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SEASONAL VARIATION IN ABUNDANCE AND SPECIES DIVERSITY IN A CRUSTACEAN ASSEMBLAGE FROM SANDY BEACH OF CLIFTON (KARACHI), PAKISTAN

Saima Imran[1], Meher Fatima[1], D. Khan[2] and Rashida Qari[1]

[1]*Institute of Marine Sciences, University of Karachi, Karachi-75270, Pakistan.*
[2]*Department of Botany, University of Karachi, Karachi – 75270, Pakistan.*
(saima_imran@ymail.com, rqari2002@yahoo.com)

ABSTRACT

This study was carried out from January 2005 to December 2005. A total of 12 species of crustaceans belonging to eight families were identified at the sandy beach of Clifton, Karachi, Pakistan. The habitat was poor in species. A total of ten crabs were well represented in all the monthly period sample assemblages. Hermit crab *Diogenes planimanus*, moon crab *Matuta planipes*, Ocypodid crabs *Dotilla blandiformes* and leucosid crabs *Philyra globosa* were dominant. Only one species of shrimp *Metapenaeus* sp. was found only in winter season and one species of epibiont crustacean *Balanus crenatus* was found most of time of the study period. The over-all density of crustaceans per m^2 was higher in April, July to September and again in November. The total number of crustacean captured monthly related with Seawater temperature in quadratic fashion. The organization of the assemblages all the round year was simple. The diversity was low and the concentration of dominance was generally high. Diversity (H') varied seasonally and maximum diversity was observed in December. The Whittaker curves indicated geometric distribution of abundance among the species throughout the year. Diversity indices exhibited linear dependence on each other. Shannon-Weiner index (Shannon and Weaver, 1963) and species richness (Margalef, 1958) related with Seawater temperature curvilinearly.

Key-words: Seasonal variation, Species diversity, richness and evenness, Crabs, Crustacean assemblage. Sandy coast, Karachi.

INTRODUCTION

The study of marine animal communities is important for understanding production and evaluating environmental and anthropogenic influences on biota as well as their management and conservation. The abundance and distribution of benthic macro fauna in near shore waters off Karachi was reported by Niazi *et al.* (2007). A total of 76 species of invertebrates were encountered by them. They reported that their distribution and abundance varied with seasons and maximum number of invertebrate species was found in monsoon season. Diversity of these invertebrates was low in winter and increased during pre-monsoon and SW monsoon. Tirmizi and Ghani (1983) had reported 16 species of crabs from Sindh mangroves. Ten species of crabs has been reported from some mangroves forests located at Sand spit, Port Qasim and Agra Taj areas of Karachi (Nazim *et al.*, 2010) - *Heteropanope glabra* being important crabs in this area. Sand Spit area is reported to bear larger crab diversity compared to other localities. In Pakistan little work has been done on sandy shore fauna. Ahmed and Mustaquim (1974) had studied the population structure of four species of porcellanid crabs (Decapoda: Anomura) occurring on the Manora rocky ledge of the coast of Karachi. Some other information is also available on the identification, distribution and zonation of macro-invertebrates of the coast of Pakistan (Khan and Dastagir, 1970; 1971; Mustaquim & Rabbani, 1976; Haq *et al*.,1978; Tirmizi and Siddiqui,1981; Tirmizi *et al.*,1982; Barkati and Burney, 1991; Siddiqui and Ahmed,1992). Siddiqui and Ahmed (1992) documented the abundance and breeding of the crabs occurring on the rocky ledges of Buleji and Manora. Kazmi (2003) reported the taxonomic studies of crustaceans in Pakistan.

Distribution, abundance and diversity indices of portunid crabs were reported by Taqween and Qureshi (2001) and population structure and reproductive biology of four species of swimming crabs from coastal area of Karachi, Pakistan were studied by Taqween and Qureshi (2005). The aim of this study was to collect information regarding the species composition, seasonal variation in density, species richness, evenness and diversity of crustaceans occurring at Clifton beach near Sea view area. The hydrological parameters such as, temperature, salinity and pH have also been recorded at monthly interval throughout the study period of one year.

DESCRIPTION OF THE AREA

The coast of Pakistan is ~ 1000 km long, stretches from the Iranian border along the Makran coast of Balochistan to Karachi in the South (Shameel and Tanaka 1992, Qari 2002). The coast of Sind is sandy, rocky or muddy in nature and relatively shallow and flat-bottomed stretching over 200 miles of continental slope. The climate is generally arid or dry with some raining during the summer months i.e. from June to September. May to August is

considered as monsoon period. The rains in winter are of low magnitude. The temperature of surface sea water ranged from 21.7 to 29.96 °C, salinity 36.62 – 38.22 ‰ and pH 6.6 to 7.17 (Qari and Siddiqui, 2005).

The sandy beach of Clifton that was selected for sampling of crustacean species is recreational beach, situated in the south of the city of Karachi at 24°47N longitude and 67°05 E latitude. The beach is mainly sandy having very fine grained sand (>200µm). It has a gentle slope with a wide surf zone.

Karachi is a windy city and the coast is much windier. The strongest winds are from Southwest and their speed is higher in June to September. The Clifton beach is polluted one and once has been subject to oil spill due to Tasman Spirit in 2003. The hydrocarbon concentration, however, became uniform in 2005 (averaging to 0.05 $\mu g.L^{-1}$ (16PAHs) and 4.08$\mu g.L^{-1}$ total 14 aliphatic hydrocarbons (Ahsan *et al.,* 2011). Fluoride concentration in Clifton Seawater has been reported to be 1.19 – 1.2 ± 0.006 mg. L^{-1}, pH, 1.72 -7.91 and salinity around 35-35.9‰ (Siddiqui *et al.,* 2011). The presence of metals such as Cu (16.09 ppm), Cr (33.01 ppm), Ni (46.06 ppm), Pb (21.04) and Zn (73.2 ppm) around Bhutto Casino (Clifton area) has been reported by Mashiatulla *et al*. (2004). Clifton is a sandy strip of Karachi coast. It is very gently sloping (around 1^{o}) and very well sorted. The deposition of fine particles is higher in winter due to low wave energy in this season compared wave height in summer around 2m. The beach fall at the confluence of micro- meso tidal characteristics (Ali and Afsar, 2013). The sediment particles are of very fine sand category (1/8 to 1/16 mm). The surf zone exposed to shoaling and breaking of waves' oscillation is nearly double in winter than that in summer and quite extensive than that in Sand Spit (SPM, 1984). The pattern of long shore drift changes from SW to NE in summer to SE to NW in winter (Ali and Afsar, 2013). The Sea level along Karachi is rising (Quraishee, 1988) but within global ranges and the rise is considered due to thermal expansion of Seawater (Masood and Rabbani; *niopk@cubexs.net.pk* ; seen in Quraishee (1998).

