Pakistan J. Zool., vol. 44 (3), pp. 615-623, 2012.

Density, Distribution and Population Biology of *Macrophthalmus* (*Venitus*) *dentipes* Lucas, 1836, From Mangrove Areas of Pakistan

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Abstract.- *Macrophthalmus (Venitus) dentipes* is a common inhabitant of mangrove areas along the Pakistan coast. Crabs from two mangrove sites, Korangi creek and Sandspit were sampled every month during Mar 2001 to Feb 2002 to study their populations. The average density of crabs ranged between 1 to 24 m^{-2}. For the density distribution, the nested design ANOVA showed no significant difference between stations, but significant difference within seasons and different tidal height (low tide level) at Sandspit and significant difference among tidal level at Korangi creek were observed. Significantly more small sized crabs were observed at the lower intertidal region. The present study demonstrates the importance of substratum characteristics in influencing the distribution and abundance of these sentinal crabs. `t' test showed carapace width (CW) of male and female crabs were significantly different at Sandspit and Korangi creek. The recruitment of juvenile crabs (CW < 5 mm) was observed throughout the year and the presence of ovigerous females from October to May indicated seasonal reproduction. The average size of ovigerous females was CW= 10.4 mm and the smallest ovigerous female was CW =7.0 mm.

Key words: Zonal distribution, Karachi, mangrove, *Macrophthalmus (Venitus) dentipes*, population biology, sentinel crabs.

INTRODUCTION

Crabs of the genus *Macrophthalmus* Demarest, 1823 commonly called sentinel crabs, usually inhabit subtidal, intertidal, and supratidal areas (Morton and Miller, 1973; Jones, 1984; Kitaura *et al.,* 2002, 2006). These crabs often construct temporary burrows and perform a number of surface functions (feeding, allocleaning, fighting and waving) around their burrows (Simons, 1981; Kituara *et al.,* 2006). They play a key role in material cycling and energy flow in ecosystems as they are detritivores and feed primarily on detritus sifted from the surface sediment (Beer, 1959; Fielder and Jones, 1979; Otania *et al.,* 2010).

Recently, the taxonomy of genus *Macrophthalmus* have been reviewed, Ng *et al*. (2008) discussed 55 extant species divided into eight subgenera, Barnes (2010) discussed 47 species, however more recently, Naderloo *et al.* (2011) discussed 59 species after addition of four new species, one from western Pacific and three from Indian Ocean. Hashmi (1963; 1964) gave a checklist of crabs of Karachi, Pakistan that included six species of the genus *Macrophthalmus.* Tirmizi and Ghani (1996) also reported six species of the genus *Macrophthalmus* from Pakistan including *Macrophthalmus (Venitus) dentipes* as *Macrophthalmus pectinipes*. Ng *et al.* (2008) designated this species as *Macrophthalmus (Venitus) dentipes* and considered the *Macrophthalmus pectinipes*, as a junior synonym.

The species of the genus *Macrophthalmus* have been studied in relation to their population and reproductive biology (Simons and Jones, 1981; Henmi and Kaneto, 1989; Emmerson, 1994; Litulo, 2005), habitat preference (Ono, 1962, 1965; Jones and Simons, 1982), relative growth (Simons, 1981), behavior (Henmi, 1984, 1992), and social behaviour and molecular phylogenetics (Schubart *et al.,* 2000; Horii *et al.,* 2001; Kituara *et al.,* 2002, 2006). Seasonal variations in density, distribution, population structure, sex ratio, recruitment of juveniles and breeding periods are the most frequently studied aspects regarding population biology (Pillay and Nair, 1971; Henmi and Kaneto, 1989; Emmerson, 1994; Takween and Qureshi, 2005; Litulo, 2005).

A review of the literature shows no previous work on the biology and the ecology of *M. (V.)*

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0030-9923/2012/0003-0615 $ 8.00/0

dentipes. The aim of this work is to study the distribution and population biology of the commonly occurring sentinel crab, *Macrophthalmus (V) dentipes* from a coastal areas of Pakistan.

