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OBSERVATIONS ON SOME ASPECTS OF THE BIOLOGY OF HORSE-SHOE CRAB, *CARCINOSCORPIUS ROTUNDICAUDA* (LATREILLE) ON MUD FLATS OF SUNDERBAN ESTUARINE REGION

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INTRODUCTION

The existing species of horse-shoe crabs, the oldest living animals on the earth, have almost remained unchanged, both morphologically and genetically during a long evolutionary course of more than 350 million years (Price, 1971). There are many fossilized records from different parts of the world related to different geologhical time scale (Mikkelsen, 1988), which reveal little structural changes from those of existing ones. Due to this fact, they are also called "living fossils"

Apart from their antiquity and uniqueness, which are subjects of deep academic interests, these animals are of tremendous importance in present day biomedical researches. Their 'blue blood' contains an important enzyme 'Lysate' which is highly sensitive to endotoxin of gram negative bacteria and therefore is used as diagnostic tester (Cohen, 1978).

Out of four extant species of the group, known from the world, except *Limulus polyphemus* (Linnaeus), which occur in the coastal waters of U.S.A., the other three species viz. *Tachypleus tridentatus* (Leach), *Tachypleus gigus* (Muller) and *Carcinoscorpius rotundicauda* (Latreille) are Asain species (Sekigachi and Nakamura, 1979). In India, the group is represented by the latter two species, both confined to north-eastern coasts of Bay of Bengal in the states of West Bengal and Orissa. While *C. rotundicauda* occurs only in Sunderban region of Hugly Matla estuarine system and adjoining coastal waters up to Digha, *T. gigus* has been reported to occur in abundance in the coasts of Orissa and adjoining region of West Bengal, up to Digha. Inspite of the earlier records of the coexistance of the two species in Sunderban region, no distributional overlap was noticed during present investigations.

While enormous amount of work has been carried out on various aspects of the abundance, distributional patterns, morphology, life history, population cycle of *Limulus polyphemus* (Barber, 1956; Botton, 1982, 1984a, 1984b, 1984c; Rudole, 1979, 1980, 1981 1985) comparatively little work has been done on Asian species and this includes chiefly the studies of Sekiguchi and Nakamura (1979) and Sekiguchi *et al.* (1976, 1981). In India, the earlier references on horse-shoe crab include the notes of Annandale (1909) and Roonwal (1944), on some aspects of the breeding biology of *T. gigus* (later on confirmed as *C. rotundicauda*). Rama Rao and Surya Rao (1972) also made some observations on the occurrence and breeding habits of *T. gigus* from Digha Coast.

After a long gap, Chatterji *et al.* (1992a, 1992b) published results of detailed studies on the biology of *T. gigus* from Orissa coasts, near Balramgarhi, where this species occur in great abundance. Besides *T. gigus*, Chatterji and Perulekar (1992) and Chatterji *et al.* (1988) have also published some aspects of growth and fecundity of *C. rotundicauda*, based on some material procured from a supplier of Canning town near Calcutta. No survey of the area was carried out by them. This has prompted the present author to undertake the studies on this species in Sunderban region. The present paper reports the results of the studies carried out during the period 1988–92 on the occurrence and abundance of the species in different zones of Sunderban region and on their length-weight relationship, food and feeding habits, spawning behaviour and fecundity.

MATERIALS AND METHODS

A. Description of study area

The Sunderban estuarine and mangrove area lies on the world's largest delta, the Ganga-Brahamputra delta and exhibits a unique ecosystem. The entire area is situated at the mouth of rivers near Bay of Bengal and is criss-crossed with a large number of estuaries, their creeks and channels (Khals), forming a number of marshy islands. These islands support luxuriant mangrove forests and are subjected to total or partial submersion twice a day during high tides. Vast areas of mud flats appear around these islands during low tides and the intertidal mud flats harbour a variety of fauna.

The Indian Sunderban, which is one third of the total Sunderban (2/3rd in Bangla Desh) is mainly formed by an offshoot of major river-Ganga and its tributaries like Roopnarayan and Haldi etc. This part of the river Ganga, known as Hugly, is the main constituent of Hugly-Matla estuarine system. The entire Sunderban area falls under the administrative districts of North and South 24 Parganas of West Bengal State, near Calcutta, between the latitude 21°40' and 22°45' N and longitude 88°6' and 89°5' and covers an approximate area of 9630 sq. km. Out of this 4262 sq. km are forested and rest reclaimed areas. The forested area includes nearly 45% of water area.

Because of the uniqueness of the estuaries and mangroves, the region has been declared as a Biosphere Reserve which includes both, a Tiger reserve and 2 Bird sanctuaries. The region has also be designated as 'World heritage Site'

The Sunderban estuarine complex is mainly comprised of three major estuaries viz. Hugly-flowing in the extreme west of the region, Thakuran-Matla in the middle region and Harinbhanga-Raimangal forming the eastern boundary. These major estuaries are connected with a number of smaller distributories (Fig. 1).

The tides in the estuarine system is always strong and variable and the tidal limit extends upto 295 km in main river Hugly. The onset and duration of twice a day tides differ from day to day and season to season. The spring tide which occurs during first half of lunar month, lasts for 12-14 days. The neap tide period covers the rest of the lunar month. The intensity of spring tides is always higher.