MATERIALS AND METHODS

The crustacean assemblages of sandy beach of Clifton were studied monthly for the year 2005. Three transect lines at a separation of 500 meters were established in sandy beach running North-South. Three quadrates of 50 x 50 cm each were randomly placed in each transect line. Samples from the quadrates were obtained by sieving the sand upto10 cm depth through 2.0 mm mesh size. Crabs were also collected by hand picking, drifted from sub-tidal zone per hour from the coast. In laboratory all animals were sorted and preserved. Physical parameters such as water temperature (°C), salinity (‰) and pH were recorded monthly through out the study period. Water temperature was noted with the help of mercury thermometer, salinity by refractometer and pH was recorded by the pH meter (Model PM-65). The division of calendar months into seasons with respect to the monsoon system was adopted from Latif *et al.,* 2013).

Table 1. Temperature, salinity and pH of the Seawater at Clifton, Karachi, during 2005.

Month	Temperature (^{o}C)	Salinity (‰)	pH
January	21	32	7.5
February	22	31	7.8
March	31	31	7.5
April	25	30	7.3
May	29	35	6.5
June	31	36	7.2
July	28	32	7.5
August	27	32	7.2
September	25	30	7.1
October	27	31	7.5
November	23	35	7.9
December	22	36	7.8
Mean ± SE	25.92 ± 1.00	32.5 ± 0.66	7.40 ± 0.11

There has been some discussion on the superiority of diversity indices (McIntosh, 1967; Shaukat and Khan, 1979; Shaukat *et al.,* 1981; Dhanmoanonda and Sahunalu, 1988; Heip *et al.,* 1998; Magurran, 2004). The dominance and diversity and its components (species richness and evenness) were calculated using the following formulae given in Ludwig and Reynolds (1988). The data was analyzed statistically. In moderately diverse situation

information theory function H' (Shannon and Weaver, 1963) measures diversity very well (Shaukat and Khan, 1979). Diversity indices N1 and N2 have been rated to be intuitively appealing to ecologists (Peet, 1974). The two measures of species richness R1 (Margalef, 1958) and R2 (Menhinick, 1964) behave similarly statistically (Shaukat and Khan, 1979). We followed equitability measures E1 (Pielou, 1975, 1977) and E2 (Sheldon, 1969) as they have commonly been used in ecological studies. Besides, the modified Hill evenness measure was also followed because it reaches progressively to zero as a species become more and more dominant in a community.

Species Richness, R1 = S-1 / Ln (N) ….. .(Margalef, 1958)
Species Richness, R2= S' = S / √ N ….. . (Menhinick, 1964)
Diversity = H' = -∑ pi. Lnpi, ….. i = 1, …S…..(Shannon-Wiener Index)
c =-∑ $pi.^2$, ……i = 1,…..S…… (Simpson, 1949)
N1 = $e^{H'}$ ….. (Peet, 1974)
N2 = 1/c …..(Peet, 1974).
Evenness = E1 = H' / H_{max} = H' / Ln S …..(Pielou, 1975, 1977)
Evenness E2 = $e^{H'}$ / S …… (Sheldon, 1969)
Evenness E5 = (1-c) -1 / $e^{H'}$ -1) …..(Modified Hill Ratio; Hill, 1973)

Here,
S = Number of species
ni = number of individuals of a species
N = Number of individuals of all species
pi = ni / N

The IVI of the constituent species was calculated by direct summation of relative frequency and relative density of the species. The dominance-diversity curves (Whittaker, 1965) were plotted to portray the underlying relative abundance pattern.

RESULTS AND DISCUSSION

Physico-chemical Characteristics of Seawater

The values of temperature, salinity and pH are given in Table 1. The values of temperature ranged from 21 to 31 degree Celsius with an average of 25.92 ± 1.0 °C. The maximum value was recorded during (June) monsoon season while the minimum values were recorded during winter season. Salinity ranged from 31 to 35‰ with an average of 32.5 ± 0.66 ‰ (Table 1). The values of pH varied from 6.5 to 7.9 (average: 7.4 ± 0.11). Both salinity and pH showed higher value in winter and low value in summer.

Abundance and the Sociological attributes

A total of 12 species of crustaceans belonging to 8 families, 10 genera were identified from the sandy beach of Clifton during the collection from January 2005 to December 2005 (Table 2). Total numbers of specimen examined were 1834. On the basis of total number of crustaceans captured, *Diogenes planimanus* was the most common species occupying a proportion of 42.3% of the total captured individuals. It was followed by *Balanus crenatus* (26.06 %), *Matuta planipes* (10.25%) and *Philyra globosa* (9.16%). Other species were rare to very rare. *Metapenatus* sp. occurred once with one individual only (Table 2.). The maximum number of individuals (906) was recovered during Southwest monsoon season and the lowest (224) in Southern inter-monsoon season (Fig. 1)

Table 2. Crustaceans collected from the sandy beach of Clifton, Karachi during the study period.

S. No	species	Family	Number of individuals *
1	*Charybdis callianassa*	Portunidae	5 (0.273) **
2	*Matuta planipes*	Calappidae	188 (10.251)
3	*Matuta lunaris*	Calappidae	57 (3.108)
4	*Balanus crenatus*	Cirripidae	478 (26.063)
5	*Clibanarius infraspinatus*	Diogenidae	3 (0.164)
6	*Diogenes planimanus*	Diogenidae	776 (42.312)
7	*Diogenes custos*	Diogenidae	51 (2.781)
8	*Philyra globosa*	Leucosiidae	168 (9.160)
9	*Doclea aduncus*	Majidae	9 (0.491)
10	*Dotilla blandiformes*	Ocopodidae	60 (3.272)
11	*Scopimera crabricauda*	Ocopodidae	38 (2.072)
12	*Metapenaeus sp.*	Penaeinae	1 (0.0545)

*, collected during the one-year study period. Families 8; Genera 10; Species 12 and total number of crustaceans:1834; **, Figures in parenthesis denote percent proportion of N (=1834)..

