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Species Composition and Faunal Diversity at Three Sites of Sindh Mangroves

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Abstract.- The present communication deals with the abundance and diversity of mud flat, seaweed and tide pool benthic fauna of Sindh mangroves. The paper provides a comparative account on seasonal basis of three sites namely, Sandspit, Port Qasim and Clifton, respectively. A total of 26 invertebrate species were recorded from Sandspit, 21 species from Port Qasim and 19 species from Clifton. Molluscs dominated in the muddy habitat of all three sites followed by crustaceans. Only five species of molluscs were regularly found and commonly abundant on the three sites. Gastropods and amphipods dominated the animal species found in the seaweeds whereas mysids in most of the samples dominated the water pool fauna of all sites. Values of species diversity indices showed seasonal variation. Moreover, values of diversity were relatively higher in least disturbed and polluted sites.

Key words: Mangroves, Sindh, diversity, abundance.

INTRODUCTION

The mangroves constitute a complex ecosystem that offers niches for free-living, climbing, crawling, burrowing and sessile organisms. In Pakistan mangroves cover about 160,000 hectares of Indus delta where *Avicennia marina* dominates occupying about 95% of the tree cover (Meynell and Qureshi, 1992). According to Saifullah (1997), only four species of mangroves now exist although eight species were reported to occur in the delta due to tampering of the environment and overexploitation by man.

Literature on mangrove is varied and numerous (Macnae, 1968; Rollet, 1981; Macintosh, 1982). Publications appeared later on fauna of mangroves include the work of Wells (1983), Zhou and Li (1986), Patra *et al.* (1990), Sasekumar *et al.* (1994), Alcantara and Weiss (1995), Guerreiro *et al.* (1995), Sasekumar and Chong (1998), Cantera *et al.* (1999), Akil and Jiddawi (2001), Koch and Wolf (2002), Macintosh *et al.* (2002), to mention a few.

Qualitative information on mangrove fauna and flora is available in Pakistan but there is a great dearth of quantitative studies. The ecology and population structure of mangrove flora have been observed by Saifullah (1982, 1985, 1991), Kogo (1986), Kogo *et al.* (1987), Vannucci (1988), Meynell (1995), Snedaker *et al.* (1995), Campbell (1999) and Khan and Aziz (2001). The work related to general description of fauna of Sindh mangroves has been reported by a number of authors (Ahmad, 1983; Hoda and Akhtar, 1983; Tirmizi and Barkati, 1983; Tirmizi *et al*., 1983; Karim, 1988; Khanum and Ahmed, 1988; Ahmed *et al.*, 1985; Ahmad, 1999). The ecology, population structure and relative growth of the abundant species from the mangroves of Karachi was analysed by Barkati and Tirmizi (1988a,b, 1987, 1990, 1991, 1994) and Barkati *et al.* (1990). Few studies on distribution and diversity of meiobenthos, microalgae and cynobacteria have recently been carried out by Qureshi and Sultana (1999), Saifullah and Taj (1995), Siddiqui *et al.* (2000) and Zaib-un-Nisa *et al.* (2000), respectively. Jawed and Khan (1974) investigated the macrofaunal population inhabiting the mudflats of Baba Island. One paper dealing with the diversity of algal associated epifauna on the rocky shores of Manora and Buleji was carried out by Zehra *et al.* (1995). Recently, Ahmed (1999) discussed the abundance and distribution of seaweeds, mangroves, zooplankton, macro-invertebrate and vertebrate fauna of the Indus delta. The present study provides detail information about the seasonal occurrence, distribution, density and diversity of organisms collected from the mud flats, water pools and seaweeds of Sandspit, Clifton and Port Qasim mangroves along the Sindh coast.

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MATERIALS AND METHODS

Description of the study area

Mangrove forests in Pakistan lie between 24° 10' and 25° 37' latitude North and 61° 50' North latitude and 61° 38' and 68° 10' East longitude. The Indus Delta mangroves are perhaps unique in being the largest area of arid land mangroves in the world, being dependent upon the River Indus for its freshwater requirements (Meynell and Qureshi, 1992). The relative humidity is high throughout the year. It is higher in summer than in winter. The rainfall is uncertain, irregular and scanty. The average annual rainfall is very low being 221.2 mm (Ansari, 1987). The soil of the mangrove islands is fine alluvium derived from land drainage and erosion. According to Ansari (1987), mangroves can be categorized into dense mangrove, normal mangrove and sparse vegetation.

