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Zonal distribution and population biology of *Ilyoplax frater* (Brachyura: Ocypodoidea: Dotillidae) in a coastal mudflat of Pakistan

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Abstract Zonal distribution and population biology of *Ilyoplax frater* were studied in a mangrove mudflat area of Pakistan. The crabs were collected from Korangi creek through transect and quadrat method from low tide level to high tide level. Two transects were delimited in a mangrove area of Korangi creek (24^{o}79'N/ 67^{o}20'E). On each transect, three 0.25 m quadrats were sampled at three tidal levels on a monthly basis during low tide periods from March 2001 to February 2002. A total of 1124 crabs were obtained, of which 482 were males and 642 were females. Density of crabs varied between 0 and 90 /m^2. The density and size distribution varied and showed significant differences from low to high tide level, and were positively correlated with the percent moisture, percent organic matter and sediment grain size. The carapace width (CW) ranged from 2.5 to 11.5 mm for male and 2.5 to 11.0 mm for female and was not significantly different. The overall sex ratio did not differ significantly from the expected 1:1 throughout the year in small crabs but was significantly different in adult crabs (χ^2 = 49.73) with more male crabs. Size frequency distribution showed recruitment of juvenile crabs (< 4 mm) nearly throughout the year except during June and July. Presence of ovigerous females in all months with seasonal peaks in September, October, December and May indicates seasonal continuous breeding. Weight of egg mass increases with weight of ovigerous females and show positive linear relationship. The estimated mean diameter of egg was 2.83$\pm$ 0.25 μm, and the average number of eggs was 3065$\pm$ 902 [*Current Zoology* 56(2): 244–251, 2010].

Key words *Ilyoplax frater*, Population biology, Zonal distribution, Sex ratio, Fecundity, Korangi creek, Pakistan

Ilyoplax crabs are members of family Dotillidae. These small deposit feeder crabs are typical inhabitants of subtidal and intertidal mud flats of mangrove forests (Kosuge et al., 1994; Kitaura and Wada, 2006). Deposit feeder crabs are considered as the link between the primary detritus and consumers at higher trophic level (Macintosh, 1984; Ashton et al., 2003). Like other ocypodid and dotillid crabs, species of *Ilyoplax* crabs also construct and reconstruct their burrows. They emerge out from their burrows to move around the exposed mud flats to feed, and reconstruct their burrow by moving out mud during low tide and returning to their burrows when tide ascends (Lim, 1997). The biotic (feeding and burrowing) activities of crab play a key role in nutrient cycling and energy flow in ecosystem and contribute to the environmental management of tidal mud flats (Lim et al., 1994). These crabs have a close relationship with the sediment, being associated with sandy-mud substrata (Henmi and Kaneto, 1989; Lim, 1997). Particle size, percent organic matter and salinity are also considered as the variables affecting the zonal distribution of ocypodid crabs (Teal, 1958; Ono, 1962).

The genus *Ilyoplax* Stimpson, 1858 includes 25 species that occur from temperate to tropical Indo Western pacific region (Kitaura and Wada, 2006), however, recently Ng et al. (2008) reported 26 species. *Ilyoplax frater* has long been reported as *Ilyoplax stevensi* from Pakistan (Kemp, 1919; Tweedie, 1937). However, Tirmizi and Ghani (1996) have reported two species of genus *Ilyoplax* from the coastal areas of Pakistan, *Ilyoplax frater* and *Ilyoplax* sp. Their report of *I. frater* is based on observing considerable variations of the species from *I. stevensi* and its similarity to the description of *I. frater*.

The behavior and ecology of tropical *Ilyoplax* species are known from taxonomic reviews of the genus (Kemp,

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1919; Tweedie, 1954). *Ilyoplax pusillus* is extensively studied with respect to its distribution and habitat preference and reproductive activity (Ono, 1962; 1965; Wada, 1983a, b, c; Wada et al., 1992), Snowden et al. (1991) studied the population biology of *Ilyoplax stevensi* from the mud flats of Kuwait.

This is the first attempt to study the zonal distribution, population structure, and biology of *Ilyoplax frater* from the coastal mudflat of Pakistan: in addition, the relationship of *Ilyoplax frater* with the habitat and the role of physical parameters in density distribution and abundance of these crabs have been studied.