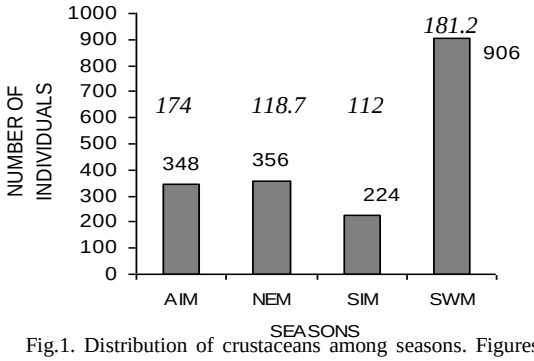


Fig.1. Distribution of crustaceans among seasons. Figures in italics above bars represent average Catch per month in a given season. AIM, autumn inter-monsoon; NEM, Northeast monsoon; SIM, South inter-monsoon; SWM, Southwest monsoon.
AIM: October and November; NEM: December, January & February; SIM: March and April; SWM: May, June, July, August and September.

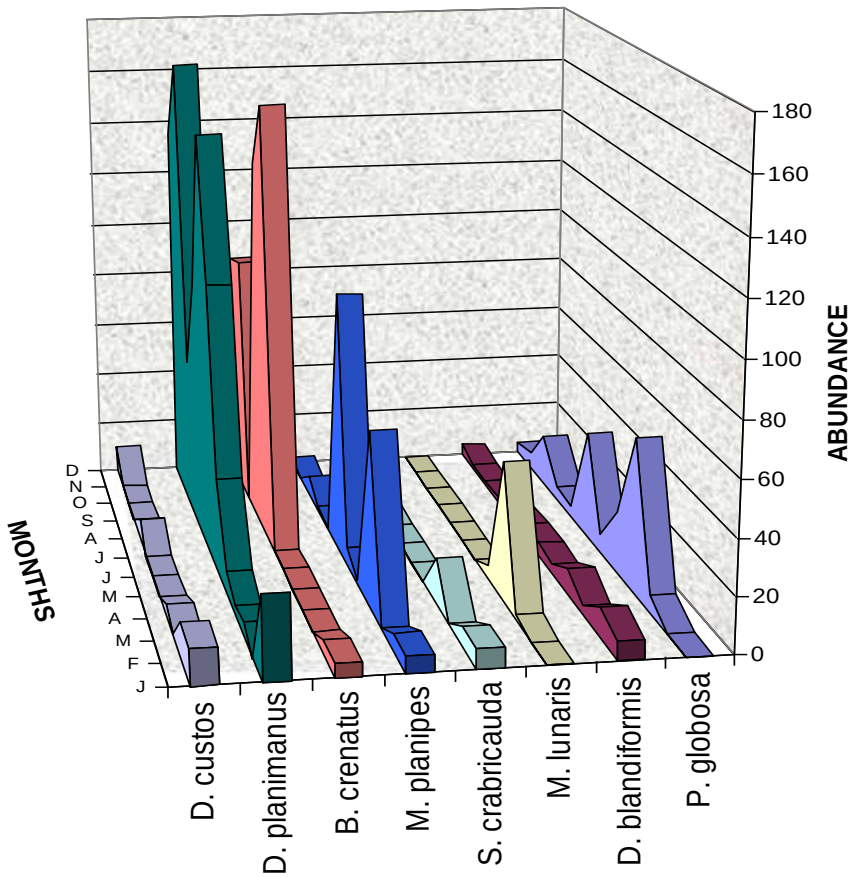


Fig. 2. Abundance, in terms of number of individuals, of some important crustaceans collected from the sandy beach of Clifton in monthly collection of a yearlong study.

Table 3. Sociological attributes of the crustaceans collected in a year long from the sandy beach of Clifton, Karachi.

S. No	species	Frequency*	F_3	Ni **	D_3	% IVI	Leading Dominant (in months)
1	*Charybdis callianassa*	25	4.23	5	0.273	2.25	-
2	*Matuta planipes*	75	12.68	188	10.25	11.46	1 (Apr)
3	*Matuta lunaris*	25	4.23	57	3.11	3.67	-
4	*Balanus crenatus*	50	8.46	478	26.06	17.26	2 (Aug, Sept)
5	*Clibanarius infraspinatus*	16.67	2.83	3	0.1636	1.50	-
6	*Diogenes planimanus*	91.67	15.49	776	42.31	28.9	6 (Jan, Jun, Jul, ,Oct Nov & Dec)
7	*Diogenes custos*	50	8.46	51	2.78	5.62	1 (Feb)
8	*Philyra globosa*	83.33	14.08	168	9.60	11.84	2 (Apr, May)
9	*Doclea aduncus*	16.67	2.83	9	0.4907	1.66	-
10	*Dotilla blandiformes*	100	16.90	60	3.27	10.09	-
11	*Scopimera crabricauda*	50	8.46	38	2.07	5.26	-
12	*Metapenaeus spp.*	8.33	1.41	1	0.55	0.77	-
	Total	591.7	100	1834	100	100	-

*, Number of crustaceans collected during the year; **, % months of occurrence out of 12; % IVI = $F_3 + D_3 / 2$.

Four families of crabs Diogenidae, Calappidae, Ocypodidae and Leucosidae were well represented in the studied samples. Hermit crab *Diogenes planimanus*, moon crab *Matuta planipes*. Ocypodid crabs *Dotilla blandiformes* and Leucosid crabs *Philyra globosa* were present more abundantly as compared to others. Leucosid crabs, *Philyra globosa* was abundant in the intertidal zone during summer season i.e., April to July. In August

several *P. globosa* crabs were observed in mating phase and ratio of females and males was 3:1. Moon crabs of family Callappidae *Matuta planipes* and *Matuta lunaris* were abundant in sub tidal zone. *Scopimera crabricauda*, another burrowing ocypodid crab occurs in upper tidal zone during winter season Crabs represented by only a few individuals, during 2 to 3 months are: Portunid crab *Charybdis callianassa, Doclea aaduncus Clibanarius infraspinatus.* Barnacles, *Balanus crenatus* were found as epibionts on sub tidal gastropod shells occupied by Hermits, mostly during monsoon period, August to September. Shrimp *Metapenaeus spp*. was caught only once during December On the basis of monthly abundance (Fig. 2) and The IVI of the species (Table 3) *D. planimanus* was the most successful species in the sandy beach followed by *B. crenatus, M. planipes, P. globosa* and *D. blandiformis* were more or less equally successful but at lower order of IVI . *D. blandiformis* was the most frequent species occurring throughout the year followed by *D. planimanus* (F = 91.67%) and *Philyra globosa* (F = 83.33%). The abundance of *D. planimanus* may probably be attributed due to its obligate nature of using empty shells of gastropods. *Diogenes planimanus* has been reported to occupy the shells of 32 species in the sandy shore of Clifton and Sands pit beaches (Fatima, 2007). The gastropod shell saves this organism from particulate abrasion due to wave action and predation. *B. crenatus*, the second dominant of sandy beach environment appears to be adapted to wide range of wave exposure due to its shielded structure (www/marlin.ac.uk/speciesfullreview.php?species ID=2718). *B. crenatus* grow rapidly except winter. Its lifespan is 18 months. The turbidity and heavy metals, however, influence the organism negatively (Barnes and Powell, 1953).

