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DIVERSITY OF BENTHIC MACROMOLLUSCAN COMMUNITIES ON THE ROCKY SHORES OF KARACHI COAST, PAKISTAN

Solaha Rahman and Sohail Barkati

Department of Zoology, University of Karachi, Karachi-75270, Pakistan
e-mail: sohailbarkati@yahoo.com

ABSTRACT

The spatial and temporal variations in the rocky intertidal molluscs communities were studied with reference to tide and seasonal variation at four rocky sites - Manora, Buleji, Nathiagali and Cape Monze along the Karachi coast. The average values of species richness was high (3.63) at Manora followed by Cape Monze (3.25), Nathiagali (3.22) and Buleji (3.06). The Species Richness and Hill diversity number N1 was inversely proportional to tidal height at Manora, Buleji and Nathiagali whereas reverse was the case at Cape Monze. The average values of Evenness (E5) were directly proportional to tidal level at Manora, Nathiagali and Cape Monze whereas no relation with tidal zone was found at Buleji. The average value of Hill diversity number (N1) from the total area was high at Manora (6.47) followed by Nathiagali (6.33), Cape Monze (5.65) and Buleji (5.31) shores. Molluscan species were more evenly distributed at Nathiagali (0.67) and somewhat less evenly at Buleji (0.64), Manora (0.63) and Cape Monze (0.61). Seasonal variation in E5 values was less evident in the four sites.

Key words: Diversity, macromolluscs, rocky shores, Karachi

INTRODUCTION

Notable contributions to our understanding of inrewrtidal fauna are those of McQuaid and Branch (1984, 1985), McQuaid *et al.* (1985), Lasiak and Field (1995) from South Africa; Seapy and Littler (1978), Littler (1980), Horn *et al.* (1983) from California; Underwood *et al.* (1983) from South Wales; Terlizzi *et al*. (2005) from Mediterranean; Kuklinski *et al*. (2006) from North Atlantic; Kurihara (2007) from Japan; Martins *et al*. (2008) from Azores; Underwood *et al*. (2008), Chapman and Underwood (2008) from New South Wales; Barrett *et al.* (2009) from Tasmania. Little attention has, however, been paid to the distribution and abundance of marine organisms from Pakistan coast. Ahmed *et al.* (1982) observed the distribution and abundance of intertidal organisms on some beaches of Makran coast. The biomass and species composition of a littoral rocky shore of the Karachi coast were studied by Barkati & Burney (1991, 1995) and Burney and Barkati (1995). The diversity of algal associated epifauna on the rocky shores of Manora and Buleji was studied by Zehra *et al.* (1995) and Ahmed and Hameed (1999) studied the seasonal variation in biomass of intertidal macroorganisms of the rocky shore of Buleji. Species composition and faunal diversity for the Sindh mangroves was documented by Barkati and Rahman (2005).

The present studies deal with the comparison of species richness, diversity and evenness in macromolluscan communities on rocky shores of Manora, Buleji, Nathiagali and Cape Monze along the coast of Karachi, with reference to the variation of tide (high, mid or low) and seasonal. Such studies are imperative for our understanding of structure and function of this valuable rocky intertidal ecosystem.

STUDY AREA

Details on location and substratum types of the shores of the area are given in Rahman and Barkati (2004). The rocky ledge of Manora lies on the southwestern side of the island facing the open Arabian Sea. It is a gently sloping shore, which receives high surf action and thus categorized as exposed shore. The Buleji rocky ledge, located near the Buleji fishing village is a gradually sloping more or less triangular platform, which protrudes out in the Arabian Sea. Nathiagali is a semi-sheltered coast in the sense that it has a raised beach and the heap of coastal detritus, situated at a height higher than the level of highest tides. Cape Monze rocky ledge is a relatively stable beach having sharply steeped vertical cliff. It is located on the border between the province of Sind and Baluchistan.