Dense mangroves are found at Port Qasim, flourishing over a vast area. The substratum is harder due to the presence of sand. Normal mangroves are found having a moderately wide belt at Sandspit ranging from 10 to 60 meters. The substratum varies in character from place to place depending partly on the soil texture and, to some extent, on the sewerage entering the mangrove areas. The mangroves grow in pockets of various sizes at Clifton (Fig. 1). These mangroves are under stress due to a number of factors *i.e.* reduction in the annual flows of freshwater, silt and nutrients down the Indus, over cutting for fuel wood and fodder, over browsing by camels and pollution from the expanding domestic and industrial areas of Karachi.

Sandspit, Clifton and Port Qasim mangroves along the coast of Sindh were visited to examine the mudflat, water pool and seaweed associated fauna from September 1984 to October 1985. A 4 cm thick muddy surface layer of 0.01 m^2 dimension was sampled from the marginal areas of the mangrove habitat. Samples of seaweeds along with the associated fauna were collected using a 0.01 m^2 steel frame. For sampling the planktonic organisms from the water pools, a hand net was used. The macrofauna, alive individuals only, were handpicked. Special search was made for the crabs from burrows and from the roots of the plants. Soft stones were broken for the sipunculids. Bivalves and gastropods were carefully taken out from the mud.

The samples were brought to the laboratory, washed in seawater, sieved with a net of 1 mm mesh size and preserved in 4% formaline. Some seaweed-associated fauna, especially the egg masses, were kept in glass bowls. The animals was sorted, counted and measured. Percent composition of species was calculated for all samples.

The species were identified using the following literature: Subrahmanyam *et al.* (1952), Chhapgar (1956a,b), Kundo (1965), Barnes (1974), Dance (1977), Lindner, (1977) and George and George (1979).

The indices used to measure richness, diversity and evenness of species are as follows:

1. Margalef's Index

Margalef's Index was used to measure richness and is represented by the formula:

$$d = (S-1) / \log N$$

where S = total number of species,

N = total number of individuals observed.

2. Hill Diversity Index

Hill diversity numbers N1 and N2 were used to measure species diversity given in Ludwig and Reynolds (1988).

The Hill Diversity number N1 is expressed by the following equation:

$$N1 = e^{H'}$$

where H′ = Shannon-Wiener index.

The Shannon-Wiener Index was determined using following formula:

$$H' = \sum_{i=1}^{S} (pi \log_e pi)$$

where pi = the proportion of the total count arising from the ith species.

S = species

Fig. 1. Map of the coastal area of Karachi showing sampling sites *i.e.* Sandspit, Clifton and Port Qasim.

The Hill Diversity number N2 was calculated by the following formula:

$N2 = 1 / \lambda$

where λ = Simpson's index.

The Simpson Index was determined by employing following formula:

$$\lambda = \sum_{i=1}^{s} pi^2$$

where pi is the proportional abundance of the ith species, given by

$$p_i = \frac{n_i}{N}$$

where n_i = the number of individuals of the ith species

N = total number of individuals for all S species

3. Modified Hill's Ratio E5

It was used as a measure of evenness and generally expressed by following equation:

$E5 = N2\text{-}1 / N1\text{-}1$

RESULTS

Environmental variables

The monthly variation in values of temperature and pH of the study sites is given in Table I**.** The water temperature of Sandspit ranged from 21 to 30°C with an average of 26.1°C, from 20.0 to 33°C with an average of 27.75°C at Port Qasim, from 21.0 to 29.0°C with an average of 25.21°C at Clifton. The pH values ranged from 7.15 to 7.98 with an average of 7.84 at Sandspit, from 6.83 to 8.19 with an average of 7.74 at Port Qasim and from 7.55 to 7.82 with an average of 7.74 at Clifton.

Mud fauna

A total of 26 invertebrate species were

recorded from Sandspit mangroves where the habitat is muddy, ranging from a minimum (3) in January 1985 to maximum (14) in March 1985 (Table II). From Port Qasim, 21 species were found ranging from a minimum (3) in December 1984 and January 1985 to maximum (12) in April 1985 whereas a total of 19 species were found ranging from minimum (3) in June 1985 to maximum (14) in July 1985 from Clifton.