MATERIALS AND METHODS

Study site

The Pakistan coastline extends over 990 kilometers, with the province of Balochistan in the west and Sindh in the east (Snead, 1985). The Indus delta, the most prominent coastal feature, presently occupies an area of 73,001 hectares dominated by mangrove vegetation (Ashraf *et al.*, 2004), which is nutritionally rich and provides an ideal habitat for a variety of estuarine fauna. Regular monthly samples of *M. (V.) dentipes* crabs were collected from two sites: Korangi creek and Sandspit backwater mangroves, from March 2001 to February 2002. Korangi creek (24°79'N, 67°20'E) is the northernmost creek of the Indus Delta located in the east near the fishing village of Ibrahim Hyedri. It is connected at its northeastern end with Phitti and Kadiro Creek, and its southwestern end with Gizri Creek and the open sea. It is bound on its sides by extensive mangrove vegetation of *Avicennia marina*. The Sandspit backwaters mangrove area (24°50'N, 66°56'E) comprises mud flats and dense mangrove vegetation of *Avicennia marina* located north of the sandy coast and is connected to the Arabian Sea through the Manora Channel (Qureshi and Sultana, 2001).

Sampling and methodology

At each site, two transects (50 meters) were set up in the mangrove area from the low tide mark to the high tide mark. On each transect, a 0.5 m quadrat frame (0.25 m^2) was placed (10 meters apart) at three different tidal levels (low tide L1, mid tide L2, and high tide L3). The square was excavated to the depth of 30 cm (as most of the crabs do not construct burrow deeper than 30 cm) and sediment sieved (1 mm mesh). The crabs present in the sample were bagged in labeled polythene bags and kept in ice box that was brought back to the laboratory, wherein crabs were preserved in 70% ethanol for further analyses. Crabs were sorted, identified, measured and sexed; the presence of ovigerous females and their proportion in the samples were noted.

To identify the relationship of crabs with the habitat, sediment samples taken by PVC cores (inner diameter (ID) 5.6 cm, up to 30 cm deep) from each tidal level of each site to analyze the sediment properties. In the laboratory, the sediment properties (percent porosity, percent organic matter content and grain size) were analyzed. Percent organic matter content was determined by monitoring the difference of mass loss after combustion in a muffle furnace. Briefly, 20–50 g of dry sediment sample was placed in a pre-weighed crucible, covered with a lid and combusted at 450°C for 3 hrs. Grain size was analyzed by dry sieving methodology following Folk (1974). Hydrographic parameters (salinity, temperature and pH) of collected interstitial water within the excavated square frame pits (dug for excavation of crabs) were measured. Salinity was measured with a refractometer and temperature and pH, with a field pH meter (Hanna 8314).

Statistical analyses

Completely randomized design (CRD) analyses of variance (ANOVA) with nested treatment arrangement were carried out by using the statistical package Minitab (Version 11.12) for differences among seasons and level for all hydrographic parameters and the density of crabs. Test of significance were accepted as significant at alpha =0.05 for statistical analyses. To observe the seasonal variability monthly data were grouped into seasons following Rao and Rama-Sharma (1990), wherein December, January and February are defined as northeast monsoon, March, April and May as pre-monsoon period, June, July and August as southwest monsoon period, and September, October and November as post-monsoon period. The size at first maturity (SFM) was based on the smallest recorded ovigerous female (Pinheiro and Fransozo, 2002) and both male and female crabs smaller than the smallest ovigerous female were classified as juveniles (Litulo, 2005). Chi Square (χ^2) test was employed to study the sex ratio. Pearson correlation coefficients were calculated to determine the relationship between the crab densities with environmental parameters.