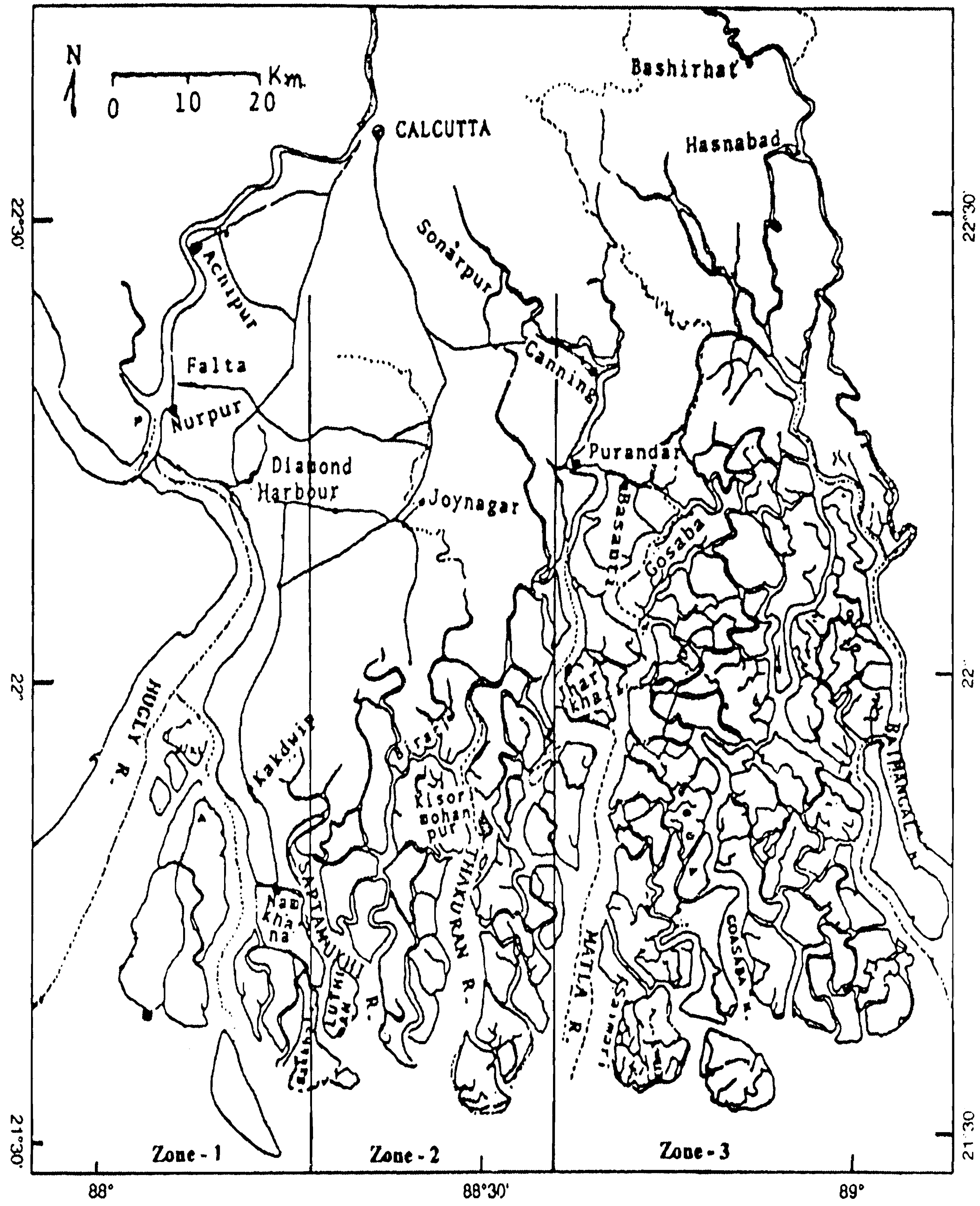

Fig. 1. Sunderban Estuarine Zone of Hughly-Matla System.

The climate in the region is hot and humid during most of the year with mean monthly temperature varying around 30°C except for a brief period in December-January when it drops to around 22°C. This comprises the brief moderate 'winter season' The climate is chiefly influenced by monsoon and therefore biological seasons are classified as Premonsoon (PRM, March-June), Monsoon (MON, July-Oct.) and Post monsoon (POM, Nov.-Feb.). These are further divided as early (I-the first two months) and late (II-the last two months).

Study Zones and sites

For the purpose of present study, the entire area was roughly divided into following three zones.

ZONE 1. **Hugly-Muriganga Zone**. The areas west of Saptamukhi river.

ZONE 2. **Saptamukhi-Thakuran Zone**. The areas east of Zone 1 and west of river Matla.

ZONE 3. **The Matla-Goasaba Zone**. Areas east of Zone 2 to the Indian boundary of Sundarban region.

B. Survey, Collection and Analysis

Extensive surveys of 40 randomly selected sites covering all zones were carried out as part of the programme on general faunal resources of Sundarban. Surveys were conducted during lowest of low tides on the days of observation, only during day light. At each site, a stripe of 100 m, between the low and high tide marks horizontally were searched thoroughly and occurrence of species was recorded. After carrying out extensive survey of the region for their occurrence, two sites were selected as detail study station, one each in Zone 2 and Zone 3. These were, Station 1-Purandar-Canning and Station II- Birati, near Pathar Protima. Studies were made on their movement on mud flats, their courtship and spawning behaviour.

For the study of morphometry, length weight relationships, food and feeding habits and fecundity, specimens were obtained from professional collectors, who sell these in local market for their use as '*Talisman*' Only telson is used for the purpose and the rest of animal body is of no use to faith healers.

The length and width of carapace and body weight of all species were measured to nearest millimeter and gram respectively. For size frequency distribution and fecundity, about 150 ova were measured and weighted portions were counted. Food and feeding habits were studied by removing the gut contents and sorting out the different food item. Identification was done to lowest possible taxa and their relative percentages were determined. Feeding intensity was calculated by classifying the guts into various stages of fullness. The food selectivity was studied by applying electivity index of Ivlev, as described earlier (Khan and Siddiqui, 1973).

$$E = \frac{ri - pi}{ri + pi}$$

Where ri is the relative content of any ingredient in the ration expressed as percentage of total ration and pi is the relative values of same ingredient in the food complex of the environment.

The values of E (electivity index) range between +1 and –1, former denoting complete positive selection and latter indicating negative selection (avoidance). A value of 0 represents the absence of any selectivity. For this, quantitative collection of macrobenthos were made by removing all animals within the measured area of 0.5x0.5 m with the help of wooden quadrate upto the depth of 15 cm and washed through a sieve of 0.5 mm mesh size. All animals retained on the sieve were picked up. Meiobenthos samples were collected with the help of a metal core sampler by pushing to a depth of 20 cm and drawing a sub samples using a plexi glass core of 0.75 cm diameter. The soil samples were washed thorough 0.5 mm mesh sieve and filtrates were preserved in 5% formalin and examined under a stereo-binocular microscope.

Feeding intensity was determined by observing the guts and arbitrarily classifying into various stages of fullness, as gorged, full, ¾ full, ½ full, ¼ full, traces and empty. These were converted into three categories *viz.* active (gorged, full and ¾ full), moderate (½ full and ¼ full) and poor (traces and empty).