The per cent composition of different species in various samples of Clifton (Table III) indicates that only two species *Cerithidea cingulatus* and *Natica didyma* were abundantly present in almost all samples, whereas *Natica lamarckii*, *Nodilittorina leucosticta, N. picta* and freshwater snail species were present in almost all samples but in low numbers. Nine species were found once or twice during the study. Among them were sea anemone, jelly fish, *Marphysa* sp. (polychaete), *Haloa japonica, Telescopium telescopium, Conus* sp., *Melampus nuxcastanea*, *Microdeutopus* sp. (amphipod) and *Macropthalmus depressus.* Table II shows that *Cerithidea cingulatus* constituting 50 per cent of the species and were present in almost all samples at Sandspit mudflats. Other species found in almost all samples but few in number were *Natica didyma*, *Nodilittorina picta* and freshwater snail species. Rest of the 22 species were found once or twice and also in small numbers. The percent composition of species at Port Qasim showed that *Cerithidea cingulatus, Natica lamarkii, N. didyma, Nodilittorina leucosticta, N. picta* and freshwater snail sp. were abundantly found in almost all samples. Rest of the 15 species was found in small numbers and also in few samples (Table IV).

Molluscs dominated on all three sites followed by crustaceans. Only five species of molluscs *i.e. Cerithidea cingulatus, Natica lamarckii, N. didyma, Nodilittorina leucostica* and *N. picta* were regularly found and commonly abundant on the three sites. However, their abundance varied seasonally and also depended on the locality as well. Only 10 species were present on all the three sites. Some species were not regularly found and were present also in few numbers. Among them were *Telescopium telescopium, Haloa japonica,* fresh water snails and empty shells of oysters. Some species were found only on one site. Among them, were *Architectonica* sp., *Ceratoxancus* sp., *Conus* sp., *Laternula* sp., *Melampus nuxcastanea*, *Nasa* sp., *Turbo coronatus*, *Sesarma* sp., *Sphaeroma terebrans* and jelly fish, whereas the sea anemone was found on two sites only *i.e.* Clifton and Sandspit. An important constituent of mud fauna were the egg masses in Sandspit samples only. Larvae and cocoons of insects were also recorded from Sandspit and Port Qasim.

Seaweed associated fauna

The abundant seaweeds in the mangrove swamps of Sind are *Enteromorpha sp.* and *Ulva* sp. Tables V-VII show that gastropods dominate the animal species found in the seaweeds of the three sites. At Clifton mangroves, four groups *i.e.* gastropods, bivalves, copepods and amphipods constitute almost 90% of the seaweed fauna. Other groups *i.e.* crab sp. and mysids were found in less numbers and also in few samples. Gastropods egg masses, fish eggs and larvae were rarely found among the seaweeds. Only two groups *i.e.* gastropods and amphipods constituted 70% in composition at Sandspit seaweeds, whereas, bivalves and crabs were found less abundantly and also in few samples. Platyhelminthes, annelids, copepods, hermit crabs, mysids, isopods, carides, insect larvae, fish eggs and fish larvae were found once or twice in the samples. At Port Qasim, only 4 groups *i.e.* gastropods, amphipods, copepods and gastropod egg masses, had more than 1% composition. Gastropods constitute almost 80% in composition followed by copepods, amphipods and gastropod egg mass. The groups or species found rarely and few in number were annelids, *Onchidella* sp., bivalves, hermit crabs, mysids, carides and fish eggs.

Water pool fauna

Table VIII shows that mysids in most of the samples dominated in the water pool fauna of all sites. However, copepods and amphipods were abundant from two samples of Sandspit, whereas caride juveniles and fish juveniles were abundant in Clifton samples. Rest of the groups, penaeid juveniles, gastropods, bivalves and barnacles were recorded once or twice from the samples.

Table I.- Seasonal changes in temperature (air, mud & water) and pH of Sandspit, Port Qasim and Clifton mangroves.

Months	Temperature											
	Air			Mud			Water			PH		
	Sandspit	Port Qasim	Clifton	Sandspit	Port Qasim	Clifton	Sandspit	Port Qasim	Clifton	Sandspit	Port Qasim	Clifton
Nov.' 84	24.75	25.25	24	25	25.5	25.5	26	25.25	25.5	7.86	7.88	7.81
Dec.' 84	22	21	-	21.25	24	-	21	22	-	7.15	6.83	-
Jan.' 85	22.5	24	22	21.5	22	17	23	20	21	7.87	7.86	7.82
Feb.' 85	24	29	26	28	27	28	25	28	22	8.66	7.81	7.81
Mar.' 85	24	33	24	24	31	24	23	31.5	23.5	7.88	8.19	7.85
Apr.' 85	27	32	-	29	30.5	-	29	31.5	-	7.55	7.87	-
May' 85	-	38	26.5	-	34	28	-	33	27.5	-	7.67	7.74
June' 85	-	30	29	-	30	28	-	29	28	-	7.81	7.55
July' 85	28	29.5	30	27.5	29	29.5	27	-	29	7.86	-	7.64
Aug.' 85	28	-	28	27.5	-	27	28.5	-	-	7.86	-	-
Sep.' 85	29	27.25	28	30	28	27.5	28.5	27.25	-	7.76	7.785	-
Oct.' 85	29.5	29	-	29	29	-	30	30	-	7.88	7.78	-

Table II.- The percent composition of organisms inhibiting the muddy substratum of Sandspit mangroves.