Nathiagali and Cape Monze are located in the naval restricted area and are thus relatively undisturbed. Conversely, Manora and Buleji are the most disturbed and polluted sites (Ahmed, 1997). The intertidal shores of Manora, Buleji and Cape Monze are open to direct surf action and are thus can be classified as exposed and wave beaten open shores. However, Nathiagali may be recognized as semi-exposed rocky shore due to the presence of a rocky cliff of considerable height. These sites are the most populated rocky ledges along the Sindh coast.

The inshore waters are characterized by high turbidity, which results from extensive beach erosion, which introduces sand and silt in the water column and renders the Sindh coast greater turbidity because of shallowness of the habitat. The physical parameters on tidal level, air and water temperatures, pH and salinity of sea water are described in Rahman and Barkati (2004).

MATERIALS AND METHODS

Sampling and Laboratory Techniques

The rocky shores of Karachi viz. Manora, Buleji, Nathiagali and Cape Monze along the coast of Karachi, Sindh were visited on quarterly basis for a period of two years from December, 1993 to September, 1995 (eight visits to each site) during the ebb tides so that maximum part of the intertidal area may be examined. Three quadrates of 1 m^2 each were studied from each tidal level from the four sites. Thus nine quadrates were studied from each site at each visit.The molluscan samples were kept in a deep freezer overnight. Next day all samples were washed with tape water and molluscs of each quadrate were identified to the species level following Subrahmanyam *et al.* (1952), Kundo (1965), Dance (1977), Barnes (1974), Lindner (1977), Kohn (1978) and George and George (1979). The individuals of each species in each quadrate were recorded.

Statistical Analyses

The indices of species diversity were calculated using natural logarithms based on density data (number of individuals per m^2). Following diversity indices are used as measure of the community structure. The Margalef's index (D') was used for richness (D' = (S-1) / log N; where S = total number of species & N = total number of individuals observed). Hill diversity number N1 was used for both richness and evenness combined (N1 = $e^{H'}$; where H′ = Shannon-Wiener index) and Modified Hill ratio E5 for evenness (E5 = N2-1 / N1-1) as described in Ludwig and Reynolds (1988). The indices were calculated using statistical software "PRIMER" v6 (Clarke and Gorley, 2006) of Plymouth Marine laboratory, UK.

OBSERVATIONS

Manora Rocky Shore

Sixty three molluscan species were recorded from this site - Gastropods (49 spp.) dominated the ledge followed by bivalves (12 spp.), amphineurans (1sp.) and cephalopods (1 sp.). However, number of species varied seasonally from 27 (December 1994) to 40 (June 1994).

Cerithium morus, C. rubus, Cerithium sp., Turbo coronatus, Cerithidea cingulatus, Morula granulata, Perna viridis, Cantharus rubiginiosus, Nerita albicilla and *Morula uva were the most abundant species.*

The values of species richness and diversity index N1 are inversely proportional whereas values of evenness are directly proportional to the tidal height. Seasonal changes in the values of three indices studied with reference to tidal heights follow different patterns. Values of richness at all three tidal levels were at maximum in summer (June) but the season of minimum values vary in three tidal zones (Table 1).

The N1 values in low tidal zone were at maximum in March (pre-monsoon period) whereas these were high in summer in mid and high tidal zones (Table 2). Likewise, N1 values of the total area (three tidal levels combined) were at maximum in summer.

Seasonal changes in E5 values showed March as the month of maximum value in low and mid tidal zones and of minimum value for high tidal zone (Table 3). The E5 values fluctuated from high in winter to low the following spring during both the years of the observation period.

Buleji Rocky Shore

Sixty eight species of molluscs were recorded from this site - gastropods (54 spp), bivalves (12 spp.), amphineurans (1 sp) and cephalopods (1sp.). The total number of species varied from 28 (June 1994) to 36 (March 1995).

Nine species viz. *Cerithium morus, C. rubus, Cerithium sp., Turbo coronatus, Planaxis sulcatus, Cerithidea cingulatus, Nerita albicilla*, *T. intercostalis* and *Cerithium hanleyi* contributed 93 % of the molluscan fauna and remaining 7% fauna was represented by remaining 59 species. Minimum number of species was found in summer and maximum in spring. A significant portion to the total density was contributed by gastropods.