1 Material and Methods

1.1 Study site

The Pakistan coastline extends 1050 kilometers, and Indus delta is the most prominent coastal feature that presently occupies 73,001 ha area and is dominated by mangrove vegetation (Ashraf et al., 2004). The Pakistan mangrove ecosystem is unique because of its arid climate (<180 mm rainfall) and large tidal excursions (Harrison et al., 1997). Monsoons play critical role in determining the various physical and chemical features of the area, as the Arabian Sea is characterized by the seasonal reversal of atmospheric and oceanic surface circulation; based on which, four major seasons have been recognized in this region namely south west (SW) summer monsoon, fall intermonsoon or post monsoon, north east (NE) winter monsoon and spring intermonsoon or pre monsoon (Schott et al., 1990).

Regular monthly samples of *Ilyoplax frater* crabs were collected from Korangi creek from March 2001 to February 2002. Korangi creek (24°79′N, 67°20′E) is the north most creek of Indus Delta located in east, near the fishing village of Ibrahim Hyedri (Fig. 1). It is connected at its northeastern end with Phitti and Kadiro Creek, and its southwestern end with Gizri Creek and open sea, bounded on its sides by extensive mangrove vegetation of *Avicennia marina* (locally known as timer). The coastal mangrove system is nutritionally rich and provides an ideal habitat for a variety of marine fauna including number of crab species.

1.2 Sampling methodology

Two transects were made in intertidal mudflat of mangrove area from the low tide mark to the high tide mark. On each transect, a 0.5 m square frame (0.25 m^2) was placed (10 metres apart) at three tidal levels (low tide L1, mid tide L2, and high tide L3). The square was excavated upto the depth of 30 cm (as most of the crabs do not construct burrow deeper than 30 cm) sieved (1 mm mesh). The crabs present in the sample were bagged in labeled polythene bags and kept in ice box that was brought to the laboratory and crabs were preserved in 70% ethanol for further analyses. In laboratory, crabs were identified, sexed, and checked for the presence of eggs on female pleopods and the proportion of ovigerous females in the samples were recorded. The size (carapace width) of the male, non ovigerous female and ovigerous females was measured using vernier caliper (± 0.01 mm accuracy). The wet weights of ovigerous females with and without egg mass (removed from pleopods) were measured, and the weight of an egg mass was calculated from the difference of the two values. Fecundity was estimated by carefully removing all eggs from the pleopods of ovigerous crabs (n = 25) that were kept in 20 ml of seawater: for counting eggs were stirred and three replicates samples of 2 ml were counted. The size range of eggs (n = 10) from each crab were measured by the ocular micrometer under the microscope.

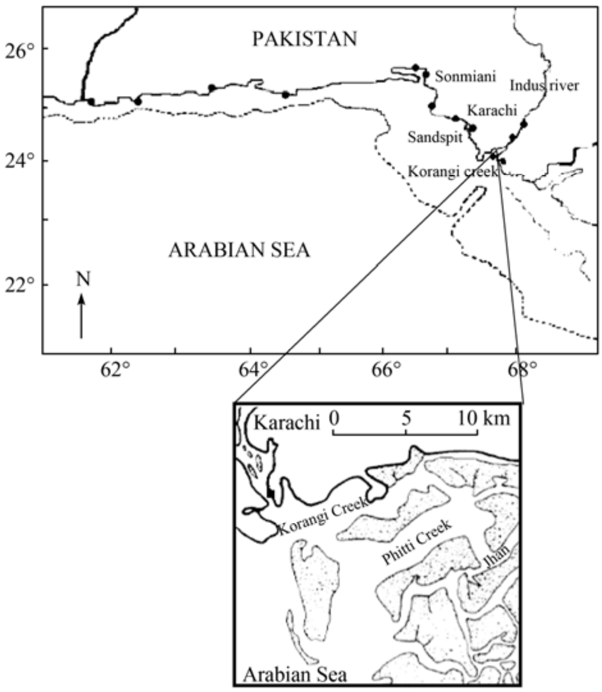

Fig. 1 Coast line map of Pakistan showing the study site (in set is Korangi creek map modified from Harrison et al. 1997)

To identify the relationship of *Ilyoplax* crabs with the habitat, sediment samples were collected by PVC cores (inner diameter 5.6 cm, up to 20 cm deep) from each tidal level. In the laboratory the sediment properties (percent porosity and 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).

1.3 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. Monthly data were grouped into seasons following Rao and Rama-Sharma (1990), wherein December, January and February are defined as north east monsoon (NE), March, April and May are defined as pre-monsoon period. June, July and August are defined as south west monsoon period, September, October and November as post-monsoon period, to observe the seasonal variability. Size at first maturity (SFM) was taken as 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 and environmental parameters.