Species / Groups	Date								
	28 Oct. 87	27 Dec. 85	30 Jan. 86	13 Feb. 85	10 Mar. 85	27 Apr. 85	21 Jul. 85	3 Sep. 85	13 Oct. 85
Sea anemone	1.49	-	-	-	-	-	-	-	-
Marphysa sp.	-	-	-	-	-	-	-	-	0.28
Cerithidea cingulatus	-	71.83	48	34.29	67.09	51.29	30.12	62.22	7.76
Natica lamarckii	16.42	-	-	7.43	0.55	3.28	2.81	1.11	1.39
Natica didyma	44.78	-	-	-	-	-	4.42	-	64.82
Nodilittorina l. leucosticta	-	1.41	-	34.86	1.46	2.09	2.81	-	7.48
Nodilittorina picta	1.49	5.63	-	14.29	9.87	8.06	6.83	4.44	7.2
Telescopium telescopium	8.96	-	-	-	-	-	-	-	-
Ceratoxancus sp.	-	1.41	-	-	-		-	-	-
Freshwater snail sp.	-	-	2	5.14	3.84	-	3.21	8.89	7.48
Thais carinifera	-	19.72	-	-	7.86	30.15	49.4	21.11	-
Laternula sp.	1.49	-	-	-	-	-	-	-	-
Empty shells of oyster spats	-	-	-	-	0.91	-	0.4	-	-
Placuna placenta	-	-	-	-	2.19	-	-	-	0.55
Haloa joponica	5.97	-	-	0.57	-	0.89	-	2.22	0.83
Melampus nuxcastanea	-	-	-	-	-	1.19	-	-	-
Onchidella sp.	-	-	-	1.71	0.18	-	-	-	1.39
Sphaeroma terebrans	4.48	-	-	-	-	-	-	-	-
Microdeutopus sp.	-	-	50	-	1.83	-	-	-	-
Illyoplax paulidicola	-	-	-	1.71	-	-	-	-	-
Illyoplax sp.	1.49	-	-	-	-	-	-	-	-
Macrophthalmus depressus	-	-	-	-	-	1.49	-	-	-
Paguristes perspicax	-	-	-	-	2.38	-	-	-	-
Insect cocoons	17.91	-	-	-	0.37	0.29	-	-	0.83
Insect larvae	-	-	-	-	-	1.19	-	-	-
Fish eggs	-	-	-	-	0.18	-	-	-	-
Nudibranch egg strings	-	-	-	-	0.18	-	-	-	-
Haloa japonica egg masses	4.48	-	-	-	-	-	-	-	-
No. of individuals / samples	67	71	50	175	547	335	249	90	361

Table III.- The percent composition of organisms inhibiting the muddy substratum of Clifton mangroves.

Species / Groups	Date									
	8 Nov.' 84	7 Jan.' 85	16 Jan.' 85	6 Feb.' 85	20 Feb.' 85	11 Mar.' 85	27 Jun.' 85	22 Jul.' 85	7 Aug.' 85	30 Sep.' 85
Sea anemone	-	-	-	-	-	-	-	0.27	-	-
Jelly fish	-	-	-	-	-	-	-	0.27	-	0.85
Marphysa sp.	-	-	-	-	-	-	-	4.38	-	-
Cerithidea cingulatus	5.62	34.78	23.87	9.25	8.89	55.86	84.62	17.26	4.52	11.97
Natica lamarckii	6.74	10.14	3.23	6.36	33.33	2.07	-	1.64	2.26	-
Natica didyma	77.53	39.61	60	70.52	53.33	-	-	4.38	88.24	-
Nodilittorina l. leucosticta	6.74	13.53	-	1.16	-	-	-	16.44	0.9	5.13
Nodilittorina picta	-	1.93	5.16	7.51	-	11.72	7.69	15.62	0.45	3.42
Haloa joponica	2.25	-	-	-	4.44	-	-	-	-	-
Telescopium telescopium	-	-	-	-	-	-	-	0.82	2.71	0.85
Conus sp.	-	-	-	-	-	-	-	0.27	-	-
Freshwater snail sp.	-	-	1.29	1.17	-	-	7.69	36.99	0.45	72.65
Thais carinifera	1.12	-	-	-	-	15.86	-	0.55	-	3.42
Empty shells of oyster spats	-	-	-	-	-	-	-	-	0.45	-
Placuna placenta	-	-	-	-	-	2.07	-	0.27	-	-
Melampus nuxcastanea	-	-	-	-	-	0.69	-	-	-	-
Microdeutopus sp.	-	-	-	-	-	-	-	0.27	-	-
Macrophthalmus depressus	-	-	-	-	-	4.14	-	-	-	-
Insect cocoons	-	-	6.45	4.05	-	7.59	-	0.82	-	0.85
No. of Individuals/ sample	89	207	155	173	45	145	13	365	221	117