The values of species richness and N1 were inversely proportional to the tidal height whereas molluscan species were found more evenly distributed in mid tidal zone. The month of minimum values of richness varied at the three tidal heights whereas the months of maximum values are same for low and mid tidal height (Table 1) and also for the total area (Table **1**).

The values of diversity index N1 decreased as the tidal height increased. The N1 values in low tidal level were minimum (3.80) in December 1993 and maximum (13.10) in March 1995 (Table 2). In mid tidal zone the values ranged from 2.98 in September 1994 to 6.51 in December 1995 whereas it varied from 2.74 in March 1995 to 5.17 in September 1995 from high tidal zone. The N1 values for total area ranged from 5.62 in September 1994 to 10.10 in September 1995. The molluscan species were more evenly distributed in mid tidal zone. The values of E5 are generally minimum in winter and maximum in autumn in low and mid tidal zones with minor differences during the study period. However, the value of E5 in low tidal zone remained high in summer during first year instead of autumn (Table 3). In high tidal zone the values fluctuated from a high in winter to a low the following autumn during both years. Values of E5 of the total area were low in spring during both years but remained high in summer during 1994 and in autumn during 1995.

Nathiagali Rocky Shore

There were 55 species in the area - gastropods (47 spp.), bivalves (6 spp.), amphineurans (1 sp.) and cephalopods (1 sp.). The total number of species per sample ranged from 22 in September 1994 to 38 in June 1994 and December 1995.

Turbo coronatus, Trochus stellatus, Cerithium rubus, C. hanleyi, Nerita albicilla, Euchelus asper, Cerithidea cingulatus, Cerithium sp., T. intercostalis, Planaxis sulcatus, Cellana radiata and *Morula granulate were the* twelve species which had an average per cent density of more than 1 %.

The values of richness and N1 were inversely proportional to the tidal height whereas E5 values are directly proportional to increase in tidal height. There is a general seasonal trend of high values of richness in summer and low in autumn at all tidal zones. However, in case of high tidal zone lowest value of the season in high tidal zone was found in spring during 1995 instead of autumn (Table 1). The values for the total area fluctuated seasonally from a high in summer to low in autumn during both the years. Species were abundantly present in low tidal zone, followed by mid and high tidal zones. No seasonal trend in N1 values is seen with reference to tidal height. N1 values at low tidal height remained almost identical throughout except in Dec. 1993. Lowest values of the year for mid tidal region were seen in September which is the season of high values for high tidal zone (Table 2). Values of E5 were directly proportional to the increase in tidal height. The E5 values from three tidal zones showed different seasonal pattern in 1994 and 1995. The values in low tidal zone were high in winter and low in spring during 1994. Conversely, the values remained high in spring and low in summer during 1995. In mid tidal zone the values were high in winter and low in summer during both the years (Table 3). The E5 values in high tidal zone were high in winter and low in spring during first year but remained high in spring to low in summer during second year of observation. The values for the total area were minimum (0.520) in June 1994 and maximum (0.764) in March 1995 with an average value of 0.663.

Cape Monze Rocky Shore

Fifty seven species were recorded from this site. The number of molluscan species per sample varies from 10 in January 1994 to 38 in March 1994. *Trochus stellatus, Morula granulata, Turbo intercostalis, Cerithium rubus, Nerita albicilla, T. coronatus, Cantharus undosus, Chiton, Morula uva, Euchelus asper, Thais rudolphi* and *Calliostoma scobinatum* were the twelve species of molluscs which contributed around 90 % of the average per cent density.

The species richness was the maximum in high tidal zone followed by low and mid tidal zones. The values of E5 and N1 were, however, directly proportional to tidal height. There is a general seasonal trend of high values in March that gradually dropped down to the lowest of the year in December (Table 1).

The N1 values in low and mid tidal zone varied from low in winter to high the following autumn. Values in the high tidal zone are high in spring instead of autumn (Table 2). The index values for the total area ranged from 2.6 (December 1993) to 9.4 (March 1994).