2 Results

2.1 Physical parameters

Seasonal fluctuations were observed in all physical parameters, temperature was the highest in south west monsoon (summer) and the lowest in north east monsoon (winter) where as, the salinity and pH were the highest in pre-monsoon (Table 1). The percent organic matter contents were high in north east monsoon season and grain size analyses revealed fine sand at Korangi creek mangrove area (Table 1). The percent organic matter contents were high (3.56 ±1.03) at the low tide level (L1) than the mid (L2) and high tide level (L3) (Table 2).

2.2 Density and distribution

Total of 1124 were collected, of which 482 were males and 642 were females (ovigerous and non ovigerous). Mean density was estimated in the range of 0 to 90 m^2. Frequency distribution showed bimodal distribution of *I. frater* with the peaks in December and May (Fig. 2). The highest density of crabs was collected in north east monsoon season and the lowest in the post-monsoon season (Table 1). The density distribution showed significant difference among seasons ($F_{3,\ 72}$ = 4.72, P< 0.005) and levels ($F_{2,72}$ = 42.50, P< 0.005). The number of crabs was significantly high at low tide level and crabs were smaller in size (mean CW 6.78 ± 1.75 and 6.76 ±_1.71 mm for male and female crabs, respectively) as compared to high tide level (mean CW

Table 1 Seasonal variation (mean±*SD*) of temperature, salinity, pH, percent organic matter content, percent porosity, mean grain size phi (ϕ) and density of *Ilyoplax frater* /m^2 collected from Korangi creek mangrove areas during Mar. 2001 to Feb. 2002

Seasons	Temperature °C	Salinity ppt	pH	Percent organic matter content	Percent porosity	Grain size mean phi	*I. frater*/m^2
Pre Monsoon	28±4.16	40.7±5.1	8.07±0.7	3.4±1.5	51.2±10.5	2.31±0.2	30.2±20.2
SW Monsoon	29±3.67	39.4±2.8	7.8±0.5	2.1±0.7	53.7±9.7	2.17±0.2	28.0±21.7
Post Monsoon	28±1.691	39.1±1.5	7.5±0.8	2.9±0.8	63.3±21.1	2.19±0.1	21.78±22.9
NE Monsoon	26±3.94	39.4±2.9	7.6±0.1	3.6±0.5	46.8±10.05	1.99±0.1	35.6±31.2

Table 2 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 *Ilyoplax frater* (Mean±*SD*) at three levels (transects have been pooled) in Korangi creek

Level	Percent porosity	Percent moisture	Percent organic matter content	No. of males	CW of males	No. of females	CW of females
Low tidal level (L1)	64.3 ± 13.0	24.4 ± 3.83	3.59±1.03	260	6.78±1.75	384	6.76±1.71
Mid tidal level (L2)	48.9±9.63	20.1 ± 7.04	2.98±0.98	196	7.69±1.64	218	7.45±1.98
High tidal level (L3)	48.0±14.96	18.1± 3.81	2.82± 1.35	26	9.57±1.17	40	8.52±1.29

9.57±1.17 and 8.52±1.29 mm for male and non ovigerous female crabs, respectively) (Fig. 2, Table 2). The size (CW) of the male and non ovigerous female crabs ranged from 2.5 to 11.5 mm (7.57±1.66) and 2.5 to 11.0 mm (8.01±1.52), respectively (Table 2), and was not significantly different (t = 0.96, P = 0.34).

Pearson correlation coefficient for sediment characters with density of *Ilyoplax* crabs was estimated, and results showed positive correlation with percent porosity (P <0.005, r = 0.469) and percent moisture (P < 0.005, r = 0.432) mean grain size (P <0.01, r = 0.39) and with the percent organic matter content (P<0.01, r = 0.361).

Monthly average size frequency distributions of *Ilyoplax frater* based on CW (pooled for male and female as there was no significant difference between sexes) showed the large sized crabs were collected during the months of June to August. Monthly size-frequency distribution showed recruitment of juvenile crabs (< 4 mm) nearly throughout the year with exception in October and November, whereas in December and January the small sized crabs were abundant suggesting peak recruitment in winter (Fig.3). The high density of small size crabs was more evident at low tide level (L1) as compare to high tidal level (L3) as shown in Table 2.

