*
45. *T. echinulata*
46. *T. rudolphi*
47. *T. tissoti*
48. *Trochus radiatus*
49. *Turbo brunneus*

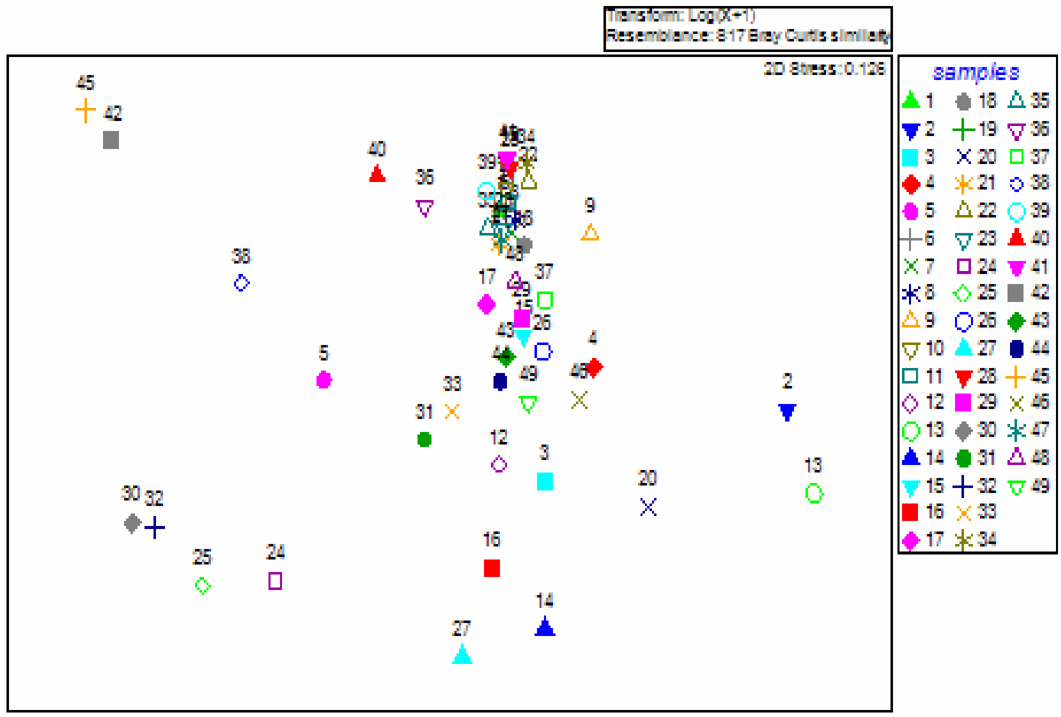
Fig. 1. Dendrogram from Bray – Curtis similarity matrix of intertidal species abundance data [log (X+ 1) transformed], with group average linking for the organisms in the NCPA shore

-0.78 with 2D stress value 0.125) (Table 2). Species abundance/biomass comparison curves along with W statistics for NCPA shore organisms revealed that the shore is moderately polluted since the abundance curve lies above the biomass curve (Fig. 3) as described by Warwick (1986).

The physico – chemical parameters of low tide water of this shore have shown wide variations. Air and water temperature varied between 28.5^{0}C and 32^{0}C and 27^{0}C and 31^{0}C, respectively (Fig. 4). Salinity and pH varied from 26.0 to 34.0 ppt and 7.45 to 8.35, respectively. Among other parameters, DO (5.4 to 6.8 mg/l) and BOD (9.6 to 11.8 mg/l) showed variations throughout the year. NO^3-N (mg/l), NO^2-N (mg/l), PO^4- P (mg/l) ranged from 0.19 to 1.3 mg/l, 0.04 to 0.12 mg/l and 0.37 to 1.2 mg/l, respectively (Fig. 5). Among all the physico-chemical parameters, the salinity has established the highest relationship with biological parameters. The high Bray- Curtis similarity matrix values of salinity (74.54 and 78.26) with organisms/month and biomass/month (Table 3) indicates that salinity is the most important factor that controls the distribution of organisms in the intertidal area.

Discussion

In the present study, 49 species of intertidal organisms including 45 molluscs were recorded. Melvill and Abercrombie (1893), Hornell (1949), Bhatt (1959) and Jaiswar (1999) reported more



1. *Alpheus* sp.
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3. *Astrea semicostata*
4. *A. stellata*
5. *Bursa granularis*
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47. *T. tissoti*
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49. *Turbo brunneus*

Fig. 2. Non metric MDS ordination of Bray – Curtis similarity matrix of species abundance data [log (X+ 1) transformed] of intertidal fauna (species wise) in the NCPA shore

than 45 molluscan species. The reason for less number of species in the present study is because the earlier workers recorded live as well as empty shells whereas only live organisms were considered in the present study. Pollution and other environmental disturbances in the coastal waters play a major role for changes in benthic community. Therefore, decline in the abundance of benthic fauna along with change in the community structure under pollution stress may be another cause for recording the less number of species compared to earlier workers (Bayne *et al*., 1982; Simboura *et al.,* 1995).