RESULTS

Taxonomic position and general morphological features

The species is a chelicerate arthropod, the oldest group of arthropoda. Its present taxonomic position is :

Phylum	ARTHROPODA
Sub/Phylum	CHELICERATA
Class	MEROSTOMATA
Sub-class	XIPHOSURA
Order	XIPHOSURIDA
Family	LIMULIDAE
Sub-family	TACHYPLEINAE
Genus	***Carcinoscorpius***
Speceis	***C. rotundicauda***

Salient features

Carapace horse-hoof shaped, moderately rounded in anterior region (Fig. 2), chitinous, consisting of two parts, the anterior Prosoma and posterior Opisthozoma. The opisihozoma fits well into the posterior part of prosoma. Well developed spines on dorsal side of prosoma, numbering seven, one just behind the median ocelli. The posterior prosomal region three sided. A short but prominent spine in the middle. The ventral side of the carapace somewhat concave and bears six Paris of thoracic appendages. The chelae or the first pair are smooth, pointed and three segmented, situated just in front of mouth. Rest of the appendages six segmented, with tips reaching near the mouth.

PLATE - I

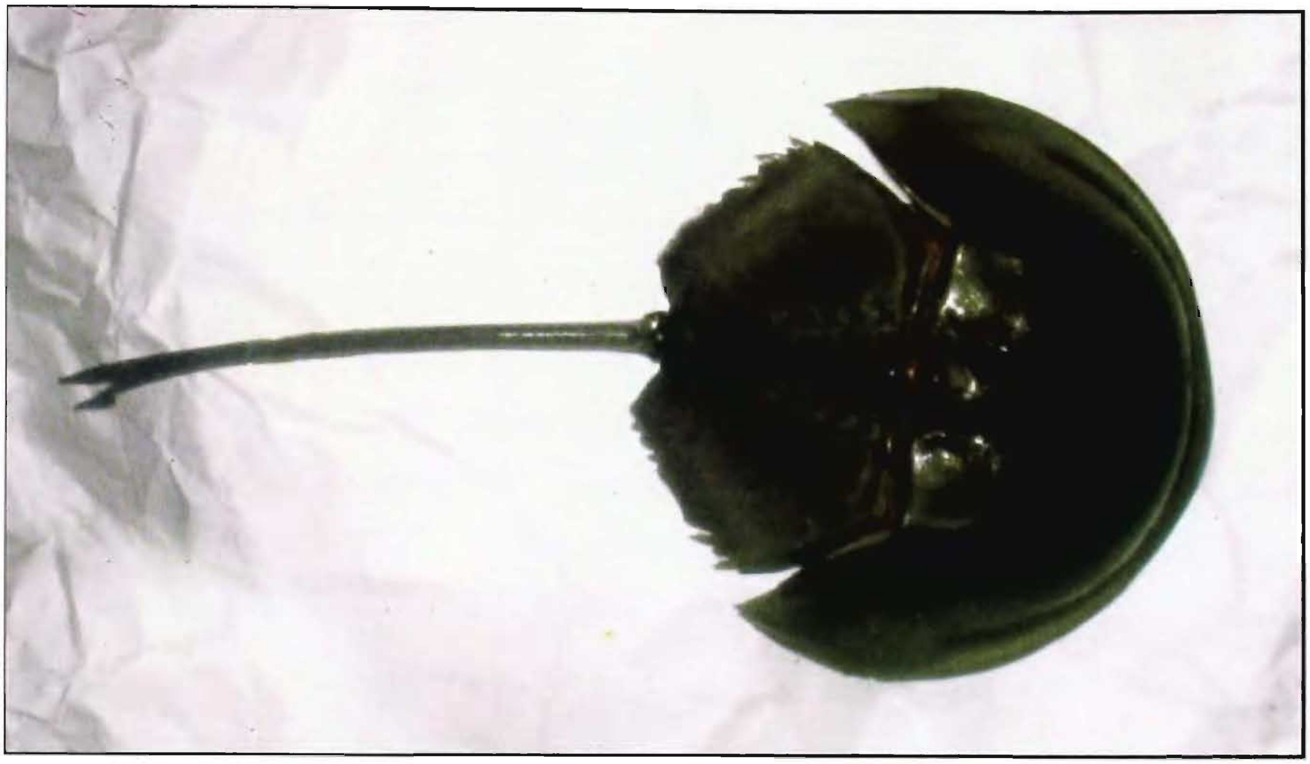

Fig. 2A. *Carcenoscorpius rotundicauda* (Latreille) from Sunderban estuarine system.- Dorsal view.

Fig. 2B. *Carcenoscorpius rotundicauda* (Latreille) from Sunderban estuarine system.- Ventral view.

The libia is fringed with flat forked structure. The chilaria is formed by plates joined together near the mouth; opisthosoma almost hexagonal, bearing six pairs of short, curved towards the telson marginal spines, two anterior one comparatively bigger in size than others. The posterior central margin is inflated towards both sides. In males spines are thin, comb or saw shaped and prominent but in females obtuse and not very distinct. Three spines along mid body line. The posterior margin is also three sided, concave but smaller than prosoma. A long pointed spear shaped telson, smooth, subcylindrical in cross section and flattened at the base. The second and third appendages of males are modified into well developed curved claspers. These claspers alongwith dactylopodite form a stout chela. The claspers are strong and blue-black in colour. No modification of thoracic appendages in females.

Under opisthosoma, there are six mesosomatic appendages near the first jointed operculum and genital pores. The genital pores are conical projections in males and broad slits in females. The other five appendages are identical but smaller in sizes and known as gill books. There are 10 gill books, each consisting of over hundred leaf like structure.

The maximum size of the species recorded during present investigations was 205 mm.

Distribution

This is an asian species, confined mainly to China, Japan, Thailand, Malaysia, Singapore, Borneo, Sabah, Brunei and northern Vietnam besides Sunderban region. Details of the distribution have been given by Mickkelsen (1988).

In India the distribution of the species is confined to Sunderban region of Hugly-Matla estuarine system and nearby coastal waters of Bay of Bengal. Ronwal (1946) observed the migration of this species into river Hugly, upto sixty km above the mouth. During present investigations, the species was found to occur only on the mudflats of Sunderban in lower region of the estuarine system near the mouth. It was never recorded from middle or upper zones.

Habitat

The species prefers mudflats in estuarine and mangrove zones and calm seas. While most of the life activity take place in open water, adults for the purpose of breeding migrate towards shores on intertidal flats.