Table IV.- The percent composition of organisms inhibiting the muddy substratum of Port Qasim mangroves.

Species / Groups	Date								
	7 Nov.' 84	28 Nov.' 84	22 Dec.' 85	21 Jan.' 85	16 Feb.' 85	14 Apr.' 85	9 Jun.' 85	25 Jul.' 85	12 Oct.' 85
Marphysa sp.	-	-	-	-	0.55	0.8	-	-	-
Cerithidea cingulatus	71.3	-	11.83	-	15.62	4.8	52.92	9.62	22.01
Natica lamarckii	2.9	-	9.3	20.66	34.79	-	2.84	0.64	-
Natica didyma	7.25	13.78	78.3	76.53	36.99	-	-	29.49	-
Nodilittorina l. leucosticta	4.06	-	-	-	1.1	20	14.69	5.13	44.97
Nodilittorina picta	1.74	34.78	-	-	0.82	41.6	15.8	1.92	8.18
Telescopium telescopium	-	17.39	-	2.82	-	-	-	-	-
Nasa sp.	-	-	-	-	0.55	-	-	-	-
Turbo coronatus	-	-	-	-	-	-	0.79	-	0.94
Architectonica sp.	-	-	-	-	-	0.8	-	-	-
Freshwater snail sp.	-	34.78	-	-	9.32	8.8	4.9	-	19.5
Thais carinifera	-	-	-	-	-	4	0.79	-	-
Empty shells of oyster spats	12.75	-	-	-	-	-	-	-	-
Placuna placenta	-	-	-	-	-	0.8	7.27	3.21	2.52
Haloa joponica	-	-	-	-	-	0.8	-	-	-
Microdeutopus sp.	-	-	-	-	-	8	-	-	-
Sesarma sp.	-	-	-	-	0.27	-	-	-	-
Barnacle	-	-	-	-	-	-	-	-	-
Insect cocoons	-	-	-	-	-	4.8	-	44.87	-
Insect larvae	-	-	-	-	-	4.8	-	-	-
Fish larvae	-	-	-	-	-	-	-	5.13-	-
No. of Individuals/ sample	345	23	355	426	365	125	633	156	318

Table V.- Seasonal changes in percentage composition of seaweed faunal groups from Sandspit mangroves.

Groups	Date										
	26 Sep.' 84	28 Oct.' 84	27 Dec.' 84	8 Jan.' 85	30 Jan.' 85	13 Feb.' 85	18 Feb.' 85	10 Mar.' 85	27 Apr.' 85	8 May' 85	21 July' 85
Platyhelminthes	-	-	-	-	-	-	-	0.27	-	-	-
Annelids	-	-	5.08	0.78	0.12	-	-	0.03	-	12.96	-
Gastropods	80.12	25.83	24.57	2.67	1.82	41.73	36.88	15.55	34.85	19.84	75.46
Gastropod egg masses	-	0.785	-	-	-	-	-	-	-	-	-
Onchidella sp.	-	-	0.84	-	-	-	-	0.27	-	-	-
Bivalve	-	1.54	6.77	-	-	-	5.32	6.66	63.02	-	7.66
Copepods	1.61	16.32	-	-	-	-	-	-	-	-	-
Hermit crabs	-	-	3.3	0.22	0.12	-	-	-	-	-	-
Brachyuran crabs	-	2.04	0.84	-	0.24	-	2.45	0.55	2.11	1.32	2.45
Mysids	-	-	-	0.11	1.09	-	-	-	-	-	-
Isopods	-	-	-	-	-	-	4.09	0.55	-	-	1.99
Amphipods	16.12	52.44	55.93	95.2	96.59	58.26	50.81	71.94	-	65.87	12.42
Carides	-	1.02	-	-	-	-	-	-	-	-	-
Insect larvae	2.15	-	-	-	-	-	-	-	-	-	-
Fish egg	-	-	-	-	-	-	0.4	0.55	-	-	-
Fish larvae	-	-	-	0.11	-	-	-	-	-	-	-
No. of individuals/ sample	186	120	118	889	822	714	244	360	284	378	652

Table VI.- Seasonal changes in percentage composition of seaweed faunal groups from Clifton mangroves.