A similar seasonal trend of changes in E5 values was observed for low and mid tidal zones with low values in March and high values in September (Table 3). In case of high tidal zone September is the month of minimum values which attained the peak values in June. The E5 values for the total area varied from high in winter to low in summer during both the years.

Comparison of species composition at the sampling Sites

The average number of molluscs per m^2 was also high at Buleji and Manora compared to Nathiagali and Cape Monze. Five species of molluscs are commonly abundant on all the four sites: *Turbo coronatus, Nerita albicilla, Morula granulata, Cerithium rubus* and *Chiton sp.*

Table 1. Seasonal variation of Richness of molluscan species in low, mid and high tidal zones of Karachi coast: Manora, Buleji, Nathiagali and Cape Monze.

Month	Manora			Buleji			Nathiagali			Cape Monze		
	Low	Mid	High	Low	Mid	High	Low	Mid	High	Low	Mid	High
Dec.93.	4.03	3.35	2.74	4.55	2.010	1.210	3.66	2.52	2.41	1.54	0.891	1.35
Mar.94.	4.95	2.30	2.39	5.11	3.110	1.620	3.26	3.19	2.57	4.97	3.200	5.99
Jun. 94.	5.66	3.63	3.21	3.60	2.040	1.760	4.26	4.75	3.99	2.58	3.420	3.62
Sep. 94.	5.09	3.41	2.13	5.26	0.816	2.070	2.94	2.04	2.70	3.93	3.280	2.96
Dec. 94.	3.22	3.45	2.56	5.81	3.390	1.820	3.31	2.71	2.47	1.28	1.770	1.83
Mar. 95.	5.18	1.96	2.89	6.02	3.450	0.998	4.00	3.94	1.80	4.76	3.200	5.52
Jun. 95.	4.99	4.30	3.63	4.22	2.300	2.210	4.13	3.91	4.19	2.51	3.630	3.55
Sep. 95.	5.07	4.06	3.02	4.70	2.910	2.370	2.57	2.67	3.40	4.67	3.980	3.49
Mean	4.77	3.31	2.82	4.91	2.50	1.76	3.52	3.22	2.94	3.28	2.92	3.54
± S.E	0.27	0.28	0.17	0.29	0.32	0.17	0.21	0.32	0.30	0.53	0.37	0.57
Gr.Mean		3.63			3.06			3.22			3.25	
± S.E		0.22			0.32			0.16			0.28	

Table 2. Seasonal variation of Hill Diversity (N1) of molluscan species in low, mid and high tidal zones of Karachi coast: Manora, Buleji, Nathiagali and Cape Monze.

Month	Manora			Buleji			Nathiagali			Cape Monze		
	Low	Mid	High	Low	Mid	High	Low	Mid	High	Low	Mid	High
Dec.93.	06.03	5.72	3.83	03.80	3.95	4.46	10.60	6.41	4.80	2.02	2.43	03.81
Mar.94.	11.40	4.89	4.57	06.52	4.19	3.33	5.39	5.36	5.29	4.87	4.96	11.30
Jun. 94.	09.27	5.41	6.50	04.10	4.57	3.76	7.00	5.89	5.87	4.91	5.72	09.21
Sep. 94.	07.89	3.99	4.54	06.14	2.98	3.43	6.98	3.76	7.04	7.41	6.12	04.89
Dec. 94.	08.65	4.29	5.63	10.20	4.84	5.14	6.29	5.24	6.87	2.35	2.50	03.10
Mar. 95.	09.08	2.79	6.36	13.10	4.09	2.74	7.10	8.30	5.23	4.80	4.96	10.50
Jun. 95.	08.42	7.15	6.81	05.35	4.83	5.01	7.27	6.93	5.29	4.37	5.04	08.01
Sep. 95.	08.57	6.99	6.49	09.49	6.34	5.17	7.61	4.08	7.34	8.85	7.05	06.30
Mean	8.66	5.15	5.59	7.34	4.47	4.13	7.28	5.75	5.97	4.95	4.85	7.14
± S.E	0.53	0.53	0.40	1.16	0.34	0.33	0.53	0.53	0.35	0.81	0.58	1.09
Gr.Mean		6.470			5.314			6.331			5.645	
± S.E		0.423			0.499			0.298			0.520	