Occurrence and abundance

Several extensive surveys conducted during 1988-92, covering different seasons, revealed that the occurrence of this species was not uniform in all zones and was localised in certain pockets. Out of 40 randomly selected sites, the species occurred only at 14 sites (Table 1). There were certain specific places, where it occurred regularly during different seasons. The species was not observed from most of the areas falling under Tiger Reserve area, inspite of dense mangrove vegetation.

Table 1. The occurrence of *C. rotundicauda* on intertidal flats of randomly selected sites of Sunderban.

Zones and Sites	Premonsoon	Monsoon	Postmonsoon
ZONE-I			
Site-1. Kakadwip	–	–	–
2. Namkhana	–	–	–
3. Bakkhali	–	–	–
4. Harwood point	–	–	–
ZONE-II			
5. Birati	+	+	+
6. Kishori Mohan Pur	+	+	+
7. Chulkati-Parsemari	–	–	+
8. Ajmalmari-Kaikalmari	+	–	–
9. Dhanchi	+	–	+
10. Printice Island	–	–	–
11. Curzan creek	–	–	–
12. Patahar Protima	–	–	–
13. Thakuran	–	–	–
ZONE-III			
14. Sajnakhali	–	–	–
15. Pirkhali	+	–	–
16. Sudhanyakhali	–	–	–
17. Nidithopani	–	–	–
18. Chamta	–	–	–
19. Saimari	–	–	–
20. Kalas	–	–	–
21. Kedokhal	–	–	+
22. Haldibari	–	–	–
23. Mayadweep	–	–	–
24. Sandeshkhali	+	–	+
25. Panchmukhani	+	+	–

Table 1. *Cont'd.*

Zones and Sites	Premonsoon	Monsoon	Postmonsoon
26. Gona	–	–	–
27. Chotahardi	–	–	–
28. Kalindi	–	–	–
29. Khatwajhuri	–	–	+
30. Bagna	–	–	–
31. Arbessi	–	–	+
32. Marijhapi, Jhila-1	–	–	–
33. Rajat Jublee	–	–	+
34. Gosaba	–	–	–
35. Rangabelia	–	–	–
36. Dayapur	–	–	–
37. Jamespur	+	–	–
38. Basanti	–	–	–
*39. Purandar	+		+
**40. Jharkhali	+	+	+

*Intensive study Station-1, **Intensive study Station-2

The occurrence in Zone 2 (Saptamukhi-Thakuran) was comparatively higher than Zone-3 (Matla-Goasaba). Out of 9 sites of Zone 2, the species was recorded from five sites. It occurred in all seasons at sites 5 and 6. Juveniles were also recorded from site 6. In zone 3, Purandar-Canning (site 39) and Jharkhali (site 40) were the two stations from where the species was recorded during all the seasons. In Zone 1, the species could not be observed at any of the four selected sites.

Table 2. gives the results of occurrence and abundance recorded from two intensive study station during the years 1990-91 and 1991-92. During first year the species was recorded in all seasons at both stations except during PRM-II, when it was absent from Station 1. Highest number of individuals was recorded during premonsoon period. At station 1, out of a total of 94 individuals observed, 74 occurred in premonsoon. Almost similar condition was noticed at Station-2. The overall density at Station-2 was lesser than Station 1, as only 55 individuals were recorded. During following year too, the occurrence and abundance patterns were marked by the abundance of individuals during premonsoon season at both stations. However, the species was altogether absent during MON-I at both Stations and was represented by only one female, each at the two stations

during MON-II. The overall population density was considerably lower than the previous year at both stations. Only 53 and 46 adult individuals were recorded from Stations 1 and 2 respectively. No juveniles were recorded. Baring one or two, all these were in the form of mating couples. This resulted in almost uniform sex ratio for most of times.

Table 2. Abundance of *C. rotundicauda* on Mudflats of two study stations.

Season	STATION-I				STATION-II			
	No. of males	No. of females	Total	Percent of total density	No. of males	No. of females	Total	Percent of total density
		1990-91						
PRM-I	27	27	54	54.45	16	16	32	58.18
PRM-II	10	10	20	20.20	3	3	6	10.91
MON-I	1	2	3	3.03	–	–	–	–
MON-II	2	4	5	5.05	2	2	4	7.27
POM-I	3	3	6	6.06	2	3	5	9.04
POM-II	5	6	11	11.11	4	4	8	14.54
Total	48	52	99		27	28	55	
		1991-92						
PRM-I	15	15	30	56.60	12	12	24	53.33
PRM-II	6	6	12	22,64	5	5	10	22.22
MON-I	–	–	–	–	–	–	–	–
MON-II	–	1	1	1.88	–	1	1	2.22
POM-I	2	2	4	7.54	2	2	4	8.88
POM-II	3	3	6	11,32	3	4	7	15.55
Total	26	27	53		22	23	45	

PRM-Premonsoon, MON-Monsoon, POM-Postmonsoon; I-early, II-late.

Length-Weight relationship

Measurements of 200 animals (80 males, 120 females) were utilised for the determination of LW relationship. Due to non availability of juveniles in sufficient numbers, their relationship could not be ascertained.

The regression equation calculated on the basis of Log body weight(W) and log carapace length (L) was linear and can be described as

$$\text{Log W} = -2.4431 + 2.2120 \text{ Log L (males)}$$

$$\text{or } W = 0.006137 L^{2.2120}$$

$$\text{Log W} = -3.8355 + 2.8464 \text{ Log L (females)}$$

$$\text{or } W = 0.006137 L^{2.2120}$$

The body weight of males was higher than females at lower size groups but females became heavier at larger sizes. The length weight curve (Fig. 3) of females crosses the curve of males at

