OPEN ACCESS
International Journal of Aquatic Science
ISSN: 2008-8019
Vol. 6, No. 1, 15-36, 2015

Population and reproductive biology of two species of brachyuran crabs (Family: Grapsidae) *Sesarma (Chiromantes) bidens* and *Metopograpsus maculatus* at coastal belt of Midnapore, West Bengal, India

Subhasish Chatterjee and Susanta Kumar Chakraborty*

Department of Zoology, Vidyasagar University, Midnapore-721102, West Bengal, India

Received: 03 December 2013 **Accepted:** 18 February 2014 **Published:** 03 January 2015

Abstract: This study deals with population dynamics, sex ratio and fecundity of two brachyuran crabs viz. *Sesarma (Chiromantes) bidens* and *Metopograpsus maculatus* belonging to order decapoda and family grapsidae. The present study was conducted during March, 2008 to February, 2010 at two contrasting eco-zones viz. Khejuri-Boga (mixed sand and mudflats endowed with mangroves patches) and Nayachar Island (a newly developed and eco-restored deltaic island) situated on the Hooghly estuary in the intertidal belts of Midnapore coast, India. Role of pronounced ecological parameters influencing the ecology, population and habitat preferences have also been taken into consideration.

Key words: Crabs, coastal belt, ecology, mangrove

Introduction

The intertidal brachyuran crabs constitute one of the most dominant macrobenthic faunal components for mangrove ecosystem because they make huge faunal biomass, their density can reach up to 80-90 individuals per m^2 (Kathiresan and Qasim, 2005) and they play vital role in bio-geo-chemical cycling (by virtue of their feeding activities which help decomposition of plant litters to detritus Wolff *et al*., 2000; Ravichandran and Kannupandi, 2007). Herbivorous crabs (Sesarmid crabs) derive benefit from the amount of primary production but assimilates only a fraction of the available energy, while the reminders fuels the microbial loop in the detritus compartment enhancing the food supply of the deposit-feeding crabs. Mangrove ecosystem being a productive one forms one of the major functional contributors of food chain in the coastal areas (Satyanarayana *et al*., 2002) and also protects coastal population and supports coastal fisheries (Chakraborty, 2011, 2013; Chakraborty *et al.,* 2012). Consumption of leaf litter by some sesarmids has a distinct effect on litter

(✉) susantachakraborty@yahoo.com

dynamics in mangrove systems (Alongi, 2009). The influence of *Sesarmid* crabs on mangrove forest nutrient dynamics is twofold (Robertson, 1986). In order to avoid interspecies and intraspecies competitions, the grapsidae crabs displayed distinct distributional pattern reflecting their adaptation to different degrees of terrestriality in respect of inundation and exposure, sediments, salinity, temperature etc. In fine sands to mud, biotic structuring of the habitat by burrowing, tube building, defecation and secretion often is significant (Mermillod-Blondin, 2011). This biogenic process collectively termed as "Bioturbation", is of special importance in the cycling of nutrients (Swift, 1993) and now recognized as an archetypal example of "ecosystem engineering" (Meysman *et al.*, 2006). Brachyuran crabs represent a good bioturbatory agent because of their different behavioural manifestations (Chatterjee *et al.*, 2008).

Reproduction is the main mechanism that keeps species continuity so that it contributes to regulate the population size. Adaptations on mating systems jointly with environmental conditions are also factors that influence fiddler crab fecundity (Costa *et al.*, 2006). In grapsidae crabs, breeding may take place year round or be restricted to a few months. It is assumed that in subtropical and tropical environments breeding is a continuous process because environmental conditions are favourable for gonad development, feeding and larval release. Crabs often show marked sexual dimorphism. Ovigerous females of two species of grapsidae crabs were used to achieve and compare their reproductive pattern. The presence of ovigerous and non ovigerous female provided one index of reproductive periodicity. Fecundity in brachyuran crabs is commonly defined as the number of eggs produced per female per clutch (Reid and Corey, 1991). Seasonal dynamics of reproductive parameters in respect of sex ratios (M:F), size classes (carapace width-CW) and fecundity of two species, were investigated at study site Khejuri-Boga and Nayachar Island through different months and seasons of a year.

The present study has attempted to deal with the habitat preference, population dynamics (density, biomass), sex ratios and fecundities of two grapsidae crabs, *Sesarma (Chiromantes) bidens* and *Metopograpsus maculatus* in relation to interactions between biotic and nonbiotic parameters.

Materials and methods

Physiography of the study sites and zonation

The coastal tract of Midnapore (East) West Bengal, India extends from the junction of longitudinal extension 87° 20′ E to 88° 5′ E and latitudinal extension 21° 30′ N to 22° 2′ N (Paul, 2002; Chakraborty *et al.*, 2012). The present study has selected two sites viz. Khejuri-Boga and Nayachar Island having contrasting ecological features (Fig. 1). The intertidal zone

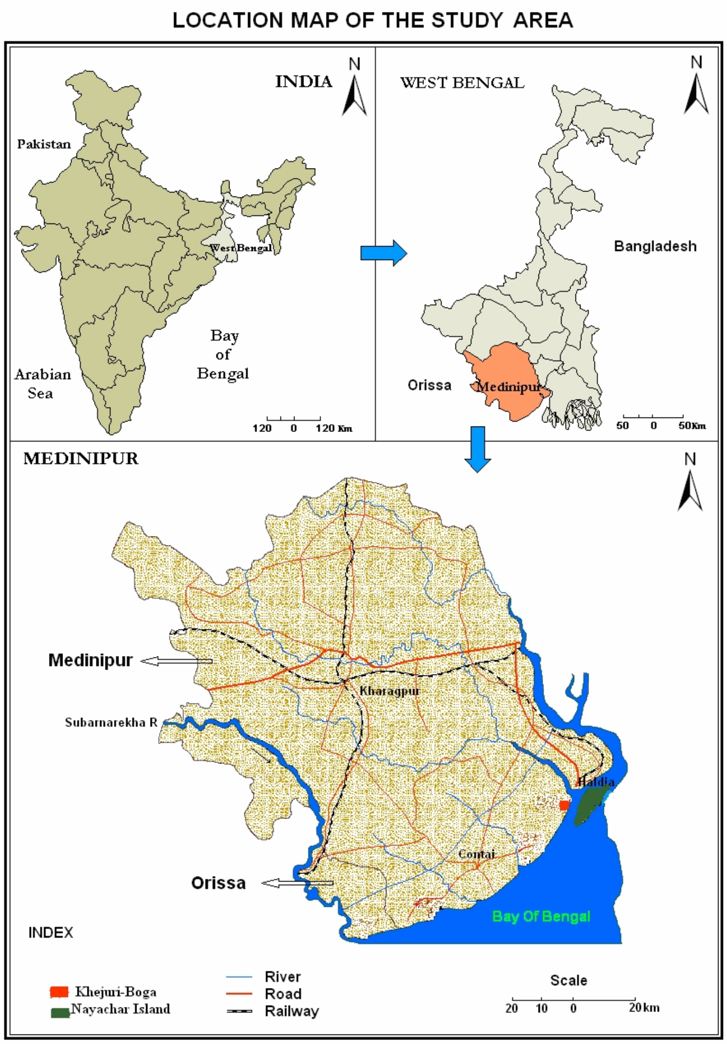


Fig. 1: Map showing the study sites Khejuri-Boga and Nayachar Island.

where the crabs displayed distinct zonation was made in 3 different subzones: low tidal level (LTL), mid tidal level (MTL) and high tidal level (HTL).

Duration of the study period

The present study was conducted during March, 2008 to February, 2010.The study period of different aspects were as: population dynamics (density and biomass) and seasonal dynamics of physicochemical parameters of water and soil - March, 2008 to February, 2010; sex ratio and fecundity - March, 2009 to February, 2010.