2.3 Sex ratio and Breeding period

The male and female crabs of *I. frater* showed that the ratio of male and female crabs did not deviate from 1:1 throughout the year in the small size crabs (< 4 mm) as the (χ^2 = 12.434, df = 11, P = 0.332) but was significantly different (χ^2 = 49.73, df = 11, P < 0.01) with more males in adult crabs (> 4 mm). Size at first sexual maturity (SFM) was at CW = 4 mm based on the smallest ovigerous female collected. The density distribution of ovigerous females of *Ilyoplax frater* indicated

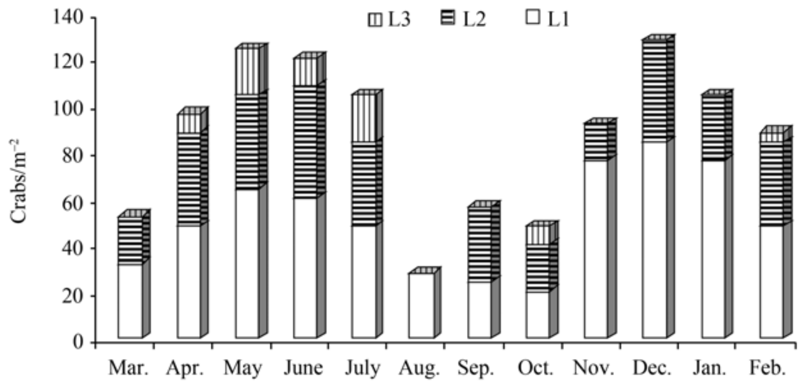

Fig. 2 Monthly zonal density distribution of *Ilyoplax frater* m^2 at Korangi creek mangrove area during Mar. 2001 to Feb. 2002 (where L1 is low tidal level, L2 is mid tidal level and L3 is high tidal level.)

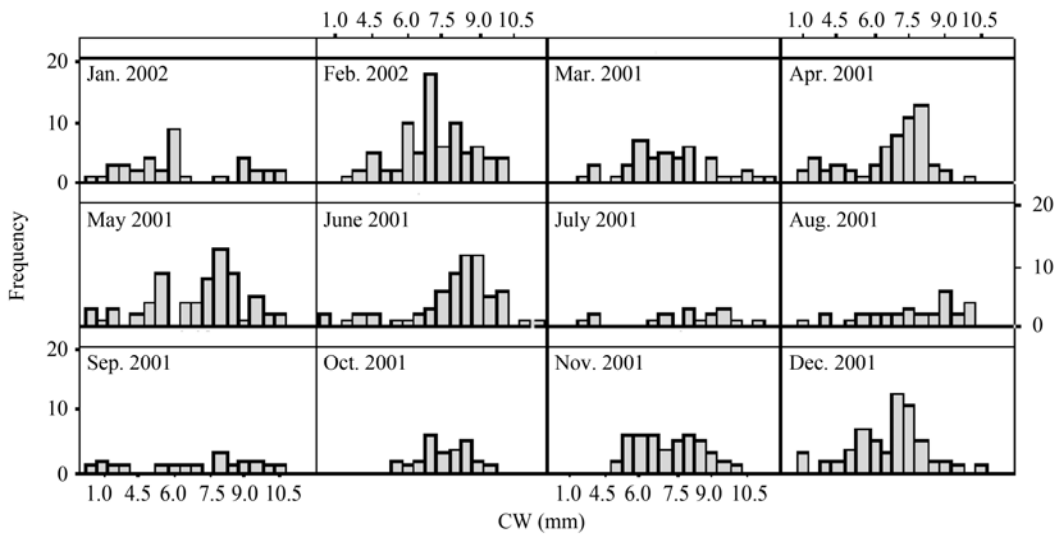

Fig. 3 Monthly size frequency distribution of *Ilyoplax frater* (data of male and female pooled) at Korangi creek mangrove area during Mar. 2001 to Feb. 2002

continuous breeding with seasonal peaks (44 to 95%) found from September to Feburary and in May (Fig. 4). The size of the ovigerous female were significantly different among the season ($F_{3,142}$ = 5.12, P<0.005). The large size ovigerous females were collected during the south west monsoon season (Fig. 5). The mean CW of ovigerous female was 7.38±1.55 mm ranging from 4.0 to 11.0 mm (Table 3).

