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Community ecology of crab larvae in the rivers of Sundarbans mangrove, Bangladesh

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Abstract. The composition, density and distribution patterns of crab larvae along with other shell- and finfish larvae in the rivers of Sundarbans with different salinity zones were investigated. Megalopa of crabs were most numerous, making up to 25.6% of the total shellfish catch. The commercial important mud crab species *Scylla* spp. were observed frequently with maximum abundance occurred during winter from November to February. No significant seasonal or lunar variation in abundance of crab larvae was observed, although major annual peak in monsoon was recorded. The results have important implications for the development of a sustainable mud crab aquaculture based on collection of juvenile crab from Sundarbans.
Keywords: Sundarbans mangrove, Crab larvae, *Scylla* spp.

Introduction

Mangroves play an important ecological role in sustaining productivity of inshore and offshore fisheries in the coast. Also mangrove waters are known for their role as suitable nursery grounds for many shell- and fin-fish species. Crabs are crustaceans that spend most of their life cycle in the mangrove environment throughout the range. Crab and molluscans are the predominant animals of the mangrove ecosystem (Macnae 1968; Jones 1984; Macintosh *et al.* 1993) and are thought to play significant ecological roles in the structure and function of the mangrove environment (Lee 1999).

Fishery and aquaculture of some crab species, especially mangrove or mud crab has significant economic activities in coastal Bangladesh due its export potentialities. Export of live crab from both shrimp farms and Sundarbans waters is increasing in recent time. The self sustainable and naturally produced crabs in the mangrove waters and coastal shrimp farms has lifted up the national export trade. In south-western Bangladesh, the sole source of crab seeds are Sundarbans mangrove waters. Expansion of crab aquaculture is likely to target all size of the crab population (megalopa, juveniles, sub-adults and broods) and affect the traditional capture fishery as well as the sustainability of the aquaculture itself. However there is significant shortage of information on the abundance, distribution and ecology of these crabs in the Sundarbans. This impacts the development of a sustainable crab aquaculture and fishery for the benefit of local coastal communities. Collection of crab larvae/juveniles for aquaculture may be difficult to manage since abundance of crabs as well as collection are poorly understood in the coastal Bangladesh. Information on biotic and abiotic factors influencing the habitat preference by crabs (megalopa and juveniles) is of increasing importance since the development of crab aquaculture in Asia, as in other parts of the world, based on wild seed collection (Rodriguez *et al.* 2007; Mirera 2011; Dumas *et al.* 2012). The present research provides information on the occurrence and abundance of crab larvae in the Sundarbans mangrove as a potential for capture based crab aquaculture development and management.

Materials and Methods

Sampling sites: Field samplings were carried out in rivers of the Sundarbans mangrove, north-west Bangladesh which is about 40-50 km upstream from the Bay of Bengal (between longitudes 89^{0}00’E and 89^{0}55’E and latitudes 21^{0}30’N and 22^{0}30'N). Five rivers namely Passur, Madar, Kholpatua, Koyra and Sibsa, based on salinity zones had been monthly sampled for two years (Fig. 1). Fortnightly samples were also collected for a period to observe the lunar cycle differences. A rectangular drag net made of bamboo spilt structure (1.6x0.6m^2) measuring a length of 2 m including cod end and 2 mm mesh size, was used for sample collection. Synthetic monofilament net material with knotless webbing was used to make the sampling net.

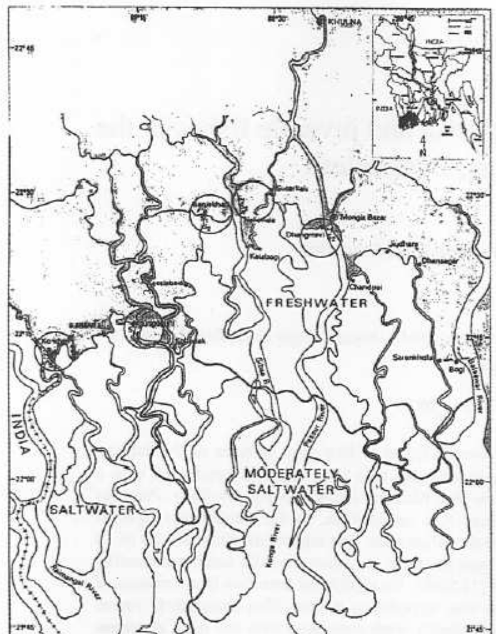

Fig. 1. Study area and location of sampling stations in the river systems of Sundarbans.