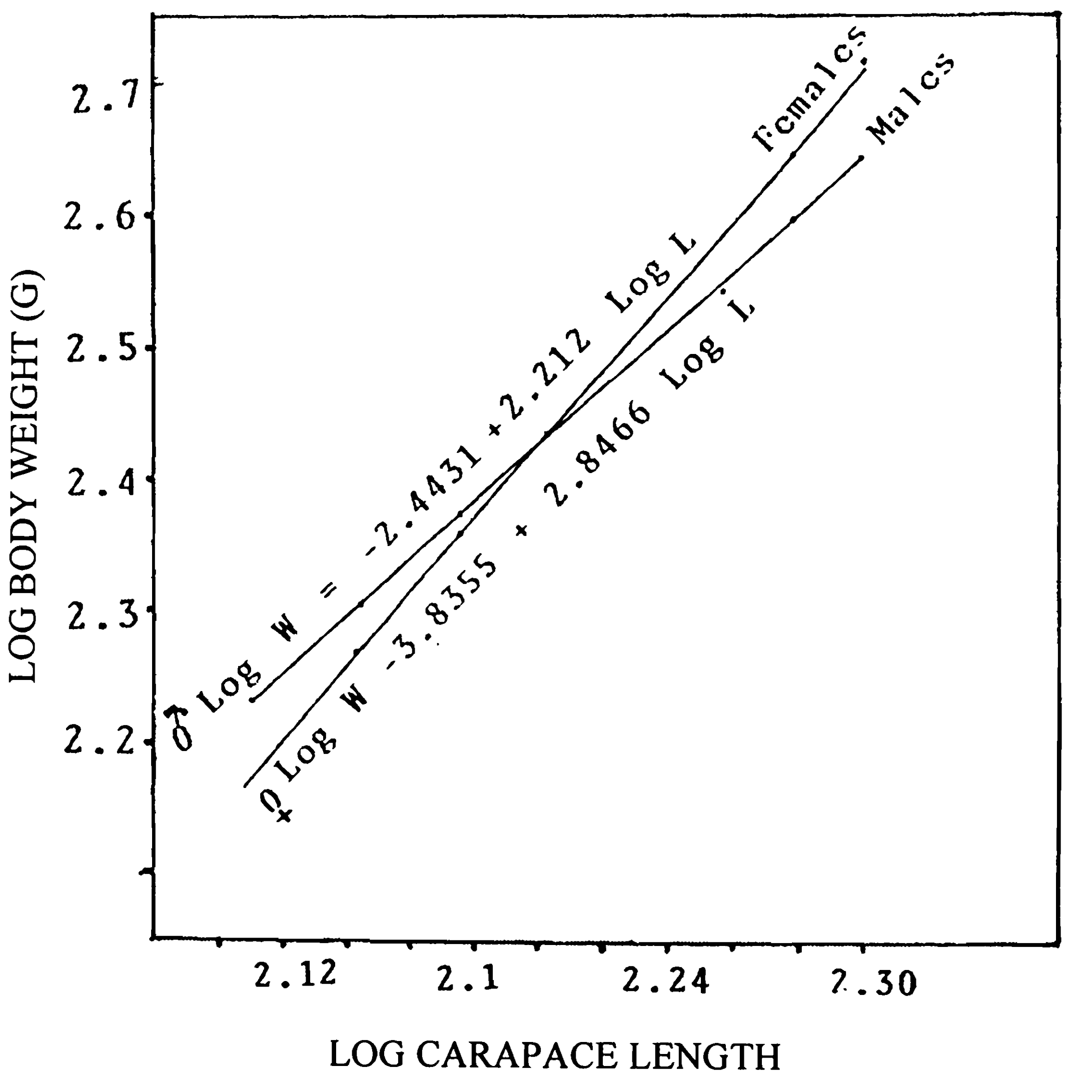

Fig. 3. Length-Weight Relationships of *C. rotunidicauda*

155 mm size group. The value of regression coefficient was also higher in females. However, the analysis of variance (ANOVA) revealed insignificant differences between the two sexes (Tables 3a and 3b) and therefore a combined relationship was worked out.

$$\text{Log W} = -3.138 + 2.5929 \text{ Log L}$$

$$\text{or } W = 0.000727 L^{2.5929}$$

Table 3a. Regression data of LW relationship of *C. rotundicauda*.

Sex	N	D.F.	Sum of square and product			b	Error of estimates	
			SX2	Sxy2	Y2		D.F.	S.S.
Male	80	79	0.28	0.6193	1.419	2.212	78	0.492
Females	120	119	0.42	1.1955	3.372	2.846	118	0.0309

Table 3b. Test of Significance.

Sources of variation	D.F.	Sum of squares	Mean squares	Observed	5% F
Daviation from individual regression with sex	196	0.801	0.0004	124.97	254.3
Differences between regression	1	0.59	0.5099		
Daviation from total	197	0.59			

Food and Feeding habits

(i) Food composition

The food of the species consisted chiefly by gastropods, bivalves, polychaetes and decayed organic matter. These four categories comprised nearly 80% of the diet (Table 4, Fig 4). Decayed organic matter, consisting mainly of plant substance, constituted by far the most abundant food item and its share in the diet varied between 15.8 and 38.3%. This was followed by bivalves (mean 20.7%) and gastropods (mean 19.0%). Polychaetes also contributed significantly (16.4%). The category "other animal groups", which was constituted by several benthic macroinvertebrates like Actinaria, Nemartea, Sipuncula, Echiura, Asteroidea, Ophiuroidea and other unidentified groups, contributed very little. The remaining categories were of little importance and their occurrence appeared to be accidental, particularly nematodes which were dominant component of meiofauna. Mud was an integral component of the diet which was probably ingested along with prey animals.

Marked variations in seasonal composition of the diet were recorded. During POM-I and II and also in PRM-I, molluscs (both gastropods and bivalves) were the chief food. Decayed organic matter contribution was highest during monsoon months. During premonsoon, the contributlon of polychaetes was maximum.

Table 4. Seasonal variations in the food composition of (%) *C. rotundicauda.*

	PRM-I	PRM-II	MON-I	MON-II	POM-I	POM-II	Annual Mean
Nematoda	1.7	1.6	2	1.9	2.1	1.6	1.8
Bivalvia	17.5	19.5	15.5	14.5	27.7	29.5	20.7
Gastropoda	27.8	13.5	14.4	15.8	19.2	23.4	19
Polychaeta	23.3	20.8	11.5	14.6	15.5	12.8	16.4
Copepoda	3.3	3	2.5	2	2.3	2.5	2.6
Brachyura	1.6	2.4	2	1.8	2	1.8	1.9
Other Crustacea	0.8	3.7	4.6	4	4.3	3	3.4
Other animals	2	7.1	8.8	4.1	7.5	5	5.8
Decayed organic matter	19.9	25.6	34.5	38.3	15.8	17.6	25.3
Mud	2.1	2.8	4.2	3	3.6	4.8	3.3