RESULTS

Physical parameters

Significant seasonal variations were observed for physical parameters and sediment structure properties at Korangi Creek and Sandspit backwater mangrove area (Table I). Temperature was the highest in southwest monsoon and the lowest in northeast monsoon at both sites. Salinity was the highest in pre-monsoon at both sites. The highest pH was observed during the pre-monsoon at Korangi creek and in southwest monsoon at Sandspit backwater mangrove area (Table I). The percent organic matter was high in northeast monsoon season at Korangi creek and in pre-monsoon at Sandspit backwater mangrove area. Grain size analyses revealed coarse sand at Sandspit and fine sand at Korangi creek mangrove area (Table I).

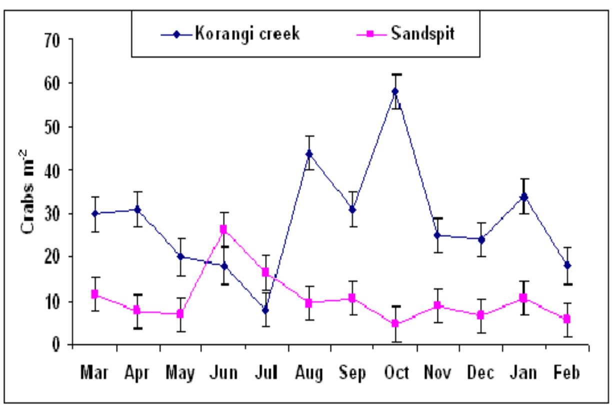

Fig. 1. Monthly distribution m^{-2} of *Macrophthalmus (Venitus) dentipes* at Sandspit backwater mangrove area and Korangi creek mangrove area during Mar. 2001 to Feb. 2002.

Density and distribution

The density (pooled for both transects and all quadrats) of *M. (V.) dentipes* was significantly different ($F_{1,71}$ = 44.82, P<0.001) between sites. *M. (V.) dentipes* were in the range of 128-224 m^{-2} at Korangi creek, and in the range of 8-112 m^{-2} at Sandspit (Fig. 1). The density of the crabs showed no significant variations among seasons at both sites but was significantly different for tidal level ($F_{2,35}$ = 6.92, P < 0.001) and ($F_{2,35}$ = 15.25, P < 0.001) at Sandspit and Korangi creek, respectively. Pearson correlation coefficient for the sediment characters with density of crabs was also estimated, and results showed positive correlation with porosity (r= 0.340), percent organic (r = 0.496) and mean grain size (r = 0.645). The density of the crabs was negatively correlated (r = -0.244) with the salinity.

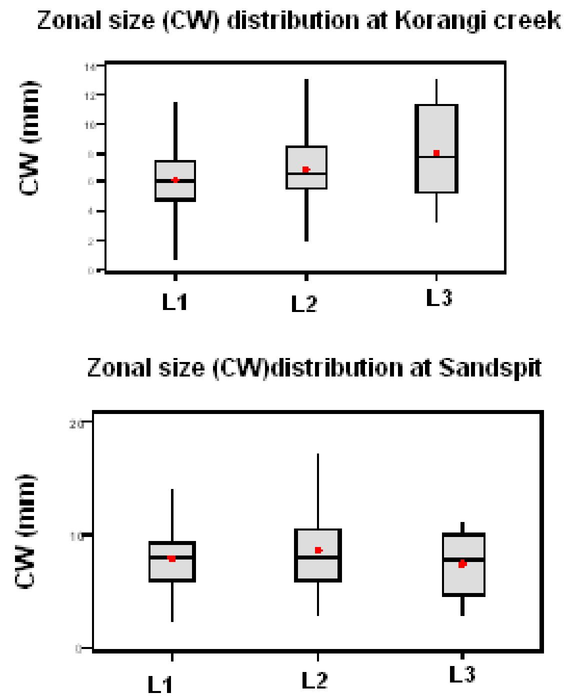

Fig. 2. Size range (CW Carapace width) distribution of *Macrophthalmus (Venitus) dentipes* at three levels (L1 = low tidal level, L2 = mid tidal level, L3 = high tidal level) at Korangi creek and Sandspit.