Random samplings of two species of grapsidae crabs from intertidal mudflats and sand flats of Midnapore (East) coastal belt and their simultaneous identification have been made following standard literatures (Alocock, 1900; Chakraborty and Chaudhury, 1992). For the quantitative estimation, the exposed part of the intertidal zones of the respective study site was selected on three transects lying on different sub zones of intertidal belts i.e. LTL, MTL and HTL with the help of a quadrat having 0.5 m^2 area. To determine the crab density (NO/m^2) and biomass (kg/m^2), each burrow was considered as being inhabited by a single crab (Alves *et al.*, 2005). Five sub samples (0.5 m^2) using each quadrat on each transect were collected and average density and biomass were assessed. The presences of ovigerous females were registered, in order to understand reproduction period of different crab species. All crabs were then dug out and their carapace widths were measured with a vernier caliper and were preserved in 5 % buffered formalin solution. Observations were made during low tide period of each month for a day on full moon period with the assumption that crab faunas do not change significantly over this time scale (Ashton *et al.*, 2003).

Samples were collected monthly during low tide period on full moon during day time over a period of approximately 1 hour duration and covering an area of about 500 m^2 of the study site for the assessment of sex ratio. Fecundity (the number of eggs per female) determines the reproductive potential of a species and the stock size of its population. On each sampling occasion, a total of twenty quadrats 1.0 m^2 (1.0 × 1.0 m) squares were set out at the study site. Ten quadrats were randomly chosen for sampling and each of which was completely excavated with a corer (8 cm diameter) to a depth of 50 cm. Crabs were collected by using diving knives or shovel with a catch effort and all ovigerous females after being unearthed were preserved in 70 % ethanol, bagged and stored until further processing. The carapace width (CW) were measured using a vernier caliper (±0.05 mm accuracy) or, with the aid of a stereomicroscope (CW<10.0mm) respect-tively. Based on carapace width, each female crab was grouped in size classes with 2.5 mm. To estimate fecundity, egg bearing females were selected for egg counting. Pleopods were removed from females, placed in Petri dishes filled up with seawater, and eggs were isolated by gradually adding a solution of sodium hypochlorite (7%). Bare pleopods were then separated by gentle stirring in a beaker filled with 200 ml seawater. Three sub samples (1.5 ml) were taken using a pipette, and eggs were counted under a dissecting microscope. The average value obtained was then extrapolated for the whole suspension to estimate the total number of eggs (Litulo, 2004a).

Water and soil samples had been analyzed monthly from the study sites for estimating different ecological parameters viz. temperature (°C), pH, dissolved oxygen (mg/L), biological oxygen demand (mg/L), turbidity (NTU), conductivity (s/m), salinity (ppt), organic carbon (%), available phosphorus, available potassium and available nitrogen (water-mg/L, soil-mg/100 gm). Such analyses were recorded using a water quality checker (TOWA 22A, Japan) and by following standard methods (APHA, 2005). Humidity and Rainfall data were collected from the Alipore Meteorological Department, Government of India, Alipore, Kolkata.

Different statistical analyses were done by following standard book (Zar, 2009) and utilizing "STATISTICA" (STATSOFT, 2001) with the help of a P-4 computer. Factorial ANOVA technique was used to compare the main effects of sites, seasons and tidal levels of all studied specie's density and biomass. Main effect means were further subjected to Duncan's test at 5% level of significance to test the homogeneity among respective means for each factor. Significance of all main and interaction effects were also tested by F tests at each ANOVA. Significant main effects for factors having more than two levels were subjected to Duncan's test. This technique was also followed for each studied water and soil quality parameters. Abundance of type of sex male, non ovigerous female and ovigerous female was analyzed following Chi square test ($\chi 2$-test, $P<0.01$) to test the independence of attributes between sex and months of availability using the frequency data of abundance. Such analysis was repeated for each type of species. Program Multi Variate Statistical Package (MVSP) version 3.1 was used for the calculation of Canonical Correspondence Analysis (CCA). In the present study canonical correspondence analysis (CCA) as a unimodal biplot scaling technique was used on the symmetric distance (encompassing both inter sample and inter species distance) matrix and with square root transformation of species data and also with the condition of down weighting the rear species. Monte Carlo simulation technique was used with 499 permutations for drawing all the species wise biplots to infer the association between the set of species data and the set of environment data.

Results

Grapsidae diversity

Based on the pilot survey of study site, 4 species of grapsidae crabs belonging to 3 genera have been collected from different intertidal zones of two study sites (Tab.1 and 2) whereas two species *Sesarma (Chiromantes) bidens* and *Metopograpsus maculatus* were selected for detailed studies because of their maximum occurrence.

Tab. 1: Zonation pattern of different grapsidae crabs in three intertidal zones (LTL, MTL and HTL) of Khejuri-Boga.

Name of the brachyurans	LTL	MTL	HTL
Sesarma (*Chiromantes*) *bidens* (de Haan)	-	+++	++
Sesarma taeniolatum White	-	++	+
Metopograpsus maculatus Milne Edwards	++	+++	-
Metaplax intermedia de Man	++	+++	+

Highly abundant (+ + +); Moderately abundant (+ +); Occasional Visitor (+); Not found (-)

Tab. 2: Zonation pattern of different selected grapsidae crabs in three intertidal zones (LTL, MTL and HTL) of Nayachar Island.

Name of the brachyurans	LTL	MTL	HTL
Sesarma (*Chiromantes*) *bidens* (de Haan)	-	+++	++
Sesarma taeniolatum White	-	++	++
Metopograpsus maculatus Milne Edwards	++	+++	-
Metaplax intermedia de Man	++	+++	+

Highly abundant (+ + +); Moderately abundant (+ +); Occasional Visitor (+); Not found (-)

Floral diversity

15 species were recorded from the study site Khejuri-Boga whereas 16 species of mangroves were found to occur at Nayachar Island (Chatterjee *et al*., 2004). *Acanthus ilicifolius, Avicennia officinalis*, *A. marina, A. alba, Bruguiera gymnorhiza* and *Suaeda maritima* represented the dominant floral component at both study sites (Tab. 3).

Habitat preferences

S. (Chiromantes) bidens and *M. maculatus* displayed almost similar habitat preferences as both preferred to inhabit the bottom floor of large mangrove trees viz. *A. ilicifolius, A. officinalis , A. marina, A. alba* and *B. gymnorhiza.*

Population dynamics

S. (*Chiromantes) bidens* has been found to occur only at MTL and HTL whereas *M. maculatus* showed their habitat preference also to LTL along with MTL in both study sites. Density and biomass of male, non ovigerous female and ovigerous female of both the species in different sites, seasons and tidal zones were recorded and statistical evaluation on population biology through ANOVA analysis and Duncan's were performed, the result of which are presented in Tab. 4 to 7. The total population density and biomass of *S. (Chiromantes) bidens* were found to be higher during monsoon followed by pre-monsoon and post-monsoon at both study sites whereas *M. maculatus* displayed higher abundance during monsoon followed by pre-monsoon and post-monsoon at Khejuri-Boga (S-I) but at Nayachar Island (S-II), it tended to be equal during pre-monsoon and monsoon. The density and biomass of ovigerous females of *S. (Chiromantes) bidens* were found to be higher during monsoon followed by post-monsoon at both the study sites. Ovigerous females of *M. maculatus* has been found to occur all the seasons of the years and the population density and biomass were found to be maximum during monsoon followed by pre-monsoon and post-monsoon at LTL followed by MTL at both study sites.

Sex ratio and fecundity

Investigation on the reproduction of two species viz. *S. (Chiromantes) bidens* and *M. maculatus,* in respect of size structure (carapace width-CW), sex ratio, breeding seasons and fecundity are also presented in the Tables 8 to 10.

Tab. 3: Floral diversity of two study sites.