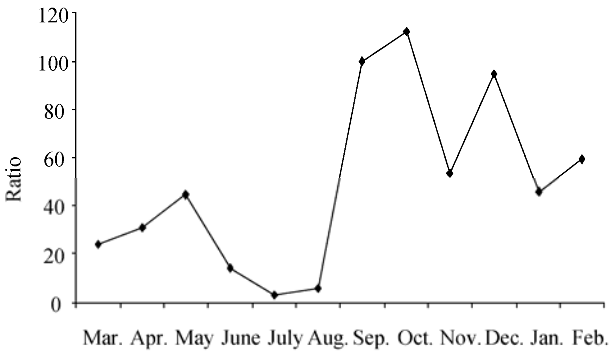

Fig. 4 Monthly ratio of ovigerous females and non ovigerous females of *Ilyoplax frater* at Korangi creek mangrove area during Mar. 2001 to Feb. 2002

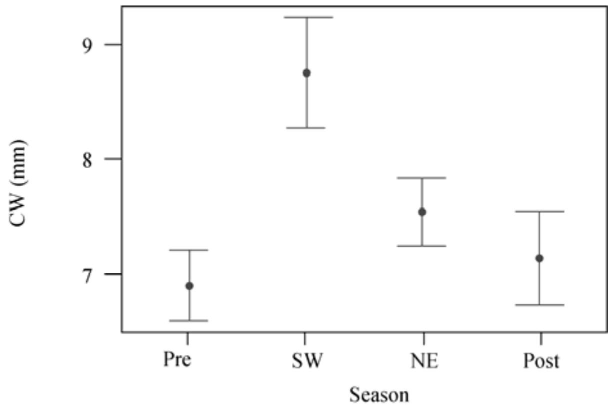

Fig. 5 The seasonal size (CW carapace width) distribution of ovigerous females collected during the study period

2.4 Fecundity

The estimated average number of eggs were 3065±902 (n = 25), the mean weight of egg mass was 0.016±0.003 g, and mean diameter of egg was 2.83± 0.25 m (n = 250) (Table 3). A positive linear relationship with good correspondence was observed (Fig. 6) between the wet weight of the female crabs and the egg mass (r = 0.316, P<0.05, Pearson correlation).

Table 3 Summary statistics of crab weight, weight of egg mass, carapace length, carapace width, abdominal width, egg number and egg size in ovigerous females of *Ilyoplax frater* collected from Korangi creek

Variables	*n*	Mean ± *SD*	Min.	Max.
Crab weight (g)	25	0.133 ± 0.057	0.050	0.271
Weight of egg mass (g)	25	0.016 ± 0.003	0.01	0.021
Carapace length (mm)	66	5.28 ±1.08	3.5	7.5
Carapace width (mm)	66	7.38 ±1.55	4.0	11.0
Abdominal width (mm)	25	7.22 ±̲0.99	5.5	9.0
Egg number	25	3065 ± 902	1640	4387
Egg size (μm)	250	2.80 ± 0.26	2.34	3.51

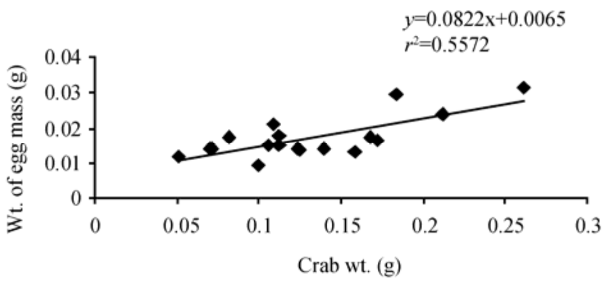

Fig. 6 Relationship between the wet weight of crab and the wet weight of egg mass in *Ilyoplax frater*

3 Discussion

Significant spatial and seasonal differences were observed in density distribution of *I. frater*. The bimodal distribution of *Ilyoplax frater* was observed with the peak abundance in December and May. Densities were low during August to October. Significant seasonal size variation in ovigerous female were also observed during the study, and comparatively more large sized ovigerous females were found in the sample during the SW monsoon period. Monthly size frequency distribution of *Ilyoplax frater* at Korangi creek showed recruitment of juvenile crabs (< 4 mm) was nearly throughout the year except in October and November and nearly all size classes were found in April to June. Snowden et al. (1991) also observed significantly higher population density and biomass of *I. stevensi* during December to March at Kuwait. The size-frequency distribution of a population is a dynamic characteristic that varies throughout the year as a result of reproduction and rapid recruitment from larvae (Thurman, 1985). No small size of the juvenile crab (CW 1 to 2.5 mm) megalopa/initial crab stage of *Ilyoplax frater* 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). The occurrence of smaller individual downshore is not uncommon in brachyurans, and amongst ocypodids (Hartnoll, 1975; Frith and Brunenmeister, 1980). The presence of small sized crabs at low tide level suggests that the majority of the settlement occurred down shore area.