The smallest crab (CW = 1.75 mm) was collected from Korangi creek. There were significant inter sexual differences in the size (CW) of male (larger) and of female at Korangi creek (t = 11.41, P = 0.000, df = 366) and at Sandspit (t = 6.80, P = 0.000, df = 168). The difference in the size range of crabs (CW) between levels (Fig. 2) was significant at Korangi creek ($F_{2,\ 428}$ = 7.35, P < 0.001) but was not significant at Sandspit.

Size frequency distribution

The overall size frequency distribution of all crabs were not normally distributed (KS_{465} = 0.061, P<0.05) and (KS_{241} = 0.059, P < 0.05) at Korangi

Table I.- **Seasonal variation of temperature, salinity, pH, mean phi, and percent organic matter and density of crabs collected from Korangi creek and Sandspit backwater mangrove areas during Mar. 2001 to Feb. 2002. (Note: Korangi creek is fine sand, Sandspit is medium sand to coarse sand).**

Sites	Seasons	Temperature (°C)	Salinity (ppt)	pH	Percent organic matter	Mean grain size (phi)	Crabs m^{-2}
Korangi creek							
	Pre Monsoon	28±4.16	40.7±5.1	8.07±0.7	3.4±1.5	2.31±0.13	114±14
	SW Monsoon	29±3.67	39.4±2.8	7.8±0.5	2.1±0.7	2.17±0.14	156±48
	Post Monsoon	28±1.691	39.1±1.5	7.5±0.8	2.9±0.8	2.15±0.11	177 ±54
	NE Monsoon	26±3.94	39.4±2.9	7.6±0.1	3.6±0.5	1.99±0.16	110 ±22
Sandspit							
	Pre Monsoon	27.8±2.7	39.9±3.1	5.9±3.8	1.63 ±0.48	1.17±0.18	66±24
	SW Monsoon	30.5±3.1	41.9±2.7	9.6±1.7	2.12±0.57	1.20±0.20	125±25
	Post Monsoon	33.2±2.4	40.6±2.7	8.1±1.6	1.76±0.69	1.21±0.23	65±25
	NE Monsoon	22.7 ±3.6	39.3±1.2	7.1±1.8	1.75±0.36	1.20±0.20	69 ±48

and Sandspit, respectively. The recruitment of juvenile crabs (CW < 5 mm) occurred nearly all year round except in August and nearly all size classes were found in May, June and September (Fig. 3a) at Korangi but were not obvious at Sandspit (Fig. 3b).

Sex ratio and breeding season

The density and distribution of male and female crabs of *M. (V.) dentipes* showed the ratio of male and female crabs deviated from 1:1 in nearly all months, however, Chi Square test showed no significant difference in sexes at Korangi creek (χ^2 = 17.36, P = 0.098 and df =11) and at Sandspit (χ^2=15.84, P = 0.147 and df =11). The numbers of female crabs were greater than the number of male crabs in almost all the months at Sandspit (Table II).

The presence of ovigerous females in the sample provides an indication of reproductive activity. Comparison of percent distribution of ovigerous females with non-ovigerous females indicates that breeding period occurs from October to May (Table III) at both sites. The mean size for ovigerous females also is significantly different (t = 7.57, P < 0.001, df = 168) at Sandspit (12.7±1.6 mm) and Korangi creek (9.26±1.7 mm). The smallest ovigerous female (CW = 7.0 mm) was observed at Korangi creek and the largest (CW = 15.0 mm) at Sandspit (Table III).