The species of family Cerithidae i.e *Cerithium morus*, *Cerithium sp.* and *Cerithidea cingulatus* were present abundantly on Manora and Buleji but were seen in few numbers at Nathiagali and Cape Monze. The molluscs abundantly present only on the beaches of Nathiagali and Cape Monze are: *Euchelus asper*, *Cantharus undosus*, *Trochus stellatus*, *Thais rudolphi*, *Turbo intercostalis*, *Nerita textilis* and *Cellana radiata*.

The bivalve, *Perna viridis* was abundantly present only on Manora rocky shore while the gastropod, *Planaxis sulcatus* was abundantly present on Buleji and Nathiagali rocky shores. *Conus biliosus* was regularly found only at Cape Monze. Some species of mollusc such as *Onchidium damellai, Glossodoris, Cypraea sp., Thais species, Bursa subgranosa, Barbatia obliquata and Cantharus rubiginiosus* were occasionally found on all the shores.

Table 3. Seasonal variation of evenness (E5) of molluscan species in low, mid and high tidal zones of Karachi coast: Manora, Buleji, Nathiagali and Cape Monze.

Month	Manora			Buleji			Nathiagali			Cape Monze		
	Low	Mid	High	Low	Mid	High	Low	Mid	High	Low	Mid	High
Dec.93.	0.366	0.728	0.658	0.351	0.629	0.907	0.751	0.753	0.758	0.490	0.781	0.727
Mar.94.	0.679	0.791	0.589	0.354	0.680	0.630	0.542	0.597	0.493	0.347	0.563	0.607
Jun. 94.	0.547	0.679	0.767	0.686	0.720	0.654	0.620	0.540	0.561	0.608	0.564	0.811
Sep. 94.	0.633	0.643	0.771	0.540	0.866	0.566	0.739	0.669	0.760	0.674	0.681	0.498
Dec. 94.	0.597	0.571	0.698	0.416	0.701	0.765	0.615	0.754	0.831	0.579	0.510	0.690
Mar. 95.	0.558	0.414	0.710	0.588	0.561	0.785	0.715	0.630	0.860	0.368	0.563	0.622
Jun. 95.	0.546	0.518	0.629	0.485	0.716	0.755	0.524	0.629	0.459	0.604	0.547	0.797
Sep. 95.	0.634	0.704	0.749	0.620	0.782	0.694	0.827	0.645	0.740	0.654	0.677	0.475
Mean	0.570	0.631	0.696	0.505	0.707	0.720	0.667	0.652	0.683	0.541	0.611	0.653
± S.E	0.034	0.044	0.024	0.044	0.033	0.038	0.038	0.026	0.055	0.044	0.033	0.045
Gr.Mean		0.632			0.644			0.667			0.602	
± S.E		0.022			0.029			0.023			0.025	

The average number of species was highest at Manora followed by Buleji and Nathiagali rocky shores. Cape Monze has the lowest average number of species. A pronounced seasonal variation in number of species was observed at the four sites. The mean number of individuals of molluscs was considerably higher at Buleji and Manora as compared to Nathiagali and Cape Monze rocky shores. Cape Monze had lowest number of individuals as compared to other three sites throughout the study period.

Species diversity as function of tide, season and locality

ANOVA of the data for the three indices is presented in Tables 4-6. Species richness as given by d'= (S-1)/log N was significantly influenced by site, tide and season ($p < 0.001$) and all these factors interacted with each other significantly (Table 4). Species richness of macromolluscan community at Manora was significantly higher than at other three sites where it didn't vary with each other. Species richness of community of low tide was higher than that of communities of mid and high tide. Richness significantly declined in September and December and was relatively high in March and June.