The densities of crustaceans captured monthly are shown in Fig. 3. The larger densities of crustaceans were observed in April, during July to September and Then in November. Maximum numbers of animals were collected in August followed by July. The density remained low during January to March. The abundance of crustaceans in Sonmiani Bay (Balochistan) is also reported to vary seasonally. The predominant occurrence was in intertidal fauna in March and December when collected by beach seine. When collected by beam trawl, crustaceans were quite abundant in March and April and very abundant in August, October and December (Gondal *et al.,* 2012). Fig. 4 presents the data on monthly collection of crustaceans which varied linearly (r = 0.998) with the density of the monthly collection as follows:

Number of crustacean captured = -1.2765 + 2.279 Density.m $^{-2}$ ± 3.008

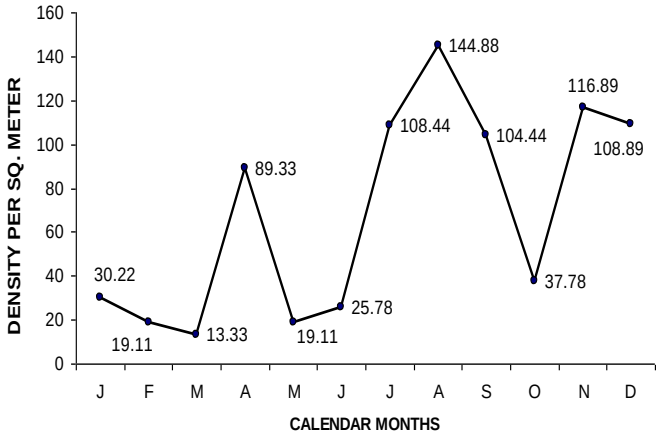


Fig.3. Variation of density of crustaceans / m^2 in various months. One peak corresponded with the South-west monsoon system and the smaller peaks correspond with spring inter-monsoon system. There was substantial increase in late autumn inter-monsoon which declined appreciably in North-east monsoon.

The seasonal abundance pattern (Fig. 5) indicated that larger number of crustaceans was captured during Southwest monsoon season followed by autumn inter-monsoon and spring inter-monsoon. The collection during Northeast monsoon was low. It appears that the abundant crustaceans are adapted to relatively high temperature of summer and their abundance declines in winter months of January, February and March.

A total of 1834 individuals of crustaceans were recorded during the present study. Previous study reported 61 species and 2089 individuals at sandy beach near Keamari oil terminal during one year collection (Ahmed and Hameed, 1999). A remarkable finding of the fauna was the occurrence of hermit crab, *Diogenes planimanus* as the most dominant representative of crustacean. These crabs inhabiting sub tidal region occupied the large shells of *Babylonia spirata, Neverita didyma, Thais carinifera, Thais tissoti, Thais lacera, Tibia curta, Monodonta australis,*

and *Turricula javana*, whereas the smaller crabs chose the empty shells of *Bullia tranquebarica, Cerithidea cingulata*, *Thais tissoti*, and *Natica pulicaris* to protect themselves from the predators. Previously only a few individuals of hermit crabs were found (Ahmed and Hameed, 1999). Another abundant species of crab at Clifton beach was a purse crab, *Philyra globosa*. It breeds during August as evident from abundance of females and observation of crabs in copulatory phase. Occurrence of Moon crabs *Matuta planipes* and *Matuta lunaris* were also in abundance, mostly during winter or north-east monsoon season and ocypodid crabs *Dotilla blandiformes* and *Scopimera crabricauda* on upper-tidal zone during winter is also remarkable. The occurrence of *Metapenaeus spp.* only once in December (2005) showed that it is not a member of this community but might have drifted here from nearby waters. Some uncommon crustaceans were also observed during the study period, these were *Charybdis callianassa, Balanus crenatus, Clibanarius infraspinatus, Diogenes custos* and *Doclea aduncus.* Some of the crustaceans encountered in the present studies are reported from other coastal places. Four species viz. *D. planimanus, M. planipes, D. custos* and *Clibanarius infraspinatus* are also reported from intertidal zone of Sonmiani (Balochistan) (Gondal *et al.,* 2012). *D. planimanus* occupied 0.36 % of the total intertidal fauna and *D. custos* occupied 0.14% of the fauna. *D. planimanus* is also reported from Astola island beaches of Pakistan coast. Of the 25 crustaceans reported from the sandy beaches of Oman, only two genera m *Dotilla* (*D. sulcata*) and *Matuta* (*M. victor*) are those which are common with the fauna of sandy beach of Clifton (cf. McLachlan *et al.,* 1998). M. planipes is also found on Chennai coast, Tamilnadu, India and is distributed in Indian Ocean, Persian Gulf, Pakistan, Sri Lanka, Myanmar, Australia, etc. (Silambarasan *et al.,* 2014). The acorn barnacle, *B. crenatus* is widespread and is primarily a species of sub-littoral zone found on the undersides and overhangs of stones, may colonize cobbles, shells, bedrock, artificial substrata ,etc. (www.marlin,ac.uk/speciesfullreview.php?species ID=2718).