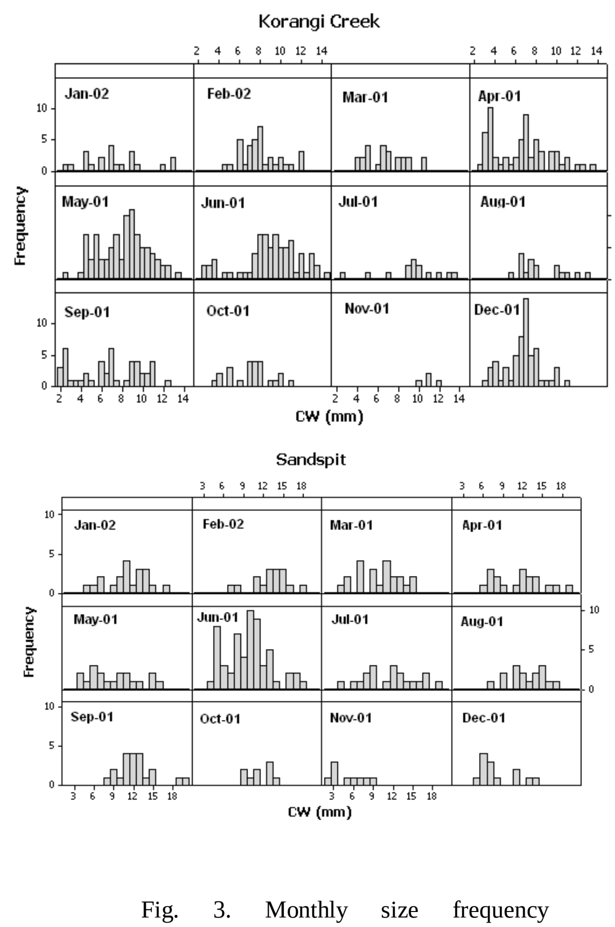

Fig. 3. Monthly size frequency distribution of *Macrophthalmus (Venitus) dentipes* (data of male and female pooled) at Sandspit (A) and (B) Korangi creek mangrove area during Mar. 2001 to Feb. 2002.

Table II.- **Variation in percent porosity, percent moisture, percent organic matter content, number of males, carapace width (CW) of males, number of females and carapace width (CW) of females *Macrophthalmus (Venitus) dentipes* (Mean±SD) at three levels (transects have been pooled) at Korangi creek and Sandspit backwater mangrove area.**

Site	Level	Percent porosity	Percent moisture	Percent organic matter content	No. of males	CW of males	No. of females	CW of females
Korangi Creek								
	Low tidal level (L1)	64.3±13.0	24.4±3.83	3.59±1.03	135	7.13±2.37	144	6.83±2.56
	Mid tidal level (L2)	48.9±9.63	20.1±7.04	2.98±0.98	69	8.31±2.83	68	8.15±2.83
	High tidal level (L3)	48.0±14.96	18.1± 3.81	2.82± 1.35	9	8.31±3.24	4	8.69±2.75
Sandspit								
	Low tidal level (L1)	45.89±6.06	17.7±2.35	1.96±0.58	55	9.4±3.78	54	9.39±3.06
	Mid tidal level (L2)	45.1±6.4	17.4±2.48	1.72±0.42	57	11.68±4.01	49	9.01±3.12
	High tidal level (L3)	43.19±6.72	16.7±2.59	1.68±0.58	4	10.24±3.22	6	11±3.67

Table III.- **Distribution of percent ovigerous female at Korangi creek and Sandspit back water mangrove area during Mar. 2001 to Feb. 2002. (Nf represents the not found).**

Months	Korangi creek			Sandspit		
	Non ovigerous	Ovigerous	% Percent	Non ovigerous	Ovigerous	% Percent
March	72	12	14.2	112	64	36.3
April	32	4	11.1	80	80	50
May	48	4	7.6	96	16	14.2
June	72	0	0	448	0	0
July	40	0	0	224	0	0
August	36	0	0	208	0	0
September	16	0	0	160	0	0
October	40	36	47.3	16	36	69.2
November	20	48	70.5	64	48	42.8
December	92	72	43.9	64	80	55.5
January	40	24	37.5	112	160	58.8
February	36	20	35.7	96	48	33.3