Sampling structure: Day time catch samples were collected during spring low/high tides (MH20 high tide) of full and new moons. During sampling, the rectangular drag net was dragged on the river from shallow waters and continued the adjacent mud bank covering a total area of 10 m^2. For collection of samples 4 nos. (rarely 2 nos. depends on weather) replicate samplings with each net were done in each netting. A distance of about 1 km was maintained for replicate sample collection (i.e. for 4 netting 2 from one spot and another 2 towards about 1 km from the first spot) in each sampling spot. Immediately after collection, the catches were cleaned of any foreign particles and large specimens, and preserved with 5 per cent formalin in river water. After transportation to the laboratory, catches were again sorted out and preserved in 5 per cent neutral formalin for species composition study. The crab larvae (megalopa) were counted and individual species were then identified using a dissecting microscope.

Water quality parameters: Water samples were collected monthly during collection of crab larvae during new and full moons from the surface of each river sites with the help of a clean bucket. Transparency of river water was measured with a Secchi disc of 20 cm diameter. Surface water temperature, salinity, conductivity and total dissolved solids (TDS) were determined with a direct reading integrated conductivity meter (Jenway 4200). Water pH was measured using a field pH meter (pH Scan-2, sensitivity 0.1±0.02), which was calibrated with pH buffer- 4.0 and 7.0 before every use. Dissolved oxygen (DO), alkalinity and hardness were measured using HACH kit (FF-2). Total suspended solids (TSS) of water was determined following the method described by Strickland and Parsons (1972).

Analysis of data: To estimate the inter-annual density changes of the crab larvae, the density coefficient of variation within each year ($C.V._w = 100S_m/\bar{X}_m$, where $\bar{X}_m$ and S_m are mean and standard deviation of monthly abundance, respectively) and among years ($C.V._a = 100S_a/\bar{X}_a$, where $\bar{X}_a$ and S_a are mean and standard deviation of annual abundance, respectively) were calculated. Two-way ANOVA with sites and times (season and lunar cycles) as fixed factors, were used to compare the equality of mean number of larvae per sampling. STATISTICA (5.5) and SPSS (10.0.1) software package were used for statistical analysis.

Results

Community structure of crab larvae: An average of 24,994 nos. shellfish and 4,975 nos. finfish individuals were collected during the two years study period in rivers of Sundarbans mangrove. Along with >20,000 mysids were also caught during sampling. Fig. 2 represents the mean (±SE) density of shrimp, finfish and crab larvae in five rivers under study. Monthly mean density of crab larvae was maximum (89/haul) in Koyra river and minimum (6/haul) in Kholpatua and Madar rivers in the 1st year sampling and maximum (147/haul) was in Passur and minimum (25/haul) in Sibsa river during the 2nd year sampling. Highest individuals of 1079/haul crab larvae was caught in Madar river during 2nd year July. Major peak (278/haul) was also recorded during July in Kholpatua river. Crab larvae density was in its peak (521-866/haul) during winter in Passur and Koyra rivers. In Sibsa river major peak was recorded in winter but comparatively lower density (90/haul) (Fig. 2).