Seasonal variations in the environmental factors and biological properties of organisms (breeding, gonadal maturity etc.) influence the occurrence of organisms in the intertidal region. In

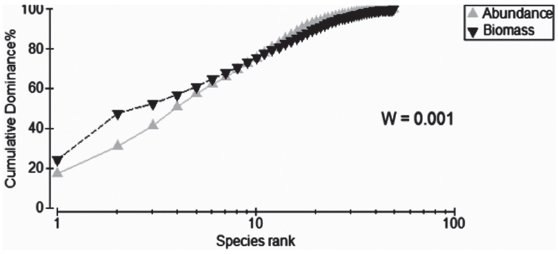

Fig. 3. Abundance Biomass Comparison Curve of intertidal organisms in the NCPA shore

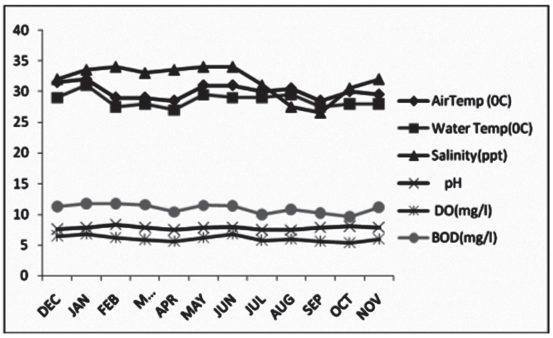

Fig. 4. Monthwise variation of air temperature (^{0}C), water temperature (^{0}C), salinity (ppt), pH, DO (mg/l) and BOD (mg/l) in the NCPA shore during 2006-2007

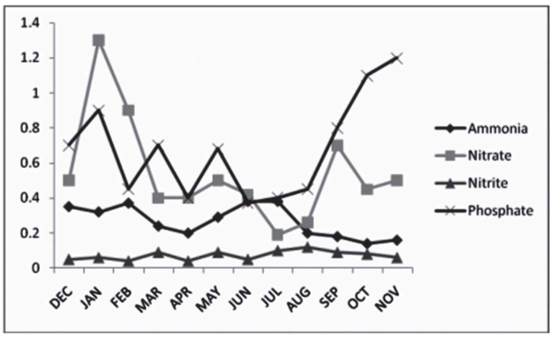

Fig. 5. Monthwise variation of ammonia (mg/l), nitrate(mg/l), nitrite (mg/l) and phosphate (mg/l) of water in the NCPA shore during 2006-2007

the present study also these factors have shown wide variations leading to variation in the abundance and biomass of organisms (Figs. 4 and 5). Distribution in different zones within the intertidal area is known to be influenced by temperature, salinity and the level of pollution (Stephenson and Stephenson, 1949; McMahon, 2001). In the present study, however, the distribution of the fauna was found to be uniform along the length of the shores.

Many researchers have demonstrated the importance of estimating indices in assessment of the biological status of a specific area of the marine ecosystem (Sunil Kumar and Antony, 1994; Nikouyan *et al*., 1998). In the present study, the number of species recorded was between 23 in November and 42 in January. This high number is also responsible for higher Margalef richness index throughout the study. Simpson's index (1- β′) also indicated highly diverse community. Pielou's evenness and Shannon's diversity indices revealed high evenness of the distribution except in the months of heavy monsoon. The most crucial factor responsible for the death of intertidal organisms is salinity which decreased considerably during monsoon (Fig. 4). In addition, very strong wave action during monsoon months would have led to the death of many organisms (Nikouyan *et al*., 1998).

Dendrogram method was used by McQuaid and Branch (1984) to know the relationship of sea temperature regime, substratum type and degree of wave exposure with the composition of rocky intertidal communities in the Cape of Good Hope. Warwick and Clarke (1991) demonstrated the utility of multivariate analyses for assessing community structure, while Boaventura *et al.* (2002) used it for rocky shore of continental Portuguese coast and Nakaoka *et al.* (2006) for Pacific coast of Japan. In the present study, the dendrogram and N - MDS ordination from Bray – Curtis similarity matrix of intertidal species abundance showed the highest similarity between *N. oryzarum* and *P. sulcatus.* Parulekar (1973) and Jaiswar (1999) also reported planaxids and neritids as dominant groups of molluscs on rocky shores.

According to Warwick (1986), in undisturbed communities, the k-dominance curve for biomass lies above that for abundance. In moderately disturbed communities, both curves roughly coincide and in grossly disturbed communities the abundance curve lies above the biomass. In the present study, the abundance curve lies above the biomass in a part of the curve indicating moderate to grossly polluted condition in the site. Low W statistics (W = 0.001) is also an indicator of the moderate to higher level of pollution status. Anthropogenic disturbances affect the physiological state of the animals leading to changes in growth rate, recruitment and mortality, ultimately affecting abundance and biomass that has been reflected in the curve (Johnston and Keough, 2002). The analysis of interrelationship between physico – chemical and biological parameters revealed high correlation between salinity, and abundance and biomass of intertidal organisms (Table 3). Thus the low salinity during the monsoon period has strong negative effect on the abundance of intertidal organisms. Low values of NO_2, NO_3 and PO_4 during the monsoon period also would have restricted the abundance of organisms. The lower abundance of organisms during the monsoon period following lower salinity as well as the lower nutrient availability was earlier reported by Zingde and Sabnis (1994).

The study indicated moderate pollution at the shore. However, the shore harboured rich molluscan diversity. The diversity of organisms have been regulated by wave action, salinity and nutrients and affected by pollution. The existing biodiversity must be protected and conserved from human interference.

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