DISCUSSION

Physical properties

Sentinel crabs are specialized as detritivores, and are surface deposit feeders (Litulo, 2005; Otania *et al.*, 2010) and therefore, the physical (hydrographic and sediment) properties can be expected to be an important factor governing their abundance and distribution. Sediment percent grain size showed 75 to 90 % sediment was coarse to fine sand at Sandspit, but medium to very fine sand at Korangi creek. Percent moisture content and porosity were high at Korangi creek compared to Sandspit. Porosity denotes the amount of pore space in sediment whereas permeability is the water flow through it. Size, mix, and compaction of sediment particles also influence the permeability or percolation rate (Pethick, 1984) especially those with a mixture of particles, i.e. low porosity and permeability in fine grained sediment and vice versa for sands. Percent organic content were the lowest during southwest monsoon at Korangi creek and of Sandspit and showed the highest values at Korangi creek during northeast monsoon season. High organic content are due to organic detritus (litter fall, etc.) settling and being formed, by growth of heterotrophic and autotrophic micro-organisms and thus high microbial population and high sediment stability and cohesion with high carbon to nitrogen ratio (Russell-Hunter, 1970). Particle size also determines the distribution and zonation of crabs by influencing the organic matter content of the substrate, as the fine grained sediments generally have high organic matter content.

The presence of more or high number of small crabs may likely be due to greater organic matter contents, soil moisture content and early settlement of juvenile crabs at low tidal level. These conditions are more suitable to smaller crabs as they suffer more quickly from desiccation than do the large crabs as well as smaller crabs likely need more food for their growth as compare to adult crabs. The zonal frequency distribution and size specific variations observed as densities of crabs showed significant difference from low tide level to high tide level. More juveniles and small sized crabs found at the lower intertidal region throughout the year at Korangi creek as the texture of the substratum was fine sand and the percent organic content was also high at lower intertidal level compared to Sandspit. Environmental parameters such as salinity, temperature, exposure and tidal heights change spatially and temporally, and often play distinct roles in determining the distribution and abundance of intertidal organisms (Teal, 1958).

Density and distribution

Spatial differences in density and distribution of *M. (V.) dentipes* were observed between the studied sites. Zonal distribution pattern i.e., significant difference in densities from low tide level to high tide level were also observed. Size specific variation with more juveniles and small sized crabs at the lower intertidal level, which indicates zonal distribution within intertidal region, was observed at both sites, but was more evident at Korangi creek throughout the year (Fig. 3). Similar zonal frequency distributions with size specific variation were previously observed in *Ilyoplax frater* from Korangi creek (Saher and Qureshi, 2009).

Our study agrees with Henmi (1992a), who studied mechanism of size-dependent distribution of *Macrophthalmus japonicus* and found large sized crabs in the upper sandy areas where food was low, and high density of crabs in the lower muddy area with more food. Many crabs are strongly dependent on mangrove propagules and leaf litter for food and sediment texture for building burrows (Dahdouh-Guebas *et al.,* 1998; Fratini *et al.*, 2000). Hartnoll (1975) observed clear habitat stratification and vertical zonation of crab species in the mangrove ecosystem. Many marine benthic organisms exhibit substrate preference for their settlement and have a differential zonal distribution during their growth and development (Grassle *et al.,* 1992a,b; Sundberg and Kennedy, 1993). Paula *et al.* (2003) suggested that the distribution of settlers and moulting competency indicates that settling follows the adult distribution. However, the zonal distribution of crab species in mangrove habitats is still far from understood. The occurrence of smaller individuals in low tidal zone is not uncommon in brachyurans (Hartnoll, 1973; Frith and Brunenmeister, 1980) and their presence suggests that the majority of the settlement occurred on low tidal regions.

The size frequency distribution changes throughout the year have been related to reproduction, recruitment and mortality (Thurman, 1985). Temporal or seasonal differences in density and distribution were also observed at Korangi creek and Sandspit. It appears that continuous settlement of *Macrophthalmus dentipes* megalopae takes place in the study area that is in balance with natural growth and mortality. Monthly size frequency distribution for both sexes showed recruitment of juvenile male and female crabs (< 5 mm) was nearly continuous throughout year except in August and nearly all size classes were found in May, June and September. Similar to our observations, Litulo (2005) recorded juvenile of *Macrophthalmus boscii* year round (monthly bimodal distribution) at Inhaca Island, Mozambique. He suggested that such a feature reflects species that produce several clutches per individuals. No small size of the juvenile crab (CW 1 to 2.5 mm) megalopa/initial crab stage was found in the collection; however, it can be assumed that settlement probably occur at around the same size (Wada 1981, 1983a; Snowden *et al.,* 1991).