Floral Components	Habitat	Khejuri-Boga	Nayachar Island
	Rhizophoraceae		
Rhizophora apiculata Bl	MSZ	+++	+++
Rhizophora mucronata	MSZ	+++	+++
Brugiera gymnorrhiza (L) Lamk	MSZ	++	+++
Ceriops decandra (Griff) Ding Hou	MLZ	++	+++
	Avicenniaceae		
Avicennia alba Blume	MLZ	+++	+++
A. officinalis L.	LTZ	+++	+++
A. marina (Forsk) Vierch	LTZ	+++	+++
	Sonneratiaceae		
Sonneratia apetala Buch-Ham	LTZ	+++	+++
	Euphorbiaceae		
Excoecaria agallocha L	LTZ	+++	+++
	Acanthaceae		
Acanthus ilicifolius L	MSZ	+++	+++
	Chenopodiaceae		
Suaeda maritima Dumort	MSZ	+++	+++
	Convoluaceae		
Ipomoea pes-caprae (L) Sweet	SZ	+	-
	Chenopodiaceae		
Salicornia brachiata Roxb	SZ	+++	++
	Aizoaceae		
Sesuvium portulacastum L.	MSZ	-	+++
	Myrsinaceae		
Aegiceras corniculatum (L)	MLZ	+	+++
	Poaceae		
Myriostachya wightiana	MLZ	-	+++
Porteresia coarctata(Rox) Tak	LTZ	+	+++

- MSZ- Mid to supralittoral zones; MLZ- Mid littoral zones; LTZ- Low littoral zones; SZ- Supra litoral zones

- Highly abundant (+ + +); Moderately abundant (+ +); Occasional Visitor (+); Not found (-)

Tab. 4: Results of ANOVA analysis on density and biomass of different sexes of *Sesarma (Chiromantes) bidens* between sites, seasons and tidal levels.

Source	Variable	SS	df	MS	F	Sig.
SITES	M_DENSITY	9.19	1	9.19	45.24	0.000**
	M_BIOMASS	12.52	1	12.52	25.02	0.000**
	NOF_DENSITY	3.68	1	3.68	2.79	0.121
	NOF_BIOMASS	5.65	1	5.65	2.43	0.145
	OF_DENSITY	0.25	1	0.25	0.11	0.752
	OF_BIOMASS	0.6	1	0.6	0.14	0.713
SEASONS	M_DENSITY	3.07	2	1.53	7.54	0.008**
	M_BIOMASS	4.79	2	2.39	4.78	0.030**
	NOF_DENSITY	3.63	2	1.82	1.37	0.29
	NOF_BIOMASS	5.46	2	2.73	1.18	0.342
	OF_DENSITY	176.66	2	88.33	37.26	0.000**
	OF_BIOMASS	199.84	2	99.92	23.85	0.000**
TIDE LEVELS	M_DENSITY	3.04	1	3.04	14.94	0.002**
	M_BIOMASS	7.78	1	7.78	15.56	0.002**
	NOF_DENSITY	3.97	1	3.97	3	0.109
	NOF_BIOMASS	0.07	1	0.07	0.03	0.866
	OF_DENSITY	7.08	1	7.08	2.99	0.11
	OF_BIOMASS	46.8	1	46.8	11.17	0.006**
SITES × SEASONS	M_DENSITY	1.92	2	0.96	4.73	0.031*
	M_BIOMASS	2.65	2	1.32	2.65	0.112
	NOF_DENSITY	1.23	2	0.61	0.46	0.64
	NOF_BIOMASS	0.94	2	0.47	0.2	0.819
	OF_DENSITY	2.7	2	1.35	0.57	0.58
	OF_BIOMASS	7.9	2	3.95	0.94	0.417
SITES × TIDE LEVELS	M_DENSITY	0.41	1	0.41	2.04	0.179
	M_BIOMASS	2.47	1	2.47	4.94	0.046*
	NOF_DENSITY	4.81	1	4.81	3.64	0.081
	NOF_BIOMASS	17.07	1	17.07	7.35	0.019*
	OF_DENSITY	6.6	1	6.6	2.78	0.121
	OF_BIOMASS	39.88	1	39.88	9.52	0.009**

Tab. 4: continued

Source	Variable	SS	df	MS	F	Sig.
SEASONS × TIDAL LEVELS	M_DENSITY	7.71	2	3.85	18.97	0.000**
	M_BIOMASS	16.19	2	8.1	16.18	0.000**
	NOF_DENSITY	3.92	2	1.96	1.48	0.266
	NOF_BIOMASS	6.55	2	3.28	1.41	0.282
	OF_DENSITY	3.76	2	1.88	0.79	0.475
	OF_BIOMASS	1.79	2	0.89	0.21	0.811
SITES × SEASONS × TIDAL LEVELS	M_DENSITY	0.15	2	0.07	0.36	0.703
	M_BIOMASS	0.16	2	0.08	0.16	0.851
	NOF_DENSITY	0.13	2	0.06	0.05	0.953
	NOF_BIOMASS	0.4	2	0.2	0.09	0.918
	OF_DENSITY	6.12	2	3.06	1.29	0.311
	OF_BIOMASS	21.06	2	10.53	2.51	0.123

M = male, NOF = non-ovigerous female, OF = ovigerous female

Tab. 5: Mean density and biomass of different sexes of *Sesarma (Chiromantes) bidens* at different seasons with Duncan's test result.

SEASON	M_DENSITY	M_BIOMASS	NOF_DENSITY	NOF_BIOMASS	OF_DENSITY	OF_BIOMASS
PRM	7.15a	9.99a	4.56a	5.90a	1.01c	1.41c
MON	7.17a	9.94a	3.65a	4.80a	7.59a	8.35a
POM	6.41b	9.02b	3.89a	5.01a	5.15b	6.02b
Total	6.91	9.647	4.033	5.234	4.583	5.26

M = male, NOF = non-ovigerous female, OF = ovigerous female

Tab. 6: Results of ANOVA analysis on density and biomass of different sexes of *Metopograpsus maculatus* between sites, seasons and tidal levels

Source	Variable	SS	df	MS	F	Sig.
SITES	M_DENSITY	1.06	1	1.06	1.18	0.299
	M_BIOMASS	0.48	1	0.48	0.75	0.404
	NOF_DENSITY	0.02	1	0.02	0.01	0.93
	NOF_BIOMASS	0.82	1	0.82	0.28	0.608
	OF_DENSITY	0	1	0	0	0.973
	OF_BIOMASS	1.04	1	1.04	2.56	0.136
SEASONS	M_DENSITY	1.37	2	0.69	0.76	0.488
	M_BIOMASS	0.83	2	0.42	0.64	0.544
	NOF_DENSITY	3.02	2	1.51	0.54	0.596