Hill diversity N1 = $e^{H'}$, was significantly influenced by site and tide. Seasonal variation had no effect on Hill's diversity of the molluscan communities. Site interaction with tide and season was significant but tide and season interacted insignificantly (Table 5). The three factors, however, interacted mutually significantly ($p < 0.0123$). Species diversity was high at Manora and more or less indifferent at Nathiagali but significantly lower at Cape Monze and Buleji. Communities at low tide locations had higher species diversity than at mid or high tide locations.

Equitability of abundance distribution or evenness expressed as modified Hill ratio E5 = N2-1 / N1-1 was found to be the function of tide and season and not of the site. The interaction of site with tide and tide with season were significant. Although site-season interaction was significant to define equitability, the total interaction of the three factors was not significant. Equitability was high at Nathiagali and Buleji, somewhat low at Manora and substantially lower at Cape monze. Equitability was higher in communities of high tide locations and progressively lower in mid tide and high tide locations. Equitability was influenced by the season – it declined in summer (March and June) in comparison to September (rainy Season) and December (winter).

Table 4. ANOVA for location, tide and season effects on species richness of macromolluscs communities of rocky coast of Karachi.

Source	SS	df	MS	F	p
Main					
Site	4.2999	3	1.4333	6.7439	0.001
Tide	33.7968	2	16.8984	79.5089	0.001
Season	13.8987	3	4.6329	21.7894	0.001
Interactions					
Site x Tide	28.9936	6	4.8322	22.7363	0.001
Site x Season	31.8578	9	3.5397	16.6549	0.001
Tide x Season	4.2675	6	0.7112	3.3465	0.007
Site x Tide x Season	16.0514	18	0.8917	4.1957	0.001
Error	10.02016	4	0.2225	-	-
Total	143.3678	95	-	-	-

DMRT and LSD calculation

Site			Tide			Season		
Rank	Treatment	Mean	Rank	Treatment	Mean	Rank	Treatment	Mean
1	Manora	3.25 a	1	Low	4.12 a	1	March	3.60 a
2	Cape Monze	3.24 b	2	Mid	2.99 b	2	June	3.59 a
3	Nathiagali	3.22 b	3	High	2.76 b	3	September	3.31 b
4	Buleji	3.06 b	$LSD_{0.05}$ = 0.2317			4	December	2.66 c
$LSD_{0.05}$ = 0.2675						$LSD_{0.05}$ = 0.2676		

Table 5 . ANOVA for location, tide and season effects on species diversity of macromolluscs communities of rocky coast of Karachi.

Source	SS	df	MS	F	p
Main					
Site	21.8981	3	7.2993	3.4498	0.024
Tide	66.7240	2	33.6320	15.7675	0.001
Season	21.7484	3	7.2494	3.4262	0.243
Interactions					
Site x Tide	79.2983	6	13.2163	6.2463	0.001
Site x Season	62.1928	9	6.9103	3.2657	0.003
Tide x Season	16.4492	6	2.7714	1.2957	0.277
Site x tide x Season	86.4097	18	4.8005	2.2688	0.0123
Error	101.5615	98	2.1159	-	-
Total	456.2823	95		-	-

DMRT and LSD calculation

Site			Tide			Season		
Rank	Treatment	Mean	Rank	Treatment	Mean	Rank	Treatment	Mean
1	Manora	6.47 a	1	Low	7.06 a	1	March	6.30 a
2	Nathigali	6.33 a	2	High	5.71 b	2	September	6.23 a
3	Cape Monze	5.65 ab	3	Mid	5.06 b	3	June	6.11 a
4	Buleji	5.31 b	$LSD_{0.05}$ = 0.7311			4	December	5.12 b
$LSD_{0.05}$ = 0.8443						$LSD_{0.05}$ = 0.8442		

Table 6. ANOVA for location, tide and season effects on equitability component of diversity macromolluscs communities of rocky coast of Karachi.