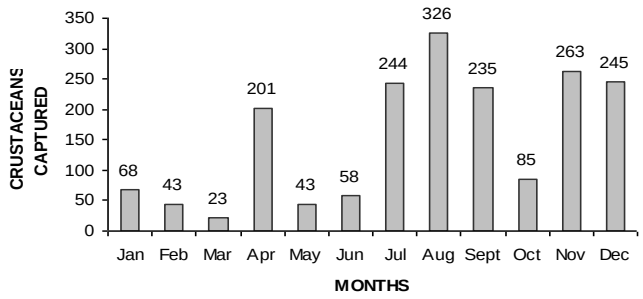
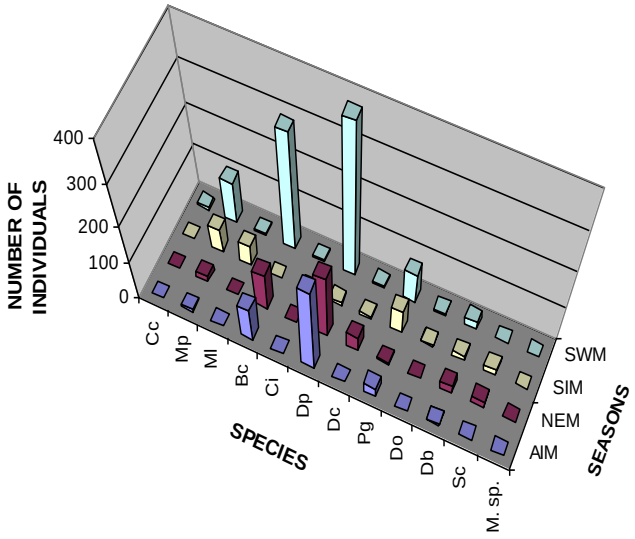


Fig. 4. The total number of crustaceans captured in various months.

Table 4. Temporal variation in species richness, diversity and evenness of the crustacean community in sandy beach of Clifton, Karachi.

Month	S	R1	R2	c	H'	N1	N2	E1	E2	E5
January	6	1.18497	0.72761	0.25461	1.55156	4.71881	3.92759	0.86549	0.78647	0.70172
February	5	1.06349	0.76249	0.21263	1.53462	4.63950	4.70313	0.95352	0.92792	1.01746
March	6	1.59465	1.25109	0.15415	1.71546	5.55926	6.48715	0.95742	0.92654	1.20353
April	7	1.13137	0.49374	0.23746	1.56940	4.80378	4.21119	0.80651	0.68624	0.84421
May	6	1.32936	0.91499	0.30675	1.41228	4.10532	3.25993	0.78821	0.68422	0.72776
June	6	1.23139	0.78784	0.39323	1.24970	3.48993	2.54308	0.69747	0.58155	0.61988
July	5	0.72764	0.32009	0.34325	1.18525	3.27150	2.91333	0.73644	0.65429	0.84232
August	6	0.89549	0.36788	0.45845	0.93378	2.54411	2.18127	0.52115	0.42402	0.70502
September	6	0.91582	0.39139	0.47507	0.87229	2.39238	2.10496	0.48683	0.39873	0.79358
October	5	0.90036	0.54232	0.47031	0.99863	2.71457	2.12627	0.62048	0.54291	0.65688
November	5	0.71855	0.30831	0.50431	0.81927	2.26883	1.98291	0.50904	0.45377	0.77465
December	8	1.27244	0.51101	0.42419	1.08948	2.972732	2.35744	0.52393	0.37159	0.68810
Mean	5.92	1.08058	0.61489	0.35287	1.24431	3.6234	3.23319	0.70554	0.61985	0.79793
CV (%)	15.2	24.15	46.05	33.52	24.69	30.58	42.43	24.53	31.16	20.83

Species Richness indices (S, R1, R2); Diversity indices (H, N1, N2); Dominance (c); Evenness (E1, E2. E5). See text for further explanation.



Key to the Seasons: AIM, Autumn Inter-monsoon; NEM, Northeast Monsoon; SIM, Spring Inter-monsoon and SWM, Southwest Monsoon

Key to the Species: Cc, *C. callianassa*; Mp, *M. planipes*; Ml, *M. lunaris*; Ci, *C. infraspinatus*; Dp, *D. planimanus*; Dc, *D. custos*; Pg, *P. globosa*; Do, *D. oduncus*; Db, *D. blandiformes*; Sc, *S. crabricauda* and Metap. Sp., *Metapenaeus* sp.

Fig. 5. Seasonal distribution of the crustacean species.

Table 5. Seasonal variation of diversity.

Indices	AIM (Oct-Nov)	NEM (Dec-Jan-Feb)	SIM (Mar-Apr)	SWM May-Jun-Jul-Aug-Sept)	Annual Average
S	5.0 ± 0	6.3 ± 0.88	6.5 ± 0.50	5.8 ± 0.20	5.92
R1	0.8095 ± 0.09	1.1736 ± 0.0606	1.3630 ± 0.232	1.0199 ± 0.112	1.0806
R2	0.4253 ± 0.1170	0.6670 ± 0.0787	0.8720 ± 0.379	0.5564 ± 0.123	0.61489
c	0.6037 ± 0.0994	0.2984 ± 0.0838	0.1958 ± 0.0417	0.3954 ± 0.0323	0.35289
H’	0.9090 ± 0.0897	1.3980 ± 0.1320	1.6424 ± 0.0730	1.1307 ± 0.1005	1.24431
N1	2.4917 ± 0.223	4.1103 ± 0.5693	5.182 ± 0.267	3.1606 ± 0.6150	3.6234
N2	2.0546 ± 0.0717	3.663 ± 0.6899	5.349 ± 1.138	2.6010 ± 0.2188	3.23319
E1	0.5648 ± 0.0557	0.7809 ± 0.1310	0.8720 ± 0.0755	0.6455 ± 0.0599	0.30554
E2	0.4983 ± 0.0446	0.6953 ± 0.1669	0.8064 ± 0.1201	0.5485 ± 0.05486	0.61985
E5	0.7158 ± 0.0589	0.8024 ± 0.1076	1.0238 ± 0.1796	0.7377 ± 0.0382	0.79793

AIM, autumn inter-monsoon; NEM, Northeast monsoon; SIM, South Inter-monsoon; SWM, Southwest Monsoon

Table 6. Pearson product moment correlation coefficients amongst various diversity indices of a sandy beach crustacean community of Clifton, Karachi, Pakistan.

S	S									
R1	0.521	R1								
R2	0.070	0.888	R2							
C	-0.078	-0.648	-0.717	C						
H	0.150	0.722	0.764	-0.980	H					
N1	0.135	0.726	0.772	-0.983	0.994	N1				
N2	0.032	0.673	0.722	-0.947	0.905	0.94	N2			
E1	-0.151	0.558	0.736	-0.958	0.951	0.945	0.893	E1		
E2	-0.277	0.488	0.721	-0.926	0.898	0.905	0.897	0.986	E2	
E5	-0.166	0.352	0.506	-0.693	0.564	0.626	0.942	0.624	0.691	E5

See test for explanation of diversity indices. The value of $r \leq 0.558$ is not significant at $p < 0.05$ for $df = 10$ (by two-tailed test).