	Date						
	8 Nov.' 84	7 Jan.' 85	16 Jan.' 85	6 Feb.' 85	20 Feb.' 85	11 Mar.' 85	30 Sep.' 85
Gastropods	5.92	69.54	81	9.535	2.75	6.63	79.14
Gastropod egg masses	-	-	4.46	-	-	-	0.9
Onchidella sp.	-	-	2.23	-	-	-	-
Bivalve	93.82	-	6.14	58.96	5.31	5.16	4.84
Copepods	-	12.75	-	11.64	90.05	67.63	11.6
Brachyuran crabs	-	0.82	0.55	18.3	0.34	3.31	-
Mysids	-	-	-	0.025	-	1.24	-
Amphipods	0.11	9.46	3.35	1.225	0.42	14.73	1.35
Insect larvae	-	5.34	2.23	-	-	-	1.91
Fish egg	0.11	-	-	-	0.08	0.62	0.22
Fish larvae	-	2.05	-	0.05	-	0.62	-
No. of individuals/ sample	1737	243	179	898	1166	482	887

Diversity indices

A marked seasonal variation in values of species richness and evenness was noticed at Sandspit mudflats as compared to Port Qasim and Clifton mudflats (Fig. 2a,b,c). Table IX shows that at Sandspit, the richness values were minimum (1.25) in summer and maximum (3.1) in autumn months with an average value of 2.42. The Hill diversity N1 values were minimum (3.83) in spring and maximum (5.7) in autumn months with an average value of 4.80. The N2 values were minimum (2.38) in spring and maximum (3.67) in winter months with an average value of 3.19. The evenness value E5 was minimum (0.488) in spring and maximum (0.694) in summer with an average value of 0.57. There is no seasonal pattern obvious in the values of four indices used. However, values of N1, N2 and E5 showed a marked decrease in spring (Fig. 2a).

Fig. 2. Seasonal variation in values of richness, Hill Diversity (N1), Hill Diversity (N2) and Evenness (E5) at (a) Sandspit (b) Clifton and (c) Port Qasim mangroves.

At Clifton, the richness values were minimum (1.41) in spring and maximum (2.29) in summer with an average value of 1.87. The N1 value was minimum (2.56) in winter and maximum (5.67) in summer with an average value of 4.52. The N2 value was minimum (2.56) in winter and maximum (4.46) in summer with an average value of 3.25. The evenness value E5 was minimum (0.581) in winter and maximum (0.742) in summer with an average value of 0.62 (Table IX). After spring there is a uniform increase in all indices values in summer followed by a decrease in autumn. However, the trend in values of different indices varied. There is an increase in values of N1 and N2 between winter and spring but a decrease in values of richness. The values of E5, however, remain unchanged (Fig. 2b).

At Port Qasim, the richness value was minimum (1.04) in autumn and maximum (2.28) in spring with an average value of 1.68, the N1 values was minimum (3.48) in winter and maximum (7.39) in summer with an average value of 5.30. The N2 value was minimum (2.76) in winter and maximum (6.21) in summer with an average value of 4.135. The evenness value was minimum (0.624) in spring and maximum (0.815) in summer with an average value of 0.72 (Table IX). A marked trend of seasonal variation was observed in the values of N1 and N2. There is a gradual increase in values of N1 and N2 from winter to summer followed by a drop in autumn. Values of N1, N2 and E5 reached to the maximum in summer whereas richness values were at minimum in autumn. As expected the N1 and N2 values shows the same trend incorporating both richness and evenness (Fig. 2c).

DISCUSSION

The mangrove trunks, forest floor, seaweeds and water pools within the mangroves provide a favourable habitat to support a wide variety of animal life at various life cycle stages. The community in the mudflats of Karachi coast is dominated by molluscs and crustaceans and are in accordance with the reports described earlier for the mud flats of Australia (Wells, 1983), Thailand (Frith *et al*., 1976; Frith, 1977), India (Dwivedi *et al*., 1975; Kumar, 1997), China (Zhou and Li, 1986; Rongguan *et al*., 1993; Yu *et al*., 1997), South Florida (Evink, 1975), Malaysia (Sasekumar and Chong, 1998) and Tanzania (Akil and Jiddawi, 2001). In addition, coelenterates, annelids, insect

Table VII.- Seasonal changes in percentage composition of seaweed faunal groups from Port Qasim mangroves.