Tab. 6: continued

Source	Variable	SS	df	MS	F	Sig.
SEASONS	NOF_BIOMASS	4.34	2	2.17	0.74	0.5
	OF_DENSITY	38.96	2	19.48	62.1	0.000**
	OF_BIOMASS	25.19	2	12.6	31.13	0.000**
TIDAL LEVELS	M_DENSITY	10.83	1	10.83	12.02	0.005**
	M_BIOMASS	0.28	1	0.28	0.44	0.521
	NOF_DENSITY	6.57	1	6.57	2.35	0.151
	NOF_BIOMASS	4.09	1	4.09	1.39	0.262
	OF_DENSITY	3.59	1	3.59	11.46	0.005**
	OF_BIOMASS	3.72	1	3.72	9.2	0.010**
SITES × SEASONS	M_DENSITY	0.18	2	0.09	0.1	0.908
	M_BIOMASS	0.4	2	0.2	0.31	0.738
	NOF_DENSITY	0	2	0	0	1
	NOF_BIOMASS	0.02	2	0.01	0	0.997
	OF_DENSITY	0.12	2	0.06	0.19	0.833
	OF_BIOMASS	0.07	2	0.04	0.09	0.913
SITES × TIDAL LEVELS	M_DENSITY	0.66	1	0.66	0.73	0.409
	M_BIOMASS	1.67	1	1.67	2.58	0.134
	NOF_DENSITY	0	1	0	0	0.988
	NOF_BIOMASS	0.03	1	0.03	0.01	0.919
	OF_DENSITY	0	1	0	0.01	0.93
	OF_BIOMASS	0.82	1	0.82	2.02	0.181
SEASONS × TIDAL LEVELS	M_DENSITY	1.73	2	0.87	0.96	0.41
	M_BIOMASS	1.54	2	0.77	1.19	0.339
	NOF_DENSITY	0.72	2	0.36	0.13	0.88
	NOF_BIOMASS	2.29	2	1.15	0.39	0.686
	OF_DENSITY	8.12	2	4.06	12.94	0.001**
	OF_BIOMASS	7.43	2	3.71	9.18	0.004**
SITES × SEASONS × TIDAL LEVELS	M_DENSITY	0.03	2	0.01	0.02	0.984
	M_BIOMASS	0.23	2	0.12	0.18	0.837
	NOF_DENSITY	0.03	2	0.02	0.01	0.994
	NOF_BIOMASS	0.13	2	0.07	0.02	0.978
	OF_DENSITY	0.01	2	0.01	0.02	0.979
	OF_BIOMASS	0.48	2	0.24	0.6	0.565

M = male, NOF = non-ovigerous female, OF = ovigerous female

Tab. 7: Mean density and biomass of different sexes of *Metopograpsus maculatus* at different seasons with Duncan's test result.

SEASON	M_DENSITY	M_BIOMASS	NOF_DENSITY	NOF_BIOMASS	OF_DENSITY	OF_BIOMASS
PRM	6.24a	5.32a	2.52a	2.64a	4.65a	4.29a
MON	6.03a	5.08a	3.37a	3.58a	4.88a	4.63a
POM	6.61a	5.54a	3.07a	3.49a	2.07b	2.30b
Total	6.293	5.314	2.986	3.237	3.867	3.74

M = male, NOF = non-ovigerous female, OF = ovigerous female

A total of 285 individual crabs of *S. (Chiromantes) bidens* (83 males, 96 non-ovigerous females and 106 ovigerous females) were recorded during the study period. The number of crabs encountered and the monthly sex ratio of which has been listed in Tab. 8 and Fig. 2. Females (n=202) were more bounteous than males (n=83), but overall sex ratio (1:2.43) was significantly deviated from the 1:1 ratio. Their monthly sex ratios have been found to be marginally female biased except the month of February where males and females were recorded in equal numbers in the month of January of the year. Among 106 ovigerous females of this species, 32 were used for fecundity studies (CW:15.5-30.5), which showed a mean fecundity of 17753±4133 eggs and measured a mean size of 22.81±3.93 CW. Number of eggs for each size class have been mentioned in Tab. 10.

A total of 309 individual *M. maculatus* crabs (159 males, 22 non-ovigerous females and 128 ovigerous females) were recorded during the study period. The number of crabs documented and the monthly sex ratio of which has been listed in Tab. 10 and Fig. 3. Males (n=159) were more copious than females (n=150), but overall sex ratio (1:0.94) was found to have been significantly deviated from the 1:1 ratio. Their monthly sex ratios were found to be mostly male biased, excepting April, May, July and September where as males and females were recorded in equal numbers in the month of August and January of the year. Among 128 ovigerous females of this species, 39 were used for fecundity studies (CW:12.5-27.5), which showed a mean fecundity of 12400±7495 eggs and measured a mean size of 19.53±4.32 CW. Egg numbers for each size class have been mentioned in Tab. 10.

Chi square test (χ^2-test -P<0.01) on the monthly distribution of occurrence of varying sexes in the form of male, non ovigerous female and ovigerous female expresses a significant influence of the change of month on sex ratios. Sex ratios of two studied crabs were not found to be equal but deviated from 1:1 ratio (Chi-squared test, $P < 0.01$). Month has significant

Tab. 8: Number of individuals, percentage and sex ratios of *Sesarma (Chiromantes) bidens*, sampled at study site Khejuri-Boga.

Months	Male		Non-ovigerous females		Ovigerous females		Total (n)	Sex ratio (M:F)
	n	%	n	%	n	%		
Mar.'08	2	14.29	4	28.57	8	57.14	14	1:0.6
Apr.'08	0	0	4	26.67	11	73.33	15	0:15
May,'08	3	16.67	7	38.89	8	44.44	18	1:5
Jun.'08	5	23.81	14	66.67	2	9.52	21	1:3.2
Jul.'08	12	46.15	2	7.69	12	46.15	26	1:1.2
Aug.'08	6	31.58	3	15.79	10	52.63	19	1:2.2
Sept.'08	7	33.33	3	14.29	11	52.38	21	1:2
Oct.'08	2	5.26	14	36.84	22	57.89	38	1:1.2
Nov.'08	8	20.51	12	30.77	19	48.72	39	1:3.9
Dec.'08	11	44	11	44	3	12	25	1:1.3
Jan.'09	14	50	14	50	0	0	28	1:1
Feb.'09	13	46.43	8	38.01	0	0	21	1:0.6
Total	83	29.12	96	33.68	106	37.19	285	1:2.4

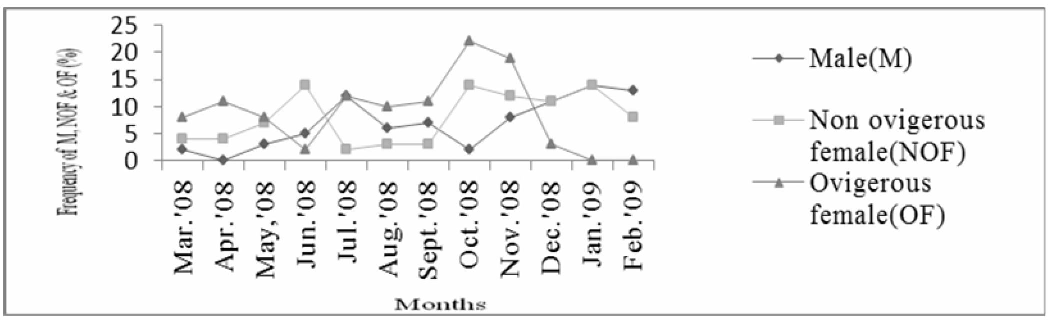


Fig. 2: Monthly variation of distribution of male, non ovigerous female and ovigerous female of *Sesarma (Chiromantes) bidens*.

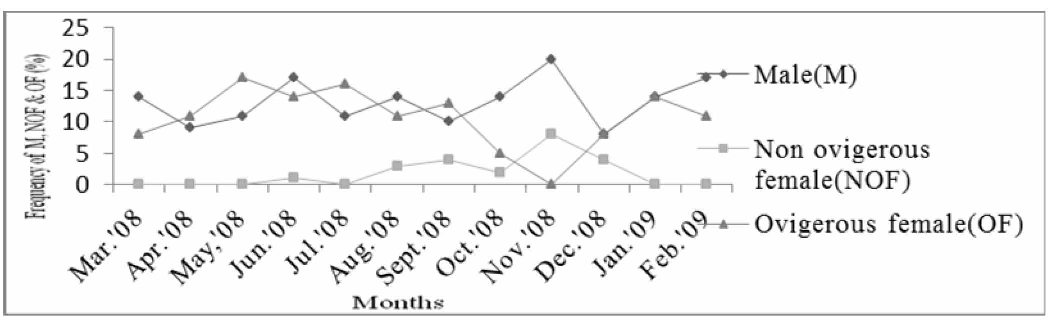


Fig. 3: Monthly variation of distribution of male, non ovigerous female and ovigerous female of *Metopograpsus maculatus*.