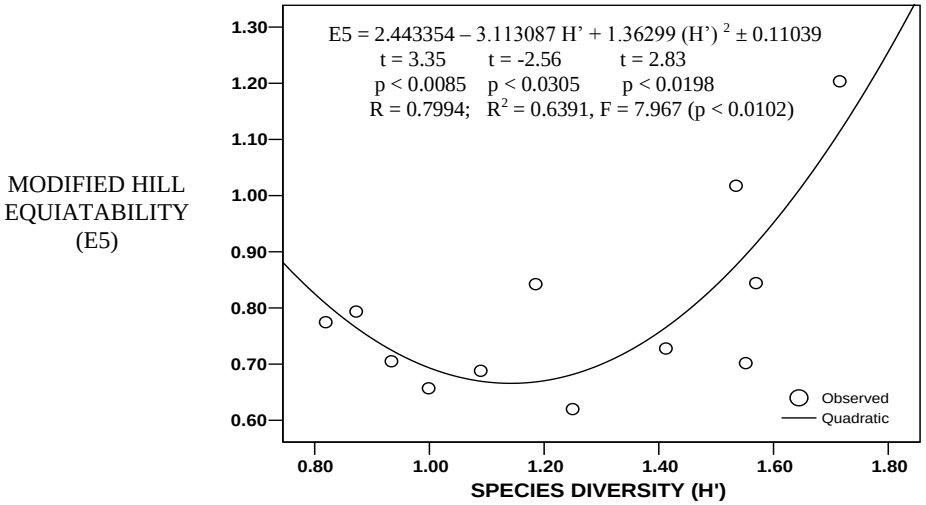


Fig. 6.Relationship of modified Hill equitability (E5) with the species diversity.

Diversity, dominance, Species richness and relative abundance pattern

Diversity an important attribute of structure, function and organization of in an assemblage was calculated on the basis of abundance. The magnitude of various diversity indices for monthly observations is given in Table 4 along with their mean values over a year basis. In comparison of the mean value species richness (R1) was higher during January to June and then December. R2 was comparatively higher in January to March, May and June and then declined below the annual mean from July to December. The Dominance measure was higher in August to December, somewhat low in January and February and the lowest in March. Contrary to it, H' was on higher side from January to May and then declined from June to December. N1 and N2 behaved in a manner similar to H'. like H', these diversity indices were also the highest in the month of march. E1 and E2 behaved like H'. Variation over the year, expressed as CV (%), was highest in case of R1 and N2 (> 40%) and moderate in R2, H;, N1, E1 and E5 (slightly > 20%). Dominance concentration among the temporal assemblages varied by 33.5%. In short, all indices except dominance had higher values in the winter months of January and February (or until March) when Seawater temperature was low whereas dominance was high in August to November when abundance of the dominant species was the highest. Ahmad and Hameed (1999b) had noted highest values of diversity and evenness indices in the month of July at sandy beach of Clifton and minimum in winter. In Buleji also diversity fluctuated seasonally from high in October to low during February to August. This decreasing trend is considered to be related to the disturbance and stress experienced by the macrofauna during monsoon period (May to August) (Ahmad and Hameed, 1999a). In Clifton mangroves, species richness expressed as number of faunal species S varied from 8 to 13 seasonally – higher in summer. Margalef index of species richness was also higher in summer followed by that in autumn. N1 and N2 presented similar pattern. Evenness was also higher in summer. However, in Port Qasim, mangrove faunal diversity was higher in spring and summer (Barkati and Rahman, 2005).

The seasonal behaviour of diversity is presented in Table 5. The variation in number of species was low – slightly high in NEM and SIM seasons. Most of the diversity indices were higher than their annual mean in NEM and SIM seasons. The dominance C was higher than its annual mean in AIM and SWM seasons.

The sandy beach of Clifton appeared to be poor in species composition with number of species in a month averaging to 5.92 (5-8; varying merely 15.2%). Number of species was little higher in December. This is in agreement with Abele (1974) that compared to several marine habitats tropical sandy beaches are poorly colonized habitat by the decapod crustaceans, around seven on an average. Contrary to it, tropical rocky intertidal zones are the richest habitat (67-78 species).

A great deal of multi-colinearity was apparent from the correlation analysis amongst various diversity indices. H' and MC were generally positively with equitability and species richness. Contrary, dominance was inversely related with the diversity measures (Table 6). Burney and Barkati (1995) have also recorded a linear dependence among the measures of diversity of Buleji macrofauna. As regard to the linear dependence among the diversity measures and diversity-dominance relations, our results are in agreement with the results of earlier workers (Shaukat *et al.*, 1978; Saifullah *et al.*, 1984). The interrelationships between diversity and its components are given below in form of linear equations (1-4).

$R1 = 0.317 + 0.6130\ H' \pm 0.178931$; $r = 0.722$, $r^2 = 0.521$, $F = 10.88$ ($p < 0.008$)… Eq. # 1.
$R2 = -0.261 + 0.704\ H' \pm 0.196850$; $r = 0.764$, $r^2 = 0.583$, $F = 13.99$ ($p < 0.004$)… Eq. # 2.
$E1 = 0.039 + 0.5360\ H' \pm 0.056200$; $r = 0.951$, $r^2 = 0.904$, $F = 94.23$ ($p < 0.0001$)… Eq. # 3.
$E2 = -0.083 + 0.5650\ H' \pm 0.088958$; $r = 0.951$, $r^2 = 0.898$, $F = 41.85$ ($p < 0.0001$)… Eq. # 4.