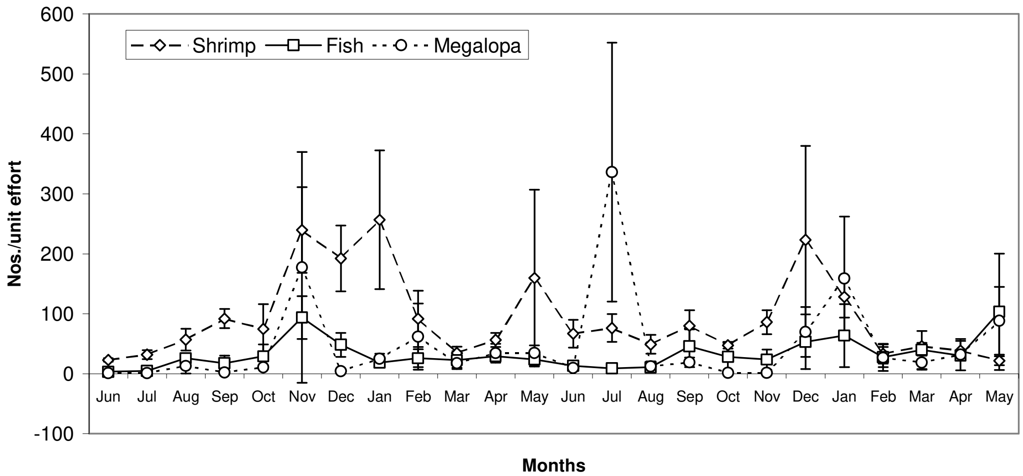

Fig. 2. Monthly distribution pattern of mean numbers (±SE) of shrimp, finfish and crab magalopa in the rivers of Sundarbans mangrove.

Analysis of Variance (ANOVA) showed significant ($p < 0.05$) differences in monthly abundance of shrimp and finfish in 1st year and crab larvae in 2nd year (Table I). Salinity zone did not show any significant effect on abundance of species composition in the rivers under study. Also ANOVA did not show significant seasonal effects on abundance of species during study period (Table II). Moreover, lunar cycle, even within a month did not show any significant effect on abundance of shrimp, finfish or crab larvae in different rivers of Sundarbans (Table III).

During the 2 years study, only two crab species i.e. *Scylla* spp. and *Neptunus pelagicus* representing Portunidae and Ocypodidae respectively were recorded. The mean carapace lengths of crab larvae were between 1-4 mm and few larvae with 10 mm carapace length were also observed during winter. Abundance of crab larvae in the Sundarbans water showed variability among individual years rather than within the years (Table IV). Variability in crab larvae abundance was observed in Passur and Koyra river in 1st year and in Madar, Kholpatua and Sibsa rivers during 2nd year. No inter-annual variation was observed.

Table I. Effects of year, month, river, salinity zone and interaction on numerical abundance of species in the rivers of Sundarbans

Year	Group	Source	df	SS	*F* value
1st year	Shrimp	Month	11	402457.4	**2.96***
		River	4	86652.9	1.4
	Finfish	Month	11	31942.98	**3.29***
		River	4	4553.9	1.29
	Crab	Month	11	135982.2	0.92
		River	4	63103.57	1.18
2nd year	Shrimp	Month	11	166362.2	1.57
		River	4	36529.33	0.95
	Finfish	Month	11	39306.53	1.05
		River	4	129845.7	**9.54***
	Crab	Month	11	520315.7	**2.86***
		River	4	101921.2	1.22
Both years	Shrimp	Year	1	7100.85	2.86
		Month	11	152536	**3.88***
		Year x Month	11	80553.64	**2.95***
		Salinity zone	2	1586.02	0.22
	Finfish	Year	1	472.15	0.76
		Month	11	6315.37	**3.02***
		Year x Month	11	7121.25	1.04
		Salinity zone	2	4357.85	11.48
	Crab	Year	1	6343.35	0.87
		Month	11	557250.4	1.91
		Year x Month	11	51797.62	0.66
		Salinity zone	2	30705.32	0.58

Table II. Effects of season and river on numerical species abundance in the rivers of Sundarbans

Year	Group	Source	df	SS	*F* value
1st year	Shrimp	Season	3	61795.52	4.26
		River	4	29882.97	1.54
	Finfish	Season	3	6005.56	5.13
		River	4	2181.65	1.4
	Crab	Season	3	9839.66	0.76
		River	4	20408.89	1.18
2nd year	Shrimp	Season	3	22733.03	1.93
		River	4	12177.64	0.77
	Finfish	Season	3	6257.52	1.39
		River	4	43283.44	**7.22***
	Crab	Season	3	40474.47	1.68
		River	4	39211.55	1.22