Tab. 9: Number of individuals, percentage and sex ratios of *Metopograpsus maculatus*, sampled at study site Khejuri-Boga

Months	Male		Non-ovigerous females		Ovigerous females		Total (n)	Sex ratio (M:F)
	n	%	n	%	n	%		
Mar.'08	14	63.64	0	0	8	36.36	22	1:0.6
Apr.'08	9	45	0	0	11	55	20	1:1.2
May,'08	11	39.29	0	0	17	60.71	28	1:1.5
Jun.'08	17	53.12	1	3.13	14	43.75	32	1:0.9
Jul.'08	11	40.74	0	0	16	59.26	27	1:1.4
Aug.'08	14	50	3	10.71	11	39.29	28	1:1
Sept.'08	10	37.04	4	14.81	13	48.15	27	1:1.5
Oct.'08	14	66.67	2	9.52	5	23.81	21	1:0.5
Nov.'08	20	71.43	8	28.57	0	0	28	1:0.4
Dec.'08	8	40	4	20	8	40	20	1:1.5
Jan.'09	14	50	0	0	14	50	28	1:1
Feb.'09	17	60.71	0	0	11	39.29	28	1:0.7
Total	159	51.46	22	7.12	128	41.42	309	1:0.9

Tab. 10: Mean fecundity (X) and Standard deviation (SD) registered for ovigerous female size classes (CW) of *Sesarma (Chiromantes) bidens* [N= 32; CW= carapace width] and *Metopograpsus maculatus* [N=39; CW= carapace width] at study site Khejuri-Boga

Sesarma (Chiromantes) bidens			*Metopograpsus maculatus*		
Size Class (mm)	X±SD	n	Size Class (mm)	X±SD	n
15.5 - 18.5	11008±1589	4	12.5 - 15.5	5495±414	9
18.5 - 21.5	14822±324	7	15.5 -18.5	8512±722	9
21.5 - 24.5	16068±734	4	18.5 - 21.5	1154±1092	8
24.5 -27.5	18158±1118	5	21.5 - 24.5	15081±1698	7
27.5- 30.5	22104±1737	12	24.5 -27.5	27121±5740	6

effect on the distribution of different sexes of two studied species of grapsidae (Tab. 11). If frequency of any sex is significantly higher or significantly lower, it can be concluded that the confidence level is 99%. Carapace width (size class) and number of eggs (fecundity) have been found to experience significant positive correlation (1% level of significance) for both of these studied species (Tab. 12).

Tab. 11: Results of Chi square (χ^2-test, P<0.01) analysis of *Sesarma (Chiromantes) bidens* and *Metopograpsus maculatus* between months and distribution of different sexes at Khejuri- Boga

Sesarma (Chiromantes) bidens	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	94.249a	22	0
Likelihood Ratio	120.458	22	.000**
n of Valid Cases	285		

a. 3 cells (8.3%) have expected count less than 5.
The minimum expected count is 4.08.
*Significant at the 0.05 level
**Significant at the 0.01 level

Metopograpsus maculatus	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	64.411a	22	0
Likelihood Ratio	76.543	22	.000**
n of Valid Cases	309		

a. 12 cells (33.3%) have expected count less than 5.
The minimum expected count is 1.42.
*Significant at the 0.05 level
**Significant at the 0.01 level

Tab. 12: Results of correlation coefficient analysis in between carapace width and number of eggs of two grapsidae crabs

Grapsidae			
Sesarma (Chiromantes) bidens		*Metopograpsus maculatus*	
CW (mm)	1	CW (mm)	1
No of eggs	0.974	No of eggs	0.924
significance of r at 5% = 0.349		significance of r at 5% = 0.316	
significance of r at 1% = 0.449		significance of r at 1% = 0.408	
Coefficient was more than 0.449 so this correlation significant at 1%.		Coefficient was more than 0.408 so this correlation significant at 1%.	

Canonical correspondence analysis

All results through biplots highlighted the facts that density and biomass are tightly linked as expected. Density and biomass are not being mentioned separately for discussing the results while only first axis is considered for discussion due to the highest association between predictor set i.e. environment variables and dependent set i.e. biomass or density of male, non-ovigerous female and ovigerous female of different crabs This study was repeated for all three tidal levels and results in the form of biplots are being depicted in Fig. 4a, 4b and 4c.

At LTL [*M. maculatus*]

Moisture of subsurface soil, interstitial water available phosphorus, organic carbon of subsurface soil, interstitial water turbidity, available phosphorus, sand content and available nitrogen of subsurface soil and interstitial water biological oxygen demand have been seen to display significant impact on non-ovigerous female. Remaining variables are associated with male and OF (Fig. 4a).

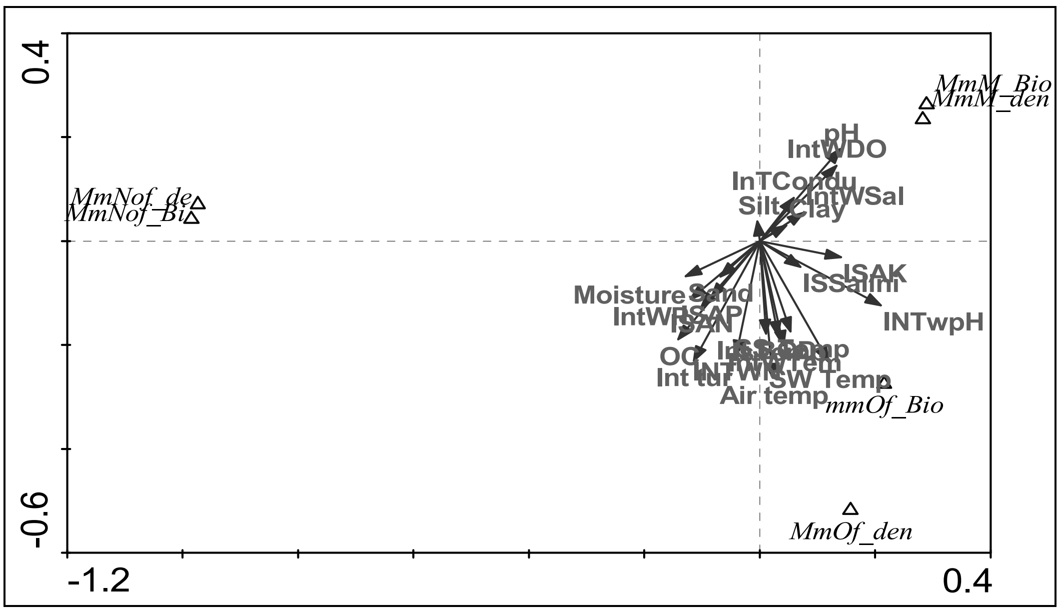


Fig. 4a: Biplot illustrating the relative position of density, biomass of male, non ovigerous female, ovigerous female of two studied crabs at low tidal level (LTL) with the environmental characteristics [*Metopograpsus maculatus*]