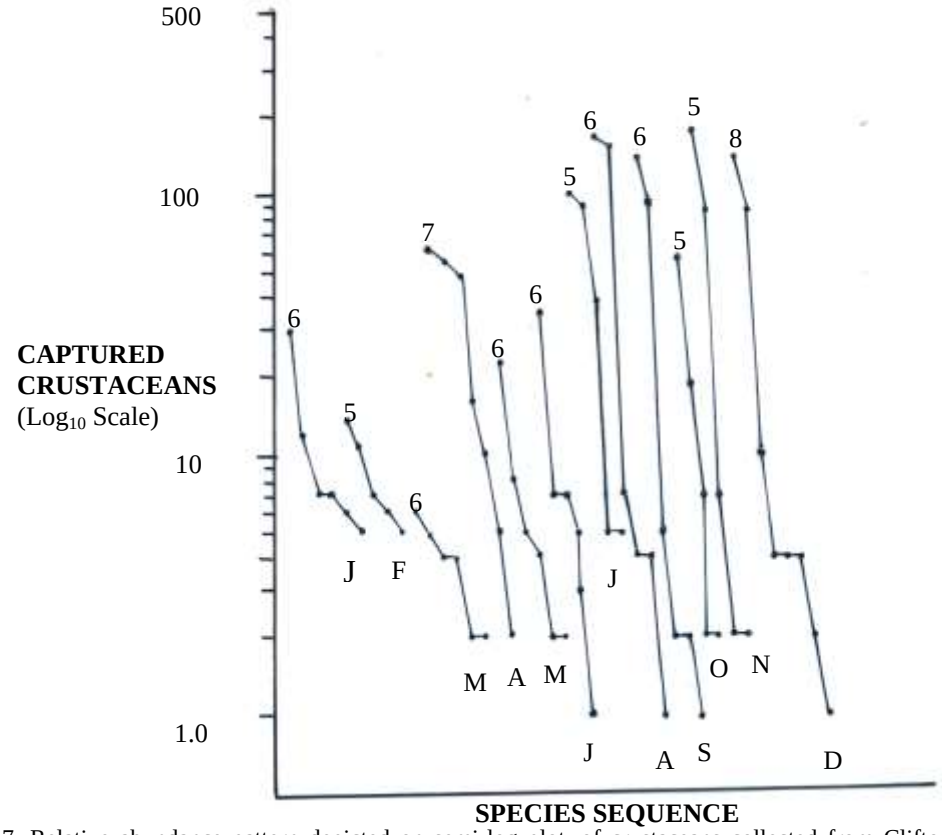


Fig.7. Relative abundance pattern depicted on semi-log plot, of crustaceans collected from Clifton, Karachi, during monthly sampling from January to December shown as J to D. The figures above the curves depict the number of crustaceans species collected during the sampling month. The distribution of abundance amongst the crustacean species was geometric throughout the year.

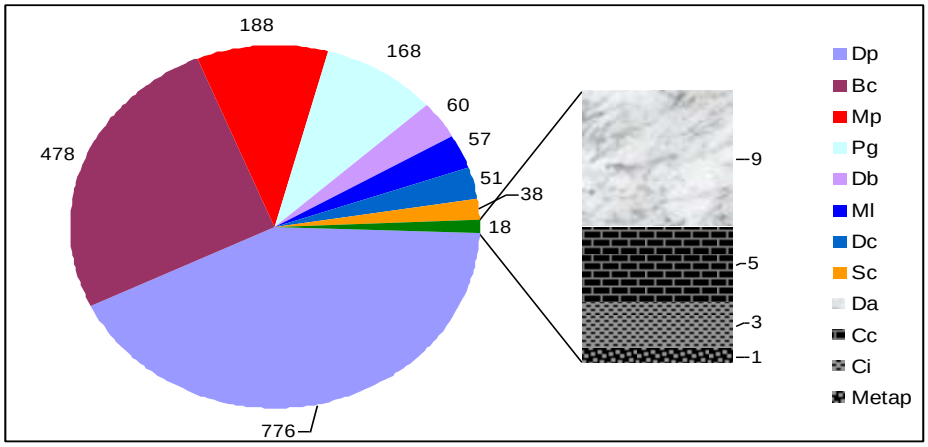
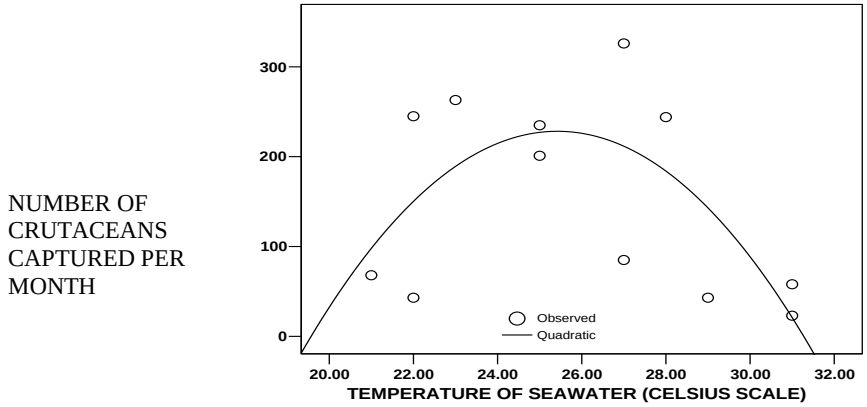


Fig. 8. Abundance pattern of species on basis of year long sampling. Key to the Species**:** Cc, *C. callianassa*; Mp, *M. planipes*; Ml, *M. lunaris*; Ci, *C. infraspinatus*; Dp, *D. planimanus*; Dc, *D. custos*; Pg, *P. globosa*; Do, *D. oduncus*; Db, *D. blandiformes*; Sc, *S. crabricauda* and Metap. Sp., *Metapenaeus* sp.

It is evident from linear equations 1 to 4 (given above) that the species diversity was more controlled by the equitability than by the species richness which varied but little among the samples. Both indices of species richness (R1 and R2) and evenness (E1 and E2) related with H' linearly. E5 related with H' curvilinearly (quadratically) (Fig. 6).

For all calendar months (J – D), the relative abundance pattern among the species, as determined by Whittaker curves on semi-log plot, was linear i.e. the distribution of abundance among the constituent species was geometric. (Fig.7). The distribution pattern of annually captured crustacean also indicated geometric pattern of abundance distribution among species (Fig. 8). These plots highlighted differences in evenness component amongst monthly assemblages (Tokeshi, 1993, Smith and Wilson, 1996). In geometric series models represented assemblages to have evenness very low in which a few or the one dominant species controlled most of the resources.

The in-hand crustacean assemblages had low diversity and high dominance by generally one or rarely a few species. Whittaker (1965) has viewed a natural community as an admixture of differentially and unequally successful species. The dominant species in a community influence the community structure and the function of the subordinate species. The structure of the crustacean assemblages in time is simple in organization as indicated by the high dominance and low diversity values. The relative abundance pattern at sandy beach of Clifton throughout the year was essentially linear on semi-log plot that indicated geometric distribution of resources amongst the species. The geometric distribution of abundance in the assemblages in hand implies that the most successful (dominant) species pre-empted a fraction 'k' of the resources, next a fraction of the remainder of the and so on (May, 1975; Tokeshi, 1990, 1996; Magurran, 2004). Such a distribution is attributed to species poor and stressful conditions of the environment (Whittaker, 1975) where the phenomenon of dominance is strongly developed. Our results indicated that two components of diversity were not equally important in determining the diversity of these assemblages. Here equitability appeared to control diversity more than the species richness. Tramer (1969) suggested that communities from adverse rigorous environments (adverse environmental conditions) very in diversity according to their relative abundance component whereas communities in non-rigorous environment (biologically controlled environment) is a function of species richness. Smith (1980) reiterated that there is no such entity as wholly physically controlled or wholly biologically controlled community. The community is rather influenced by the interaction of the two.