Source	SS	df	MS	F	p
Main					
Site	0.05435	3	0.0178	2.1061	0.1118
Tide	0.2301	2	0.1150	13.5730	0.001
Season	0.0921	3	0.0307	3.6217	0.0195
Interactions					
Site x Tide	0.1213	6	0.0202	2.385	0.043
Site x Season	0.1678	9	0.0186	2.200	0.038
Tide x Season	0.1342	6	0.0223	2.639	0.027
Site x Tide x Season	0.2162	18	0.0120	1.417	0.168
Error	0.4069	48	0.0084	-	-
Total	1.4223	95	-	-	-

DMRT and LSD calculation

Site			Tide			Season		
Rank	Treatment	Mean	Rank	Treatment	Mean	Rank	Treatment	Mean
1	Nathiagali	0.667 a	1	High	0.668 a	1	September	0.678 a
2	Buleji	0.644 ab	2	Mid	0.650 a	2	December	0.651 a
3	Manora	0.632 ab	3	Low	0.571 b	3	June	0.624 ab
4	Cape Monze	0.602 b				4	March	0.594 b
$LSD_{0.05}$ = 0.0534			$LSD_{0.05}$ = 0.0462			$LSD_{0.05}$ = 0.0534		

DISCUSSION

Diversity attributes of macromolluscan communities in intertidal areas of rocky shores at four places (Manora, Buleji, Nathiagali and Cape Monze) of Karchi coast were studied for two years to elucidate their community organization. The results of the present investigations are in accordance with the observations of Warwick and Clarke (1993) and Lasiak and Field (1995) showing that the trends in species richness, diversity and evenness are not significantly different among sites. The richness was only slightly higher at stable and undisturbed sites i.e. Cape Monze followed by relatively more unstable and disturbed sites: Manora, Nathiagali and Buleji. Species were more evenly distributed at Buleji and less evenly at Nathiagali, Manora and Cape Monze rocky shores. Such trends were in agreement with the results of Littler (1980) and McQuaid and Branch (1984). Studying the macro-invertebrates of Cayucos Point, California, Seapy and Littler (1978) recorded high species richness values at sheltered boulder beach. Conversely, the evenness and Shannon indices indicated a higher diversity on exposed Sea Stack of California. The evenness results were in contrast to those of the richness. The sea stack had high evenness than the boulder beach for total macro-biota (0.78 versus 0.61), as well as for macrophytes (0.80 versus 0.58) and macro-invertebrates (0.51 versus 0.44). Shannon index were in agreement with the evenness index.

According to Littler (1980) the richness at Coal Oil Point (15.42), a community stressed by both oil and sand inundation, was much lower than at the other sites. Sites high in richness and number of taxa were often low in evenness (Ocean Beach and Santa Cruz Island). Wu and Richards (1981) observed an increase in species diversity with increasing salinity and decreasing silt- clay fraction of the sediment in a sub tropical estuary in Hong Kong.

According to McQuaid and Branch (1984) richness was low and evenness was high on unstable substratum. However, no significant differences in richness or evenness were found in exposed and sheltered rocky beaches around Cape of Good Hope, S. Africa. Contreras *et al.* (1991) stated that the species diversity in littoral molluscs was high on rocky shores with heterogeneous substrate and low in areas with smooth rocks partially protected in the Chamela Bay, Mexico. The results of the present study showed that the species richness and diversity are slightly higher on heterogeneous and stable substrate (Cape Monze).

According to Warwick *et al.* (1990) macrofaunal diversity was lowest in disturbed and polluted areas and highest in undisturbed areas of Hamilton Harbour, Bermuda. Gray *et al.* (1990) found a reduction in number of species and diversity and increase in dominance of opportunistic species in response to oil as a stress factor from the Ekofisk and Eldfisk oilfield, North Sea. According to Dye (1998), there were no clear long-term trends in species diversity in either undisturbed or experimentally cleared areas on rocky shores of South Africa. Terlizzi *et al.* (2005)

investigated the potential effects of sewage discharge on spatial patterns of highly diverse molluscan assemblages in Mediterranean rocky subtidal habitats. The Shannon diversity of molluscs was significantly lower near sewage outfall, but no difference among locations was detected for the total number of species.