The zonal frequency distribution and size specific variations were observed as densities of crabs showed significant difference from low tide level to high tide level. More juveniles and small sized crabs were found at the lower intertidal region throughout the year. The texture of substratum was fine sand and the percent organic content was also high at lower intertidal level. Environmental parameters such as salinity, temperature, exposure and tidal heights change spatially and temporally, and often play distinct role in determining the distribution and abundance of intertidal organisms (Teal, 1958). In temperate region, seasonality is a well-known phenomenon for invertebrates where the main ecological activities are in spring and summer due to elevated temperature (Levinton, 1982). Whereas the evidences indicates that seasonality in tropical waters is due to salinity differences between dry and rainy seasons, which plays as the major controlling factor (Livingston et al., 1975; Conde and Diaz, 1989). 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 needing food for their growth. Hartnoll (1975) also observed clear habitat stratification and vertical zonation of crab species in the mangrove ecosystem. Fishelson (1983) recorded small size *Dotilla sulcata* at lower edge of the adult zone at mean high tide level in Red Sea, and similarly, Jones and Clayton (1983) found this for *Cliestostoma kuwaitense* in Kuwait. Emmerson (1994) reported effects of temperature, latitude, larval food availability and intertidal zonation in the lower shore area. Henmi (1992) studied size-dependent distribution of *Macrophthalmus japonicus* and also found large sized crabs in the upper areas where food was low, and high density of small crabs in the lower muddy area where food was more abundant. In *I. frater*, size specific intertidal zonal distribution was observed related to habitat stratification, food availability, moisture, and sediment structure.

The male and non ovigerous female crabs of *I. frater* showed that the ratio of male and female crabs did not deviate from 1:1 throughout the year in the small size crabs (< 4 mm), but was significantly different with more males in adult crabs (> 4 mm). Many authors have reported the deviations from 1:1 sex ratio in brachyuran crabs and differential growth, mortality, nutrition, utilization of different habitat by each sex, activity and out migration of one sex have frequently been suggested as a causative factor (Wenner, 1972; Conde and Diaz, 1989). Snowden et al. (1991) proposed that the preponderance of adult males might be due to differential growth especially related to morphological changes associated with sexual maturity that requires a greater commitment of body resources in males therefore spend more time in adult size class. The males were larger than females, suggesting sexual dimorphism although the difference was not significant. Snowden et al. (1991) found difference in size ranges of the male and female crabs (2.5 mm to 10 mm and 2.5 to 9.5 mm, respectively). The sex ratio in *I. frater* varied significantly for larger males with more adult crabs due to deferential behaviour of each sex, likely more active males than females staying longer in burrow that affect their catchability.

In *I. frater* ovigerous females were present throughout the year with the highest percentage of ovigerous females observed during September to December, in February and in May. Snowden et al. (1991) reported reproduction to occur throughout the year with strong seasonality and presence of high percentage of ovigerous females from the months of September to March in *Ilyoplax stevensi* in Kuwait. This pattern of reproduction has been termed as seasonal continuous (Pinheiro and Fransozo, 2002). In *M. grandidieri,* continuous reproduction was observed in the low intertidal area and seasonal reproduction in the middle and high shore areas (Emmerson, 1994) and related this to temperature; latitude, larval food availability and intertidal zonation (Sastry, 1983; Emmerson, 1994). Tropical invertebrate species have been considered to breed continuously throughout the year (Pillay and Nair, 1971), however, studies reveal tropical groups like sponges, corals, polychaetes, mollusks show seasonal periodicities in the reproductive cycles (Perez, 1990 and references cited there in). Many tropical crustaceans species have also been reported to breed continuously with seasonal periodicities, examples are: *Panulirus argus* (Kanciruk and Herrnkind, 1976), *Cryptodorrnia hilgendorfi* (McLay, 1982), *Scylla serrata* (Hill, 1975) and *Portunus pelagicus* (Potter et al., 1983, Takween and Qureshi, 2005) *Matuta lunaris* (Pillay and Nair, 1976), *P. sanguinolentus* (Takween and Qureshi, 2005). *I. frater* therefore appears to be a tropical brachyuran species that demonstrates a seasonal continuous reproductive pattern.

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