Total Number of crustaceans = -4076.312 + 338.6523 Temp. – 6.66071 (Temp) ^{2} ± 89.23

t = -2.25 t = 2.40 t = 2.47

p < 0.0513 p < 0.0397 p < 0.0357

R = 0.6692; R^2 = 0.4478, Adj R^2 = 0.4478. F = 3.65 (p < 0.069)

Fig. 9.Relationship of total number of crustaceans captured in a month with the temperature of the Seawater (^{o}C).

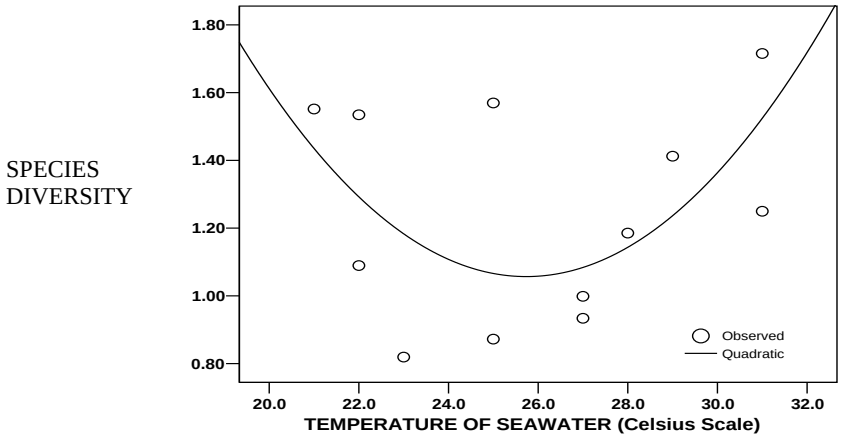
Temperature relations of the number of monthly captured crustaceans

The number of crustacean captured in monthly collection related with Seawater temperature curvilinearly (Fig. 9). The number of crustacean collected increased with the temperature from 22 to 28 ^{o}C and then declined. It appears that optimum temperature for sandy beach crustacean fauna of Clifton (Karachi) is 25-28 ^{o}C. No such

relationship was observed with pH and salinity. Indeed, *Philyra globosa* has been reared at 28 ^{o}C in water of salinity of 30 ‰ (Krishnan and Kannupandi (1990).

Seawater-Temperature relations of diversity

Species diversity H' was found to relate with Seawater temperature curvilinearly (Fig, 10). It declined in magnitude from 20 to 27 ^{o}C but then increased up till 32^{o}C. This range of temperature corresponded with spring and Southwestern monsoon seasons. Species richness (R1) also showed curvilinear relationship with Seawater temperature (Fig. 11) but none of the equitability indices exhibited such relationship with Seawater temperature. The results highlight the environmental control over diversity and species richness of the crustacean assemblage of the sandy beach of Karachi



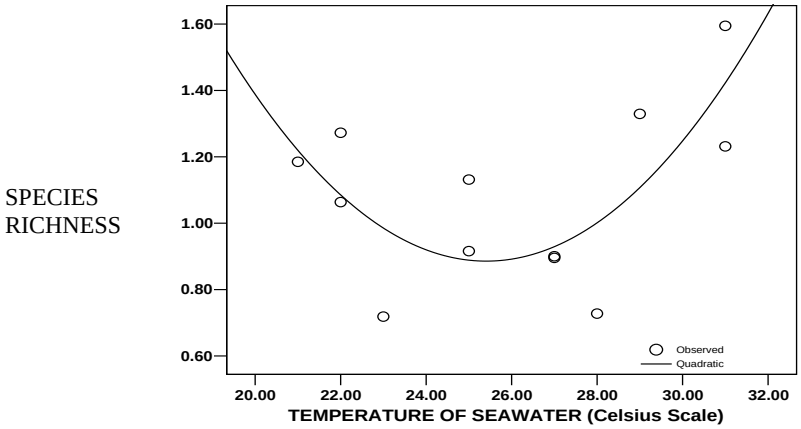
Species Diversity (H') = 12.227256 - 0.868078 Temp. + 0.016854 (Temp) ^{2} ± 0.28108

t = 2.14 t = - 1.956 t = 1.984

p < 0.0611 p < 0.0822 p < 0.0786

R = 0.7209; R^2 = 0.5191, Adj R^2 = 0.1627, F = 4.88 (p < 0.0369)

Fig. 10.Relationship of species diversity (H') of crustacean assemblage in sampling months with the temperature of the Seawater.



Species richness (R1) = 11.974403 - 0.872839 Temp. + 0.017176 (Temp) ^{2} ± 0.19999

t = 2.95 t = - 2.77 t = 2.84

p < 0.0163 p < 0.0195 p < 0.0219

R = 0.7209; R^2 = 0.5191, Adj. R^2 = 0.4129, F = 4.88 (p < 0.0369)

Fig.11. Relationship of species richness (R1) of crustacean assemblage in sampling months with the temperature of the Seawater.

It is obvious that crustacean fauna in sandy beach of Clifton is subject to intense environmental stress. Coastal development around the world is profoundly altering the beach ecosystems. Besides physical factors of the

environment and the degree of pollution, the sandy beach of Clifton is subject to great degree of disturbance. Many of the crustaceans have become extinct or are under heavy stress and losing ground. Ahmad (1997) has documented that several species have disappeared from the intertidal zone due to higher temperature and salinity and pollution and over-exploitation. Rizvi *et al.* (1999) also observed a loss of marine fauna and flora in the near shore environment due to pollution, coast development and changes in river discharge.

PS: According to McLaughlin and Holthius (2001) *Diogenes planimanus* and *D. violaceus are actually D. custos.* From this view-point *D. planimanus* is not included in the Checklist of marine anomurans (Crustacea: Decapoda) of Pakistan, Northern Arabian Sea, by Siddiqui and Kazmi (2003). Since *D. planimanus* and *D. custos* have been treated as two separate species in literature pertaining to Pakistan coast, in this paper we have dealt them as separate species for the sake of comparison.

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