Moreover, Warwick and Clarke (1993) pointed out that diversity behaves neither consistently nor predictably in response to environmental stress. Lasiak and Field (1995) documented that exploitation has no significant effect on species richness or on diversity in Transkei coast, S. Africa. According to Chakraborty *et al.* (1992), the species diversity of macrozoobenthos of Sagar Island, Sunderbans India was correlated with salinity, dissolved oxygen, pH, temperature, organic carbon and texture of the substratum.

The present study showed that the diversity values not only varied seasonally but varied from site to site and are thus in accordance with the observation of Littler (1980). The diversity values on Manora rocky shore were at maximum in summer season of both the years but remained low in September 1994 and December 1995 during first and second year, respectively. The same inference was drawn by Nasreen *et al.* (2000) working on macroinvertebrates of Manora rocky ledge. The diversity values of Buleji rocky shore fluctuated seasonally from a high in winter to a low in the following autumn during 1994 but remained low in summer and increased in autumn during 1995 as observed by Barkati and Burney (1995) on the same site. The diversity index of Nathiagali rocky shore fluctuated seasonally from a high in winter to a low in summer during first year but remained high in spring to a low in summer during second year of study. The diversity values of the Cape Monze rocky shore were low in winter and high in spring during both the years of investigation.Littler (1980) also observed less seasonal variation in richness at some sites than at the other sites within southern California Bight. Seasonality in evenness was apparent at many sites. According to Seapy and Littler (1982) species diversity fluctuated from a high in October to low the following May during two years due to increased period of day time aerial exposure in late fall and winter. Burney and Barkati (1995) working on the macrofauna of Buleji rocky shore recorded a linear interdependence among the measures of diversity. Changes in the values of diversity were more or less identical to those of species richness and evenness. Species diversity fluctuated seasonally from a high during October to January to a low during February to August. This decreasing trend in diversity was in association with the disturbance and stress experienced during monsoon period (May to August), which probably had exceeded an optimal intermediate level of disturbance. Species diversity and dominance are negatively correlated with each other. According to Fatima and Barkati (1999) the average species diversity, evenness and species richness were 2.55, 0.67 and 1.72, respectively on a natural bed of the green mussel *Perna viridis* at Paradise point, Karachi. They noted that the values of species richness were highest (1.8) in winter months (February & November) and lowest (1.47) in summer (August) at Paradise point, Karachi. Similarly, Shannon-Wiener diversity index were also relatively higher in winter (November) compared to summer. Nasreen *et al.* (2000) working on macro-invertebrates of Manora rocky ledge showed that Shannon-Wiener Index of diversity and evenness values were highest in April, May and June on Manora rocky shore. According to Underwood *et al.* (2008) density was unreliable as an estimate of diversity on rocky shores of New South Wales, because it revealed spurious trends in summer when there was no increased number of species from north to south.

The diversity values were significantly different among three tidal zones. The results of the present investigation showed that the richness was inversely proportional to the tidal height i.e. the richness is highest in low tidal zone and decreases as the tidal height increases on Manora, Buleji, Nathiagali and Cape Monze rocky shores. The diversity values N1 were inversely proportional to the tidal height on Manora, Buleji and Nathiagali rocky shores. However, the N1 index of the Cape Monze rocky shore was directly proportional to tidal heights i.e. values increases with an increase in tidal height. The values of species evenness are directly proportional to the tidal height on Manora, Nathiagali and Cape Monze rocky shores. The evenness values on Buleji rocky shore was high in mid tidal zone followed by high and low tidal zones. Loi (1981) observed significant variation in species diversity among levels and stations for intertidal assemblages on hard substrates in the Port of Long Beach, California. The values gradually decreased from +1 ft. to level +5 ft. The mean species evenness exhibited a pattern similar to those of the mean species diversity. Dominance was often closely related to abundance. Since environmental stresses are less severe at low tidal levels, these trends are expected. Martins *et al*. (2008) detected significant variation in the lower and mid zone communities, but not on the upper zone in the rocky intertidal zone of Azores.

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