* = $p < 0.05$. (df = degree of freedom, SS = sum of squares, MS = SS/df, F = MS among/ MS within)

Table III. Lunar cycle effects and river on numerical abundance of species in the rivers of Sundarbans

Year/Month	Group	Source	df	SS	*F* value
1st year	Shrimp	Lunar cycle	1	1738.71	0.93
		River	4	5409.01	0.72
	Finfish	Lunar cycle	1	4.46	0.00
		River	4	8234.23	1.82
	Crab	Lunar cycle	1	7067.09	1.7
		River	4	16998.81	1.02
2nd year	Shrimp	Lunar cycle	1	19272.1	2.97
		River	4	27024.48	1.04
	Finfish	Lunar cycle	1	680.63	0.7
		River	4	5725.85	1.48
	Crab	Lunar cycle	1	603.26	3.67
		River	4	1359.29	2.07
Within month	Shrimp	Lunar cycle	1	25815.54	2.31
		River	4	63812.85	1.55
	Finfish	Lunar cycle	1	0.39601	0.00
		River	4	5862.48	3.04
	Crab	Lunar cycle	1	7040.53	0.88
		River	4	32760.9	1.06

(df = degree of freedom, SS = sum of squares, MS = SS/df, F = MS among/ MS within)

Table IV. First collection time, mean density (d_w = nos./unit effort) and coefficient of variation ($c.v._w$ = %) within each year, and inter-annual mean density (d_a = nos./unit effort) and coefficient of variation ($c.v._a$ = %) within year for the crab larvae abundance in rivers of Sundarbans

Rivers	1st year			2nd year			Among years	
	Month	D_w	$C.V._w$	Month	D_w	$C.V._w$	D_a	$C.V._a$
Passur	October	52.5	141.79	"	147.1	106.31	-	115.64
Sibsa	"	19.34	74.15	July	24.75	116.69	-	98
Koyra	"	70.38	302.16	"	38.67	191.18	-	262.79
Kholpatua	"	4.92	126.83	June	29.58	267.17	-	247.19
Madar	"	4.71	149.25	"	105.17	293.29	-	287.11

Seasonality and variation on crab larvae abundance: Highest number of individuals of 1079/haul was recorded for crab larvae during monsoon in Madar river, followed by 866/haul during post-monsoon in Koyra river, 521/haul during winter in Passur and 263/haul during pre-monsoon in Koyra river observed. Seasonal abundance of shrimp species was higher in 1st year, whereas abundance of crab larvae was higher in 2nd year. Shrimp species were less abundant in monsoon and crabs were more abundant in monsoon and post-monsoon period in the rivers of Sundarbans. Seasonal distribution of crab larvae was uniform in the rivers of Sundarbans. Table V represents ANOVA of year, month, river site effect and interaction on numerical abundance of crab larvae in Sundarbans water. No significant effect in monthly abundance was observed.

Table V. Effects of year, month, river site and interaction on numerical abundance of crab larvae in the Sundarbans water

Species	Source	df	SS	*F* value
Crab larvae	Year	1	6411.82	0.9
	Month	11	51976.86	0.66
	River	4	79541.63	1.15
	Year x Month	11	449907.5	1.9
	Year x River	4	63492.48	0.74
	Month x River	23	689298.7	1.73

* = $p<0.05$. (df = degree of freedom, SS = sum of squares, MS = SS/df, F = MS among/ MS within)

No significant effect of season or lunar cycle on the abundance or distribution of crab larvae was also observed in the rivers of Sundarbans under study (Tables VI).