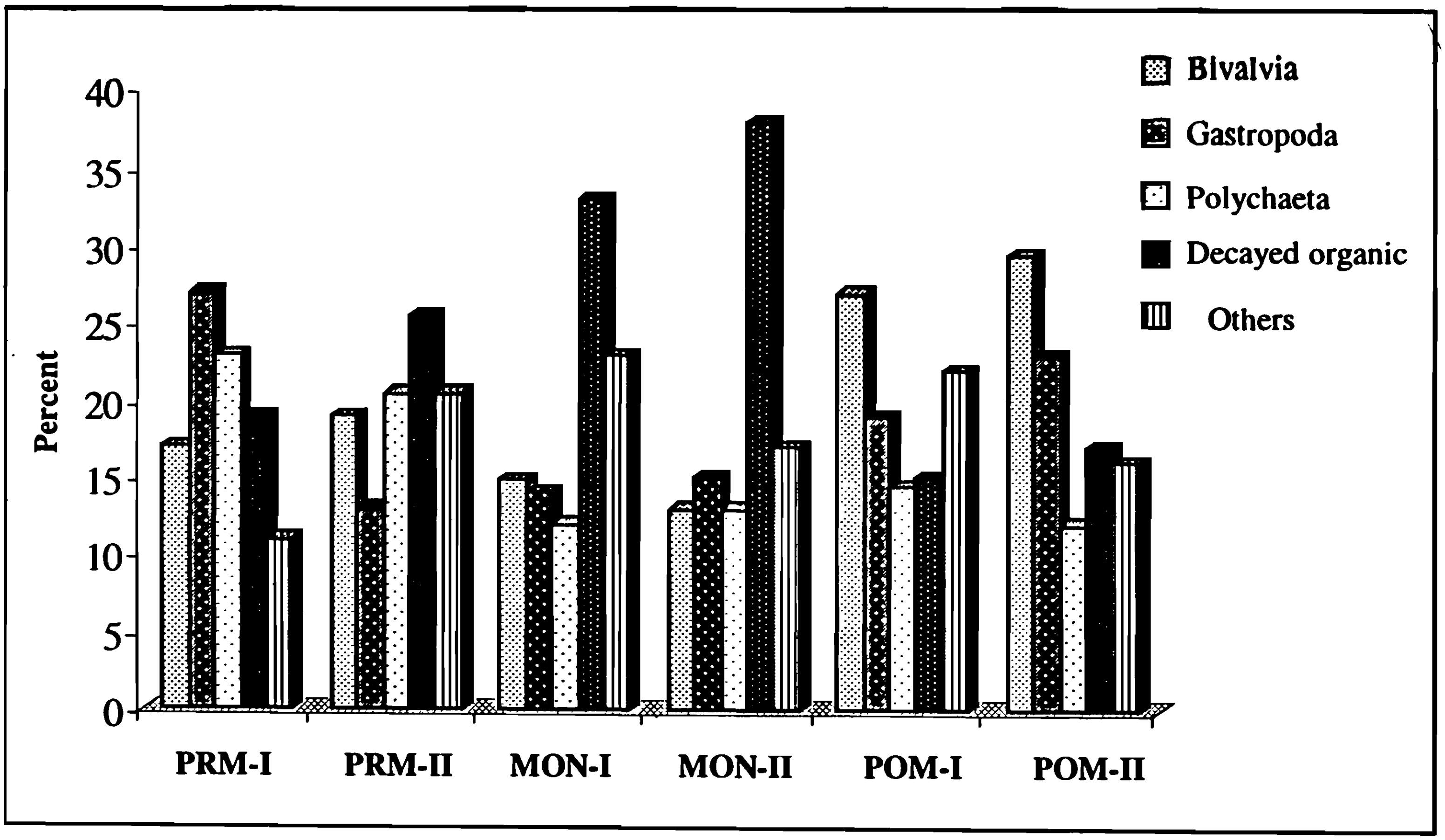

Fig. 4. Seasonal variations in the relative food composition of *C. rotundicauda.*

(ii) Intensity of feeding

Feeding intensity of the individuals studied was not overall good, as percentages of empty guts, guts with traces or ¼ full were high. While gorged guts were never observed, full and ¾ full guts were observed in small numbers during premonsoon and post monsoon months. The percentage of empty guts were highest during monsoon period, both in early and late part (Fig 5). The feeding intensity categorized as active, moderate and poor (Fig. 6) revealed that the ratio of actively fed individuals was highest in premonsoon which was followed by a sharp drop during monsoon. The highest ratio of poorly fed individuals was observed in monsoon-I. Thereafter conditions improved moderately during postmonsoon.

(iii) Food selection

Definite and strong food selectivity was noticed (Fig. 7). The animals fed on certain items vigorously and avoided some others equally, inspite of latter's abundance in the environment. The index of electivity revealed that out of 9 major categories for which comparable quantitative data were available, only three groups viz. bivalves (+0.619), polychaetes (+0.255) and gastropods (+0.221) were preferred with positive electivity indices. Rest of the categories were avoided, some very strongly, like nematodes (–0.620).