Abbreviations

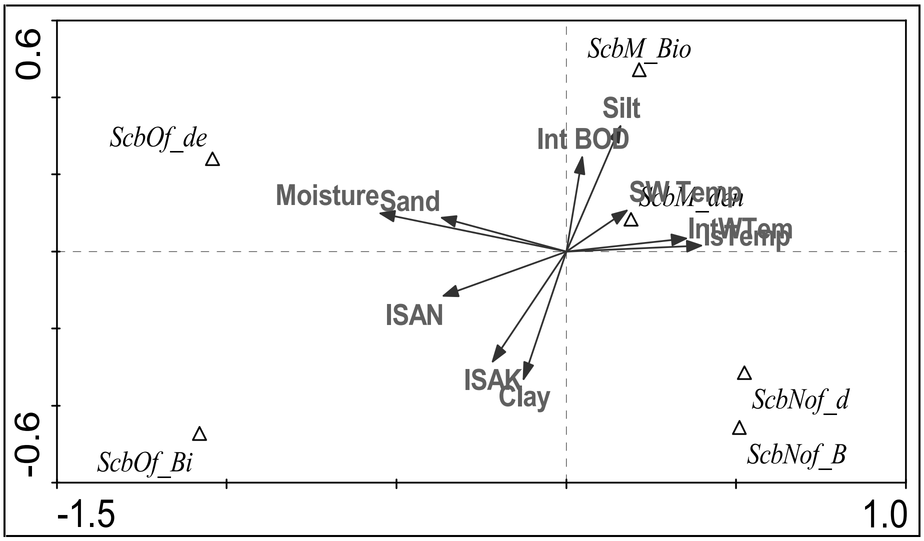
Den / den =density; Bio/bio =biomass; M =male, NOF/ Nof =non ovigerous female, OF/ Of =ovigerous female; *Scb= Sesarma (Chiromantes) bidens, Mm=Metopograpsus maculatus;* Air temp = Air temperature; SWTem = Surface water Temperature; IntWTem= Interstitial water Temperature; InTwpH = Interstitial water Ph; IntWDO = Interstitial water Dissolved Oxygen; InTCondu = Interstitial water Conductivity; IntWSal= Interstitial water Salinity; Int tur = Interstitial water Turbidity; Int BOD = Interstitial water Biological Oxygen Demand; InTWN = Interstitial water available Nitrogen; IntWP= Interstitial water available Phosphorus; SS Temp= Surface soil temperature; IS tem = Subsurface soil temperature; IS Moister = Subsurface soil Moisture; pH= Subsurface soil pH; ISSalini = Subsurface soil Salinity ;OC = Subsurface soil Organic Carbon; ISAK = Subsurface soil available Potassium; ISAP = Subsurface soil available Phosphorus; ISAN = Subsurface soil available Nitrogen.

At MTL [i) *S. (Chiromantes) bidens*, ii) *M. maculatus*]

i) Moisture, sand, clay, available nitrogen and potassium of subsurface soil were in a state to show significant impact on ovigerous female. Remaining variables are associated with male and non-ovigerous female (Fig. 4bi).

ii) Conductivity of interstitial water, pH and sand of subsurface soil have been observed to display significant impact on non-ovigerous female and male. Remaining variables are associated with OF (Fig. 4bii).

i)



ii)

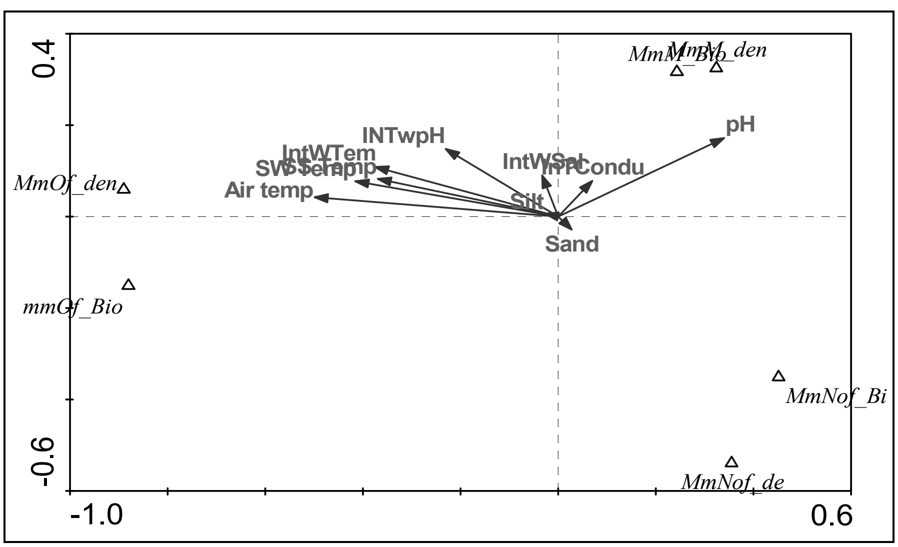


Fig. 4b: Biplot illustrating the relative position of density, biomass of male, non ovigerous female, ovigerous female of two studied crabs at mid tidal level (MTL) with the environmental characteristics [i) *Sesarma (Chiromantes) bidens*, ii) *Metopograpsus maculatus*]

At HTL [*S. (Chiromantes) bidens*]

Salinity, conductivity of interstitial water, air temperature and silt of subsurface soil have been noted to display significant impact on non-ovigerous female and male. Remaining variables as displayed in biplot i.e. clay, available phosphorus, sand of subsurface soil, dissolved oxygen of interstitial water and moisture of subsurface soil are significantly associated with ovigerous female (Fig. 4c).

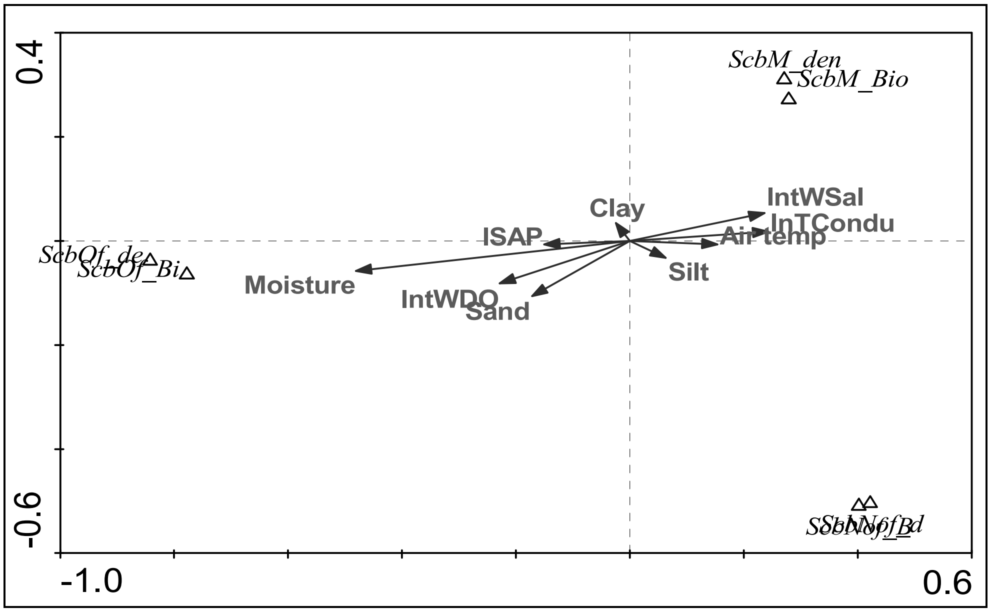


Fig. 4c: Biplot illustrating the relative position of density, biomass of male, non ovigerous female, ovigerous female of two studied crabs at high tidal level (HTL) with the environmental characteristics [*Sesarma (Chiromantes) bidens*]

Discussion

Brachyuran crab communities tightly interlinked with the trees used to exhibit complex patterns of zonation across intertidal zones. Considerable differences have been observed regarding habitat preferences as well as zonation pattern of S. (*Chiromantes*) *bidens* and *M. maculatus.* Density and biomass of male, non ovigerous female and ovigerous female of two species of grapsidae crabs have been found to exhibit seasonal variations among the different tidal levels and study sites.