Sex ratio and breeding season

The ratio of male and female crabs deviated from 1:1 in nearly all the months and more females were found this agreed with other studies of brachyurans crabs (Siddiqui and Ahmed, 1992; Takween and Qureshi, 2005) and ocypodids, *Macrorhthalmus hitripes* (Simons and Jones, 1981), *Macrophthalmus grandidieri* (Emmerson, 1994) and *Macrophthalmus boscii* (Litulo, 2005). This difference in sex ratio has been related to the differential life span, migration pattern, temporal utilization of habitat, or may be intrinsic due to differential production of gametes resulting in greater production of females (Litulo, 2005). Female bias is generally thought to result from common behaviour of reproductively active females (Colby and Fonseca, 1984; Conde and Diaz, 1989; Emmerson, 1994; Litulo, 2005).

Reproductive intensity in brachyurans has been studied by the relative frequency of ovigerous females in monthly samples of populations obtained throughout the year (Pillay and Nair, 1971; Pinheiro and Fransozo, 2002; Litulo, 2005; Takween and Qureshi, 2005). In this study, presence of ovigerous females indicates that the breeding period ranges from October to May, which can be classified as seasonal reproduction following Sastry (1983) and Pinheiro and Fransozo (2002). Year–round-breeding with peaks in January and September were reported for *Macrophthalmus bosci* and it was suggested that breeding activity was controlled by temperature (Litulo, 2005). Studies have shown continuous reproduction in the low intertidal area of the ovigerous females of *Macrophthalmus grandidieri,* a shallow-water tropical species, which was collected throughout the year (Emmerson, 1994). Emmerson (1994) suggested this to be the effect of intertidal zonation on breeding periodicity with continuous breeding in the low shore area to seasonal breeding in middle and high shore. *Macrorhthalmus hirpites* also lives in low intertidal areas in New Zealand and carries eggs for nine months and shows seasonal reproduction (Simons and Jones, 1981). Thorson (1950), Sastry (1983) and Emmerson (1994) suggested that temperature; latitude, larval food availability and intertidal zonation are the major controlling factor for breeding periodicity.

Absence of ovigerous females during the summer southwest monsoon (June to September) could be related to unfavourable environmental conditions during southwest monsoon. Barkati and Burney (1995) recorded low diversity and biomass of macrofauna during southwest monsoon season in their study of the rocky beach at Buleji near Karachi coast. Seasonal changes due to the reversal of monsoon in the Arabian Sea are well known phenomena that influence various oceanographic conditions. The southwest monsoon occurs between June and September and is very intense with strong winds (20-25 knots) blowing along the Somalia and Arabian coasts, which modifies near surface water masses, mixed layers and influences the sea surface temperatures (Harrison *et al*., 1994). The high energy coastal areas, due to high tidal amplitude during spring and neap tides during southwest monsoon (Qari *et al.*, 2005) may influence breeding patterns.

CONCLUSIONS

The present study demonstrates the importance of substratum characteristics in controlling the distribution and abundance of the sentinal crab and this has interesting implications on the interspecific dynamics of *Macrophthalmus* (*Venitus*) *dentipes* at both sites. Observations suggest that the distribution appears to be controlled by the physical factors, physiological adaptations and or competition with each other for space and food. For these burrowing crabs, substrates are associated with several important activities including burrow construction, feeding and courtship. The most important components that are playing distinct roles in determining the distribution and abundance of these organisms are substratum, food, salinity, exposure or tides and predation.

ACKNOWLEDGEMENT

This work was funded by the Pakistan Science Foundation project PSF/Res/S-KU/Envr(51) grant to NAQ and is gratefully acknowledged.

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(Received 12 July 2011, revised 17 December 2011