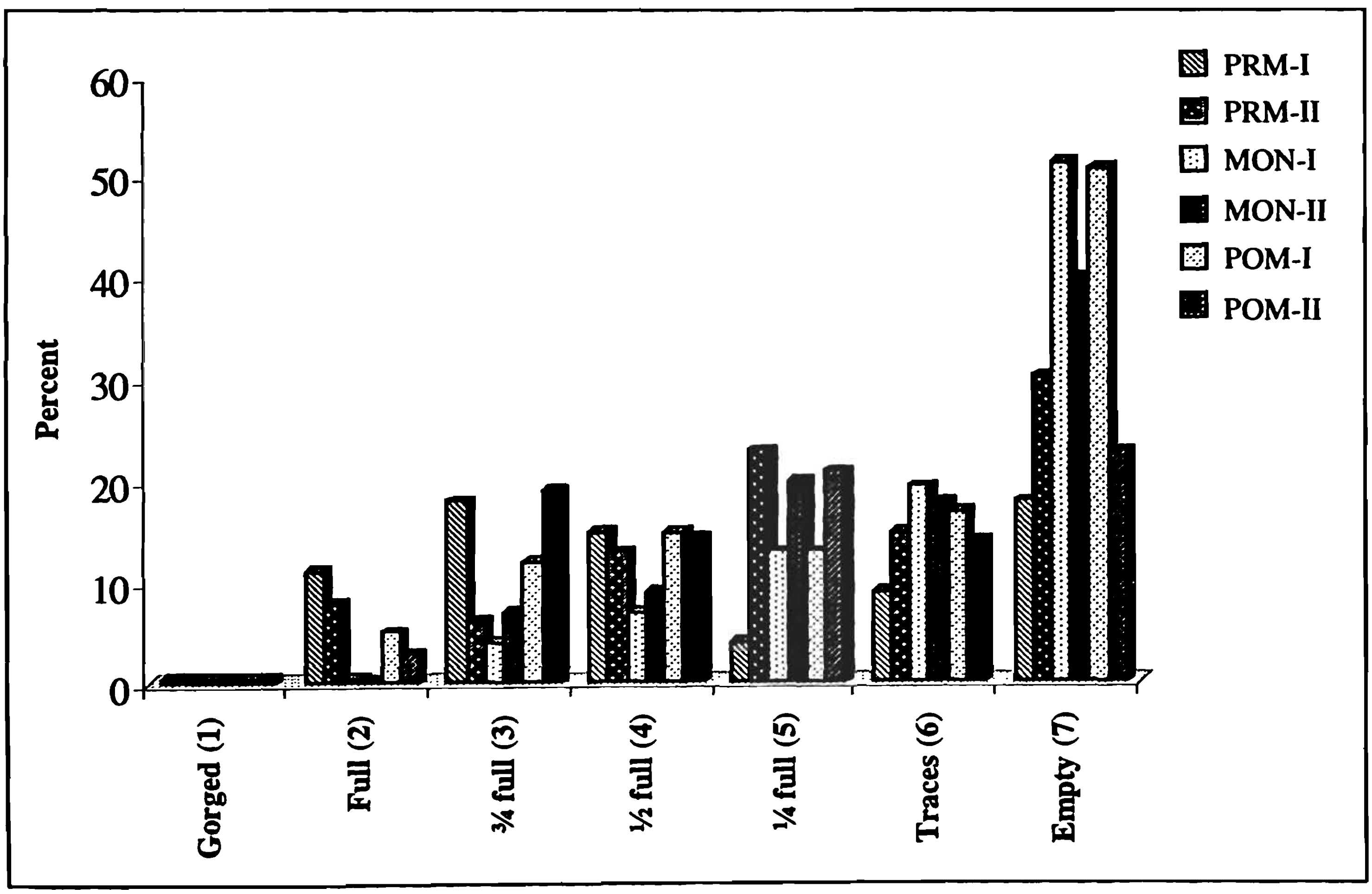

Fig. 5. Seasonal variations in the relative fullness of the guts of *C. rotundicauda*.