It was found from the ANOVA analyses and Duncan's test, several factors like sites, seasons and tidal levels imparted considerable effect on the density and biomass of male, non ovigerous female and ovigerous female of studied crabs (Tables 4-7). These factors acted independently or interacted in combination with each others on the density and biomass of different studied species of brachyuran crab. Brachyuran crabs revealed a distinct zonation pattern in coastal environment with respect to their physiological needs or tolerance to water, salinity, dissolved oxygen of interstitial water, soil moisture, nutrient contents, temperature and ecological associations with other organisms, all of which are controlled by meteorological and climatic processes. Crab density was variable because of low growth rate in addition to seasonality in growth pattern and recruitment. These crabs exhibited lower production and turnover rate in comparison with other tropical species. The varied growth rates between males and females of different studied brachyuran crabs could be due to higher investment in somatic growth by males, while females spend a major proportion of their energy for the purpose of reproduction. These results substantiated with the early findings of Colpo and Negreiros-Fransozo, 2004; da Silva *et al.,* 2007.

The overall sex ratio of *S. (Chiromantes) bidens,* was (M:F = 1:2.43) i.e. female biased but the sex ratio of *M. maculatus* was 1:0.94 i.e. minor male biased (Tables 8 and 9). The overall sex ratio did not differ significantly from the expected 1:1 ratio. However significant deviation was observed in most months. There can be several reasons like differential life span and gamete production, temporal utilization of habitats, migration patterns growth and death (Johnson, 2003). Several factors that contribute to a strong male operational sex ratio are common for brachyuran crabs. Such a large male bias to the operational sex ratio yields polygynous mating systems and provides the opportunity for strong sexual selection (Luis and Helena, 2006). Present research results on sex ratio revealed a similarity with the early findings of Johnson, 2003. These findings are in corroboration with other brachyuran crabs like *D. myctiroides* (Hails and Yaziz, 1982), *Uca annulipes* (Litulo, 2005a) and *U. inversa* (Litulo, 2005b). The mean size of males was larger than females. This seems to be a common trend in brachyurans: females have a large decline in somatic growth presumably because energy is channeled into gonad development and egg production. On the other hand, males reach larger sizes due to the requirement to fertilize more than one female and, at the same time, males with larger dimensions have greater chances of obtaining females for copulation and winning intra-specific fight (Johnson, 2003). In the present population, this pattern is supported by the larger size attained by males. This result corroborates with the early findings of Emmerson, 1994; de Rivera, 2003; Luis and Helena, 2006. Several factors that may contribute to sex ratio biases in brachyuran crabs include (i) differential growth rates, (ii) differential production of gametes, and (iii) differential mortality between the sexes. Alternatively biased sex ratios may be intrinsic, resulting from a greater production of male offspring. Juvenile crabs are often excluded from present studies because of brachyuran crabs owing to their small size and incomplete sexual dimorphism.

In grapsidae, body size is the main determinant of fecundity and it does depend on the allometric constraints on yolk storage within the cephalothorax (Leme, 2010). Different factors viz. salinity, temperature and food availability fluctuate with some annual periodicity and therefore it might be expected that fecundity will also vary seasonally. Many marine animals including brachyuran crabs show reproductive rhythms following the semilunar or lunar tidal cycle (Mizushima *et al*., 2000). Adaptations on mating systems jointly with environmental conditions are also factors that influence crab fecundity (Costa *et al*., 2006). Reproductive intensity in brachyuran crab can be measured by quantifying the relative frequency of ovigerous females. According to Sastry (1983), the beginning and the duration of the reproductive period are dependent on the occurrence of favorable environmental conditions. The major controlling factors appear to be latitude, temperature, larval food availability, and intertidal zonation (Sastry, 1983). The breeding period becomes protected from cool to warm subtropical localities (Emmerson, 1994). Since most studies have been conducted in temperate region, seasonal breeding is well reported in the literature (Thurman, 1985 for *U. subcylindrica* in U.S.A.). Yet, the majority of tropical crabs breed continuously, i.e., throughout the year, or have prolonged breeding seasons compared to species at higher latitudes (Sastry, 1983). For ovigerous females were registered all the year round of different studied species. For many fiddler crab species there is a close association between mating and incubation place and fecundity. According to Thurman (1985), the fecundity of the genus *Uca* from tropical and temperate areas could vary according to environmental conditions. Fecundity differences were observed as much between both species as between individuals of the species. These differences were related to many factors: the weather during which females were collected; food availability; multiple spawning (1ª, 2ª or 3ª spawning of reproductive cycle); individual variation on egg production and natural egg losses related to female activity on the surface. The fecundities of *S. (Chiromantes) bidens* and *M. maculatus* were found to be higher in respect of egg production. The production of eggs requires an optimal allocation of energy into growth and reproduction for the maximization of parental fitness. Egg production plays important roles in the evolution of life history strategies such as egg size, size at maturity, lifespan and reproductive effort because the production of eggs is an energetically expensive process. The fecundity of brachyuran crabs increased in accordance with increasing carapace width, as observed in crabs (Litulo, 2005b). The carapace width has been identified as to be a good predictor of fecundity as revealed from this present research finding (Tables 10 - 12) and present research results on fecundity are in compliance with the findings of Sastry (1983); Thurman (1985); Costa and Negreiros-Fransozo (2006) and Litulo, 2005a,b.

Environmental physico-chemical measurements should be treated with caution; they only give a general indication of conditions because they vary with the time of day, and in relation to tidal inundation, seasons, and weather (Ashton *et al.,* 2003). Multivariate technique was used for looking at the whole picture and providing a better understanding of population dynamics. Canonical correspondence analysis (CCA), a multivariate statistical analysis, has been used to evaluate the impact of different physico-chemical parameters of water and soil on the density or biomass of *S. (Chiromantes) bidens* and *M. maculatus*. CCA of the present investigation revealed that different environmental and meteorological parameters of different tidal levels of two different study sites had different intensity of impact on male, non ovigerous and ovigerous female of studied crab's distribution and density, biomass (Figures 4a to 4c).

Different physic-chemical parameters like temperature, pH, dissolved oxygen, salinity, sediment texture (sand, silt and clay), soil moisture, nutrient contents like organic carbon, available nitrogen, phosphorous, potassium are being most important abiotic factors in ecological investigation, particularly to the grapsid ecology. Present research results in relation to population dynamics and physic-chemical parameters are in compliance with the early findings of Vijayakumar *et al.* (2000); Lee (2008) and Damotharan *et al*. (2010).

Acknowledgements

First author is thankful to Ministry of Environment and Forest, Government of India for financial support for providing research fellowship [Sanctioned No. *3/6/2001 – CSC* (M) dated 5th Nov.2001]. Authors are thankful to the authority of Vidyasagar University for providing library and laboratory facilities.

References

- ✓ Alcock A. (1900) Materials for a Carcinological fauna of India, No. 6. The Brachyura Catometopa or Grapsidae. Journal of the Asiatic Society of Bengal, 69(2): 279-476.
- ✓ Alongi D.M. (2009) The Energetics of Mangrove Forests. Springer, pp. 1-216.
- ✓ Alves R.R.N., Nishida A.K. and Hernández M.I.M. (2005) Environmental perception of gatherers of the crab "caranguejo-uçá" (*Ucides cordatus*, Decapoda, Brachyura) affecting their collection attitudes. Journal of Ethnobiology, 1: 10.
- ✓ APHA (2005) American Water Works Association and Water Pollution Control Federation, Standard Methods for the Examination of Water and Wastewater. 21st ed. American Public Health Association, New York, USA.
- ✓ Ashton E.C., Macintosh D.J. and Hogarth P.J. (2003) A baseline study of the diversity and community ecology of crab and molluscan macrofauna in the Sematan mangrove forest, Sarawak, Malaysia. Journal of Tropical Ecology, 19: 127-142.