Table VI. Effects of season, lunar cycle and river on numerical abundance of crab larvae in the Sundarbans water

Species	Source	df	SS	*F* value
Crab larvae	Season	3	10303.91	0.76
	River	4	21290.14	1.18
	Lunar cycle	1	2950.15	2.54
	River	4	6520.61	1.4

(df = degree of freedom, SS = sum of squares, MS = SS/df, F = MS among/ MS within)

Water parameters: During study period, water temperature did not vary among the rivers under study. Water temperature was highest in April (33.5^{0}C) and lowest in January (20.9^{0}C). Low water salinity was recorded during August to December months. After monsoon, water salinity was steadily increased to reach its maximum in March. During 2 years sampling period, highest water salinity was recorded in Madar river as 30.1 ppt. In the Passur and Sibsa rivers salinity fell below 1 ppt from the month of August to November.

The Sundarbans river water was characterized by slightly alkaline pH and high conductivity during study period. Water transparency ranged from 6.3 to 28.7 cm and decreased with the water temperature increases. In the rivers, TDS values decreased with the concurrent of monsoon, and higher TDS values occurred during pre-monsoon period. TDS value was low in Passur and Sibsa rivers. Analysis of variance indicated a significant ($p<0.05$) inter-month variations in water temperature and transparency, and inter-month and inter-river site variations in salinity regimes (Table VII). No significant variation was observed in water pH. Both water conductivity and TDS values showed significant inter-month and inter-river variations.

Table VII. Water quality parameters in the rivers of Sundarbans

Source of variation	SS	df	MS	*F* value
Temperature				
Year	0.16	1	0.16	0.06
Month	1008.53	11	91.68	35.69*
River	0.93	4	0.23	0.17
Year x Month	520.79	11	47.34	34.50*
Year x River	12.23	9	1.36	0.53
Month x River	1110.99	59	18.83	6.78*
Salinity				
Year	172.08	1	172.08	20.13
Month	3224.205	11	293.11	35.85*
River	911.45	4	227.86	61.13*
Year x Month	1614.21	11	146.75	39.37*
Year x River	2022.51	9	224.72	27.49*
Month x River	5379.59	59	91.18	10.67*
pH				
Year	3.89	1	3.89	15.99
Month	3.68	11	0.33	1.68
River	0.16	4	0.04	0.58
Year x Month	1.83	11	0.17	2.37
Year x River	4.84	9	0.54	2.70
Month x River	9.989667	59	0.17	0.70
Transparency				
Year	54.14	1	54.14	3.77
Month	873.98	11	79.45	7.22*
River	35.74	4	8.93	2.73
Year x Month	438.14	11	39.83	12.16*
Year x River	173.97	9	19.33	1.76
Month x River	1235.88	59	20.95	1.46
Conductivity				
Year	514.56	1	514.56	18.56
Month	8434	11	766.73	30.90*
River	2517.78	4	629.45	64.16*
Year x Month	4218.04	11	383.46	39.09*
Year x River	5597.09	9	621.90	25.06*
Month x River	14337.70	59	243.01	8.77*
TDS				
Year	193.75	1	193.75	33.57
Month	3541.38	11	321.94	52.87*
River	831.46	4	207.86	55.21*
Year x Month	1761.80	11	160.16	42.54*
Year x River	1915.30	9	212.81	34.95*
Month x River	5525.34	59	93.65	16.23*

Discussion

Mangroves act as a nursery ground and feeding habitat for juveniles of many commercial fish and shellfish including crab species (Robertson and Duke 1990; Chong *et al.* 1996; Huxham *et al.* 2004; Mirera *et al.* 2010). In general, mud crab populations are typically associated with mangroves and used as indicator for mangrove habitat condition (Walton *et al.* 2006b). Most of the lifecycle part of the mud crab is associated with mangrove habitats and crabs larvae are abundant in mangrove swamps and estuaries (Overton *et al.* 1997; Walton *et al.* 2006a). Species composition of shrimps indicated that the larval shrimp assemblage in the Sundarbans mangrove was constituted of a few species in large numbers. Megalopa of crabs were more abundant during winter in freshwater zone (Passur, Koyra and Sibsa rivers), whilst their abundance was peak during monsoon in semi-saline (Kholpatua river) to saline zone (Madar river).