Groups	Date								
	21 Oct.' 84	22 Dec.' 84	21 Jan.' 85	6 Mar.' 85	14 Apr.' 85	29 Apr.' 85	25 May' 85	25 July' 85	5 Sep.' 85
Annelids	-	-	0.13	-	-	-	-	-	-
Gastropods	96.15	87.58	98.7	88.92	49.38	69.31	67.57	82.88	93.2
Gastropod egg masses	-	2.21	-	0.72	-	-	0.54	-	6.8
Onchidella sp.	-	0.3	-	-	-	-	4.51	-	-
Bivalve	-	0.5	-	1.74	0.3	-	-	-	-
Copepods	-	-	-	7.72	-	28.4	18.05	13.9	-
Hermit crabs	-	-	-	-	-	-	0.13	-	-
Brachyuran crabs	-	-	0.33	0.43	5.24	-	0.13	-	-
Mysids	-	-	0.06	-	-	-	-	-	-
Amphipods	2.88	9.38	0.06	0.43	41.97	2.27	8.89	1.6	-
Carides	-	-	-	-	2.46	-	0.13	1.06	-
Fish egg	0.96	-	0.13	-	0.3	-	-	-	-
Fish larvae	-	-	-	-	-	-	-	-	-
No. of individuals/ sample	312	991	1472	686	324	88	731	187	250

Table VIII.- Percentage composition of organisms collected from the water pools of Sandspit, Clifton and Port Qasim mangroves.

Dates	Locality	Groups %									No. of individuals / samples
		Fish juveniles	Penaeids juveniles	Amphipods	Gastropods	Bivalves	Copepods	Mysids	Barnacles	Carides juveniles	
28 Oct.' 84	Sandspit	3.09	1.03	32.98	4.12	-	58.76	-	-	-	97
8 Nov.' 84	Clifton	-	-	-	-	-	-	100	-	-	29
27 Dec.' 84	Sandspit	1.05	-	89.47	-	-	9.47	-	-	-	95
8 Jan.' 85	Sandspit	-	-	3.38	-	-	-	96.61	-	-	118
16 Jan.' 85	Clifton	0.045	-	-	-	12.33	8.37	79.26	-	-	684
21 Jan.' 85	Port Qasim	-	-	-	-	-	-	100	-	-	18
30 Jan.' 85	Sandspit	-	-	27.41	-	-	-	72.58	-	-	62
13 Feb.' 85	Sandspit	-	-	-	24.16	-	-	66.44	0.67	8.72	149
20 Feb.' 85	Clifton	-	-	-	-	-	-	96.87	-	-	32
11 Mar.' 85	Clifton	66.66	-	-	-	-	-	22.22	-	11.11	9
27 June' 85	Clifton	-	-	-	-	-	-	-	-	100	8

cocoon, insect larvae and fish larvae were also found. However, polycheates were the dominant taxa in West Bengal, India (Patra *et al*., 1990), Mexico (Alcantara and Weiss, 1995), Mozambique (Guerreiro *et al.*, 1996) and Taiwan (Cheng and Chang, 1999). Tirmizi *et al.* (1983) also observed that crabs, isopods and amphipods are the permanent members of the benthic community in the mud flats of the Sandspit mangroves. However, Ahmed and Hameed (1999) documented that polycheates occupied the highest rank in abundance on the exposed sandy beach at Clifton, Karachi.

A total of 122 benthic species was recorded from Australia (Wells, 1983), 87 species from Mexico (Alcantara and Weiss, 1995), 84 species from China (Yu et al., 1997), 76 species from Tanzania (Akil and Jiddawi, 2001) and 14 species from Malaysian mangroves (Sasekumar and Chong, 1998). In the present investigation, total 34 species of benthic fauna was recorded from the mud flats of

Table IX.- Seasonal variation in values of diversity indices of benthic fauna in three mangrove sites of Karachi.