- ✓ Chakraborty S.K. and Chaudhury A. (1992) Ecological studies on the zonation of brachyuran crabs in a virgin mangrove island of Sundarbans, India. Journal of the Marine Biological Association of India, 34: 189-194.
- ✓ Chakraborty S.K. (2011) Mangrove Ecosystem of Sundarbans, India; Biodiversity, Ecology, Threats and Conservation. *In. Mangroves: Ecology, Biology and Taxonomy.* Ed. James N. Metras (Publ. NOVA publishers) pp.83-112.
- ✓ Chakraborty S.K., Chatterjee S., Dey M.K., Bhakat R.K. and Paul A.K. (2012) Ecological Changes of an Eco-rehabilitated Delta of Hooghly Estuary. Journal of Coastal Environment, 3(1): 9-27.
- ✓ Chakraborty S.K. (2013) Interactions of environmental variables determining the biodiversity of coastal-mangrove ecosystem of West Bengal, India. The Ecoscan (Special issue), 3: 251-265.
- ✓ Chatterjee S., Chakraborty S.K., Chakravarty G., Chandra A. and Khalua R.K. (2004) Distributional pattern of mangroves and associated floral and faunal components of East Midnapore district coastal tract, West Bengal, India. Paper presented in the national seminar on State of the art on Conservation of biodiversity in India with particular reference to Himalaya. Held on 22nd to 24th March, 2004. Organised by CORD and PG Department of Environmental Science (University of Kashmir), India.
- ✓ Chatterjee S., Bhunia G. and Chakraborty S.K. (2008) Bioturbation of Brachyuran crabs and its impact on coastal ecosystem of Midnapore district, West Bengal, India. In proceedings of Forth International Conference on Environmental Science and Technology, at Houston, Texas U.S.A.
- ✓ Colpo K.D. and Negreiros-Fransozo M.L. (2004) Comparison of the population structure of the fiddler crab *Uca vocator* (Herbst, 1804) from three subtropical mangrove forests. Scientia Marina, 68: 139-146.
- ✓ Costa T.M., Silva S.M.J. and Negreiros-Fransozo M.L. (2006) Reproductive pattern comparison of *Uca thayeri* Rathbun, 1900 and *U. uruguayensis* Nobili, 1901 (Crustacea, Decapoda, Ocypodidae). Brazilian Archives of Biology and Technology, 49(1): 117-123.
- ✓ Damotharan P., Perumal N.V. and Perumal P. (2010) Seasonal variation of physico-chemical characteristics of Point Calimere coastal waters (South east coast of India). Middle-East Journal of Scientific Research, 6(4): 333-339.
- ✓ da Silva S.M.J., Hirose G.L. and Negreiros-Fransozo M.L. (2007) Population dynamic of *Sesarma rectum* (Crustacea, Brachyura, Sesarmidae) from a muddy flat under human impact, Paraty, Rio de Janeiro, Brazil. Iheringia Serie Zoologia, 97(2): 207-214
- ✓ de Rivera C.D. (2003) Causes of a male-biased operational sex ratio in the fiddler crab, *Uca crenulata.* Journal of Ethology, 21: 137-144.
- ✓ Emmerson W.D. (1994) Seasonal breeding cycles and sex-ratios of 8 species of crabs from Mgazana, a mangrove estuary in Transkei, southern Africa. Journal of Crustacean Biology, 14: 568–78.
- ✓ Hails A.J. and Yaziz S. (1982) Abundance, breeding and growth of the ocypodid crab Dotilla myctiroides (Milne-Edwards) on a West Malaysian beach. Estuarine Coastal and Shelf Science, 15: 229-239.
- ✓ Johnson P.T.J. (2003) Biased sex ratios in fiddler crabs (Brachyura, Ocypodidae): a review and evaluation of the influence of sampling method, size class and sex-specific mortality. Crustaceana, 76(5): 559-580.
- ✓ Kathirensan K. and Quasim S.Z. (2005) Biodiversity of Mangrove Ecosystem; Hindustan Publishing Corporation (India), New Delhi, pp.251
- ✓ Lee S.Y. (2008) Mangrove macrobenthos: assemblages, services, and linkages. Journal of Sea Research, 59: 16-29.
- ✓ Leme M.H.A. (2010) Seasonal changes in reproductive traits of the crab *Sesarma rectum* (Grapsoidae: Searmidae) on the northern coast of Sao Paulo state, Brazil. Journal of Crustacean Biology, 26 (2): 141-147.
- ✓ Litulo C. (2004a) Reproductive aspects of a tropical populationof the fiddler crab *Ucaannulipes* (H. Milne Edwards, 1837) (Brachyura: Ocypodidae) at Costa do

Solmangrove, Maputo Bay, southern Mozambique. Hydrobiologia, 525: 167-175.

- Litulo C. (2005a) Population biology of the fiddler crab *Uca annulipes* (Brachyura: Ocypodidae) in a tropical East African mangrove (Mozambique). Estuarine Coastal and Shelf Science, 62: 283-290.
- Litulo C. (2005b) Population structure and reproductive biology of the fiddler crab *Uca inversa* (Hoffman, 1874) (Brachyura: Ocypodidae). Estuarine Coastal and Shelf Science, 27(3): 135-14.
- Luis E.A.B., Helena M.C. (2006) Population and reproduction biology of the fiddler crab *Uca thayeri* Rathbun, 1900 (crustacean: ocypodidae) in a tropical mangrove from Northeast Brazil. Acta Oecologica, Elsevier 31(3): 251-258.
- Mermillod-Blondin F. (2011) The functional significance of bioturbation and biodeposition on biogeochemical processes at the water - sediment interfacein freshwater and marine ecosystems. Journal of the North American Benthological Society, 30: 770−778.
- Meysman F.J.R., Middelburg J.J. and Heip C.H.R. (2006) Bioturbation: a fresh look at Darwin's last idea. Trends in Ecology & Evolution, 21(12): 688-695.
- Mizushima N., Nakashima Y. and Kuwamura T. (2000) Semilunar spawning cycle of the humbug damselfish *Dascyllus aruanus*. Journal of Ethology, 18: 105-108.
- Paul A. (2002) Coastal Geomorphology and Environment. ACB publications, Kolkata, India.
- Ravichandran S. and Kannupandi T. (2007) Biodiversity of crabs in Pichavaram mangrove environment. *Zoological Survey of India.* National Symposium onconservation and Valuation of marine Biodiversity, 331-340.
- Reid D.M. and Corey S. (1991) Comparative fecundity of decapod crustaceans, II. The fecundity of fifteen species of anomuran and brachyuran crabs. Crustaceana, 61(2): 175-189.
- Robertson A.I. (1986) Leaf- burying crabs: their influence on energy flow and exportfrom mixed mangrove forests (*Rhizophora* sp.) in northeastern Australia. Journal of Experimental Marine Biology and Ecology, 102 (2-3): 237-248.
- Sastry A.N. (1983) Ecological aspects of reproduction. In The biology of Crustacea. Environmental adaptations, vol. 8 (ed. F.J. Vernberg and G.W. Vernberg). pp. 179-270. New York: Academic Press.
- Satyanarayana B., Raman A.V., Frank D., Kalavali C. and Chandramohan P. (2002) Mangrove floristic and zonation patterns of Coringa, Kakinada Bay, East Coast of India. Wetlands Ecology and Management, 10: 25-39.
- Statsoft (2001) Statistica*:* data analysis software system, version 6.0. Tulsa, StatSoft, Inc.
- Swift D.J. (1993) The macrobenthic infauna of Sellafield (North Eastern Irish Sea) with special reference to bioturbation. Journal of Marine Biological Association of United Kingdom, 73: 143-162.
- Thurman II C.L. (1985) Reproductive biology and population structure of the fiddler crab *Uca subcylindrica* (Stimpson). Biological Bulletin, 169: 215-229.
- Vijayakumar S.K., Rajesh K.M., Mendon R. and Hariharan V. (2000) Seasonal distribution and behaviour of nutrients with reference to tidal rhythm in the Mulki estuary, southwest coast of India. Journal of Marine Biological Association of India, 42: 21-31.
- Zar J.H. (2009) Biostatistical Analysis*.* 5th ed. Pearson International Edition, Upper Saddle River.