During present study about 15 species of shellfishes were recorded, which is comparable with the study of Basu *et al.* (1998) at Hooghly estuary, Indian Sundarbans. They recorded 10-21 crustacean species with major abundance of *Acetes* spp. (12.88%), followed by *S. serrata* (9.74%) and *P. monodon* (6.01%) and maximum species diversity during pre-monsoon. Studies on zooplankton in Satkhira estuary by Zafar and Mahmood (1989) revealed 14 major taxonomic group, where mysids represented 65.19% of total population. Other groups were Copepods 15.87%, Amphipods 6.07%, crab larvae 3.02%, Acetes 2.85%, Chaetognaths 1.64%, shrimp larvae 1.22% and fish larvae 1.05% with major peak in monsoon. In the present study, mysid were excluded from the calculation although they were abundant numerously in Passur, Kholpatua and Madar rivers during sampling.

Peak abundance of juvenile *Scylla serrata* is recorded during post-monsoon (Jan.-Feb.) with total absence in monsoon (October-November) in Pichavaram mangrove, India (Chandrasekaran and Natarajan 1994). Two peak abundance for crab larvae were recorded in the present study. Winter (Dec.-Feb.) peak was observed in freshwater zone, whereas monsoon (Jun.-Aug.) was in saline zone (Kholpatua and Madar rivers) and crab larvae was less abundant in post-monsoon period. Although the months were in agreement with Pichavaram mangrove, but seasons were not similar with present study. The adults of mud crab, *Scylla* spp. move about in deeper waters while the larvae and juveniles prefer shallow water habitat, muddy substrate and shelter provided by mangrove roots (Hill *et al.* 1982). The mangrove crab supports year-round fisheries in much of South Asian countries including Bangladesh. A few reliable fisheries statistics are available in the country for *Scylla* or mud crab fishery because it supports an entirely artisanal fishing (Hoq and Rahman 1995). There are clear indication that mud crab is being overfished in many parts of coastal region and also in rivers of the Sundarbans. Easy availability of crab seed has stimulated renewed interest in mud crab fattening and has boosted the market price for crabs produced by backyard farming in the coast. Mub crab is also cultured with shrimps in *gher* culture system in southwestern Bangladesh.

The water salinity was found to determine the recruitment of crustacean populations (Easo and Mathew 1989), and at moderate rainfall it extends the nursery area (Garcia and Le Reste 1981). In the present study, higher water salinity were recorded during March to May and lower during August to December months. A similar trend was also found in the Indian Sundarbans (Bandyopadhya 1986). The effects of temperature and salinity on abundance of shell- and finfishes are species-specific and also changed with time. Due to the shallowness in the mangrove rivers the water of Sundarbans river was turbid during all months.

Considering the economic value and culture potential of mud crabs, surprisingly little is known about their larval ecology. The nursery habitat of *S. paramamosain* has only been identified in Vietnamn (Walton *et al.* 2006b), but not known for other *Scylla* species. Despite considerable sampling in estuarine habitats, the settlement habitat of the crab megalopa has never been identified, and small juvenile crabs of *S. serrata* have rarely been found in the mangroves habitats (Webley *et al.* 2009). The lack of megalopa and small juvenile crabs within mangrove habitats has led to suggested that the postlarvae settle and metamorphose occurred outside estuaries, where after the benthic juveniles invade mangrove habitats (Webley and Connolly 2007). There is a general lack of understanding of the processes that affect the abundance and distribution of young juvenile mud crabs- megalopa.

Understanding the ecology of crab larvae in Bangladesh coast particularly in Sundarbans habitat is of more than merely of academic interest given the feedback to develop aquaculture of *Scylla* spp. as a source of income for coastal communities. The present culture systems growing large crabs in small enclose with stocking of young juvenile crabs are not optimal and sustainable. However, since crab hatcheries are not till established in Bangladesh, wild seed crabs will have to be used. At present the lack of understanding of the processes that control the abundance and distribution of young juvenile mud crabs may prevent the development of such aquaculture in near future.

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