Sites	No. of Species	Margalef's Index (Richness)	Hill Diversity (N1)	Hill Diversity (N2)	Evenness (E5)
Sandspit					
Winter	12	2.4	5.29	3.67	0.62
Spring	19	2.96	3.83	2.38	0.49
Summer	8	1.25	4.41	3.37	0.69
Autumn	17	3.1	5.7	3.36	0.50
Clifton					
Winter	10	1.76	3.68	2.56	0.58
Spring	8	1.41	4.02	2.78	0.59
Summer	13	2.29	5.67	4.46	0.74
Autumn	10	2.03	4.72	3.2	0.59
Port Qasim					
Winter	10	1.58	3.48	2.76	0.71
Spring	12	2.28	6.19	4.24	0.62
Summer	11	1.85	7.39	6.21	0.82
Autumn	7	1.04	4.15	3.33	0.74

Karachi mangroves. Only five species of molluscs are commonly abundant on three sites. However, their abundance varies seasonally and also depends on locality as well. Same inference was drawn by Dwivedi *et al.* (1975), Kolehmainen and Hildner (1975), Ahmed (1977, 1979, 1997), Rongguan *et al.* (1993), Jinang and Li (1995), Walthew (1995) and Guerreiro *et al.* (1996). According to them, the qualitative and quantitative distribution of benthos is related to sediment form, tidal flow, current, temperature, salinity, pollution and over exploitation. It is also supported by Tirmizi and Barkati (1983), who observed that only *Cerithidea cingulatus* occurred in significant numbers in Karachi mangroves. Day (1975) also observed that *Sesarma, Uca* and *Cerithidea decollate* were abundantly present on the mud surface at Morrumbene estuary, Mazambique.

The species inhabiting the seaweeds at Karachi mangroves mostly belonged to gastropods, amphipods and copepods. The animals associated with the seaweeds showed almost same type of composition as shown for seaweeds from South West Florida (Evink, 1975) and Mexico (Cruz-Abrego *et al.*, 1994). Martin *et al.* (1995), Timmons and Price (1996), Lali and Padmakumar (1999) and Parker *et al.* (2001) have done similar type of work from other areas of the world. However, variation in the abundance or dominance of the taxa has been observed. Amphipod constitutes 90 per cent of the seaweed associated fauna (Timmon and Price, 1996). Evink (1975) showed that amhipods and isopods were abundant. Lali and Padmakumar (1999) documented that amphipods were the dominant group followed by polycheates and molluscs. Gastropods and amphipods dominate in the present investigation.

Only two publications on the mangrove tide pool fauna of the world are known to the present authors. Day (1975) documented that tide pools of Mazambique mangroves comprise of copepods, mysids, cumacea and the larvae of benthic invertebrates. However, Dwivedi *et al.* (1975) observed that pools of Goa mangroves supported phytoplankton and that zooplankton was not rich. In the present study, mysids, copepods, amphipods, caride and fish juveniles were present in the tide pools.

Different types of diversity indices are used to characterize species abundance relationship in the biological communities. Burney and Barkati (1995) working on the macrofauna of Buleji rocky shore observed that species diversity fluctuated seasonally from a high between October and January to low during February and August. This decrease was in association with the disturbance and stress

experienced during monsoon period (May to August). According to Fatima and Barkati (1999), richness and diversity index were relatively higher in winter compared to summer months. Ahmed and Hameed (1999) noted highest values of diversity and evenness indices in the month of July at Clifton sandy beach. Nasreen *et al*. (2000) showed that diversity index and evenness values were highest in April, May and June on Manora rocky shore. The diversity values at Clifton and Port Qasim mangroves were minimum in winter and maximum in summer as observed by Ahmed and Hameed (1999) and Nasreen *et al*. (2000). Evink (1975) also observed reduced diversity during December reflecting absence of species using estuaries as nursery areas. The diversity values of Sandspit mudflats was minimum in spring and maximum in winter months as previously documented by Burney and Barkati (1995) and Fatima and Barkati (1999).

Wu and Richard (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 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. Wells (1983) suggested that the marine invertebrates of the Bay of Rest constitute a community dependent on detritus resulting from a breakdown of the primary production of the mangrove forest. According to Schrijvers *et al.* (1995), human impact (cutting) has resulted in a drastic decrease in densities of macro infauna around Gazi Bay mangroves, Kenya. Macintosh *et al.* (2002) working on the diversity, biomass of crustacean and molluscan macrofauna in the Ranong mangrove, Southern Thailand documented that crustaceans were related by shore level while molluscan diversity and abundance were related by soil moisture contents.

Investigating the natural and human threats to biodiversity in marine ecosystem, Ahmed (1997) documented that several species have disappeared from the intertidal zone due to high temperature and salinity, pollution and overexploitation. Similarly, Rizvi *et al.* (1999) also observed a loss of marine fauna and flora in the near shore environment due to pollution, coastal development and changes in the river discharge. Burney and Barkati (1995) working on the macrofauna of Buleji rocky shore recorded a linear interdependence among the measures of diversity. 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. In the present investigation, the values of diversity indices at Port Qasim were relatively higher, which is least disturbed and polluted as compared to other two sites.

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