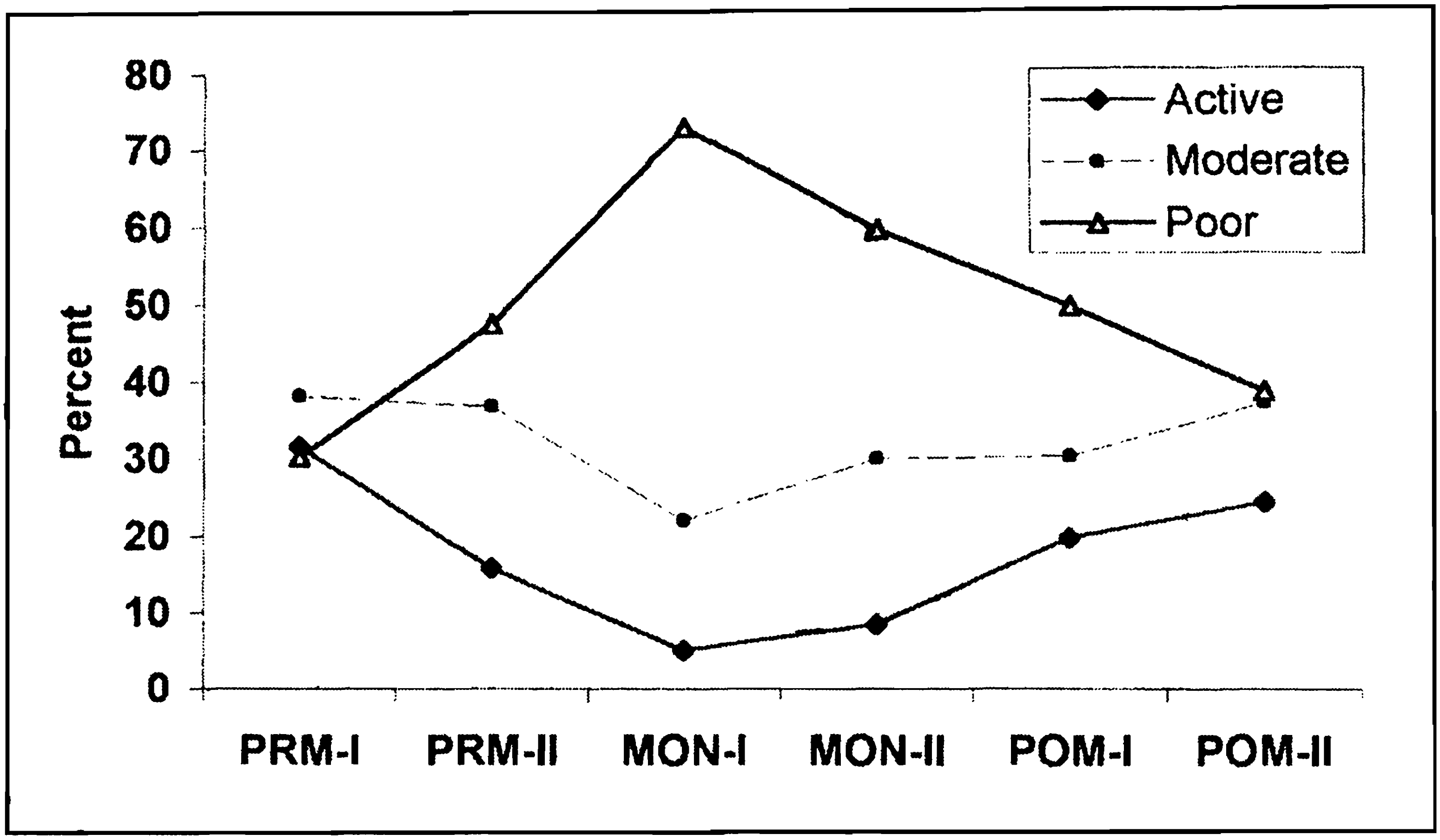

Fig. 6. Seasonal variations in the intensity of feeding of *C. rotundicauda.*

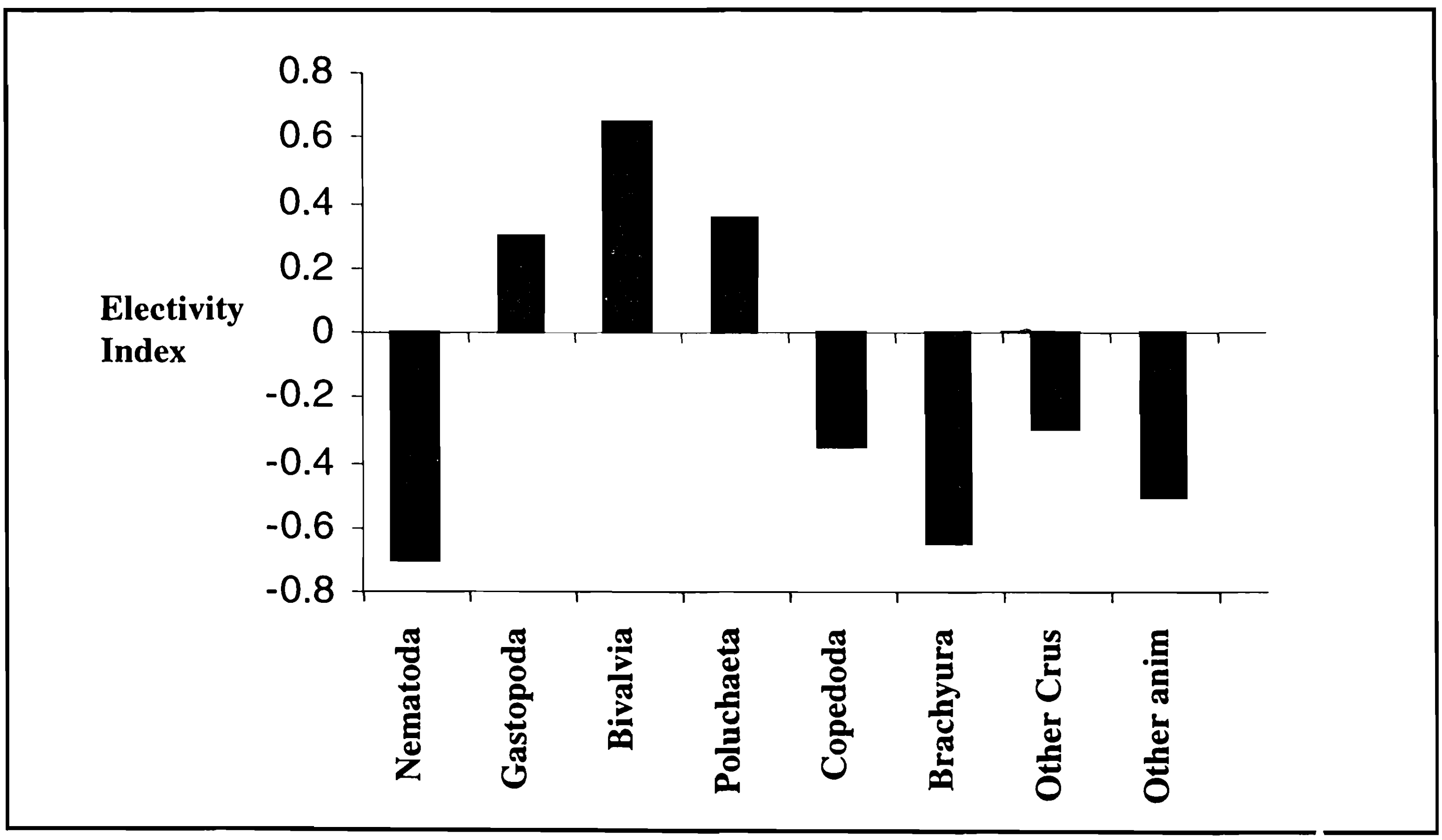

Fig. 7. Food selection in *C. rotundicauda.*

Reproduction

(i) Spawning behaviour

Animals occurred most of the time in spawning couples on mud flats during low tide of full moon period. With gradually receding water marks during low tides, animals were seen slowly coming out of water and crawling on soft mud. While crawling, the animals exhibited a peculiar behaviour. The females were moving while males comfortably positioned themselves on the top of females. They were attached to the prosoma of females completely. After reaching to a site, above mid tidal level, where the mud was not hard and retained some amount of water, the pair stopped. During courtship, males were either on top of female or besides female, sometimes upside down. Females were also seen lying sometimes upside down along with the males. Several turnings from ventral to dorsal and vice versa were noticed. After approximately 1½ or two hours, females started digging the soft mud for nests. Since the soil was soft, it took very little time to make a depression of just about her size in and 12-15 cm deep. The depth was such that after settling of females and males on her top, the entire depression was filled up and only top of the carapace of males was slightly visible from above. With the result, it was difficult to locate the spawning couples in the nest on mud flats. The animals remained in this condition till the next flooding during high tide. No animal was seen at the place of nesting after high tide receded which indicates their return to open waters.

Some females were lifted from the nests just before the flooding in order to examinee the eggs laid. Eggs were not found in all the nests. Out of 7 nests examined at Station-1, six contained the eggs and at Station-2, the eggs were present only in three out of 5 nests examined. Eggs were taken out with the help of a spoon and roughly counted after putting little water. After examination, the eggs and females were placed at their original position with minimal disturbance. The number of eggs laid ranged between 20-72 and measured between 1.25-1.50 mm. The non-occurrence of eggs in some nests indicated unsuccessful spawning. After high tide was over, no trace of eggs were found at the place where the nests were made. The fate of eggs could not be followed after the second tide. Because of the soft mud, the nests were also disappeared /distorted after flooding.

(ii) Spanning period

The spawning season was determined on the basis of the occurrence of adult males and females on mudflats involved in courtship. The frequency of occurrence of spawning couples in term of percentage of the total population during different seasons is given in Fig. 8. During premonsoon-I, all observed pairs at both stations were found involved in courtship. During next season also the ratio of spawning couples to total population was moderately high, but after that, both number of individuals and pairs involved in courtship were low.

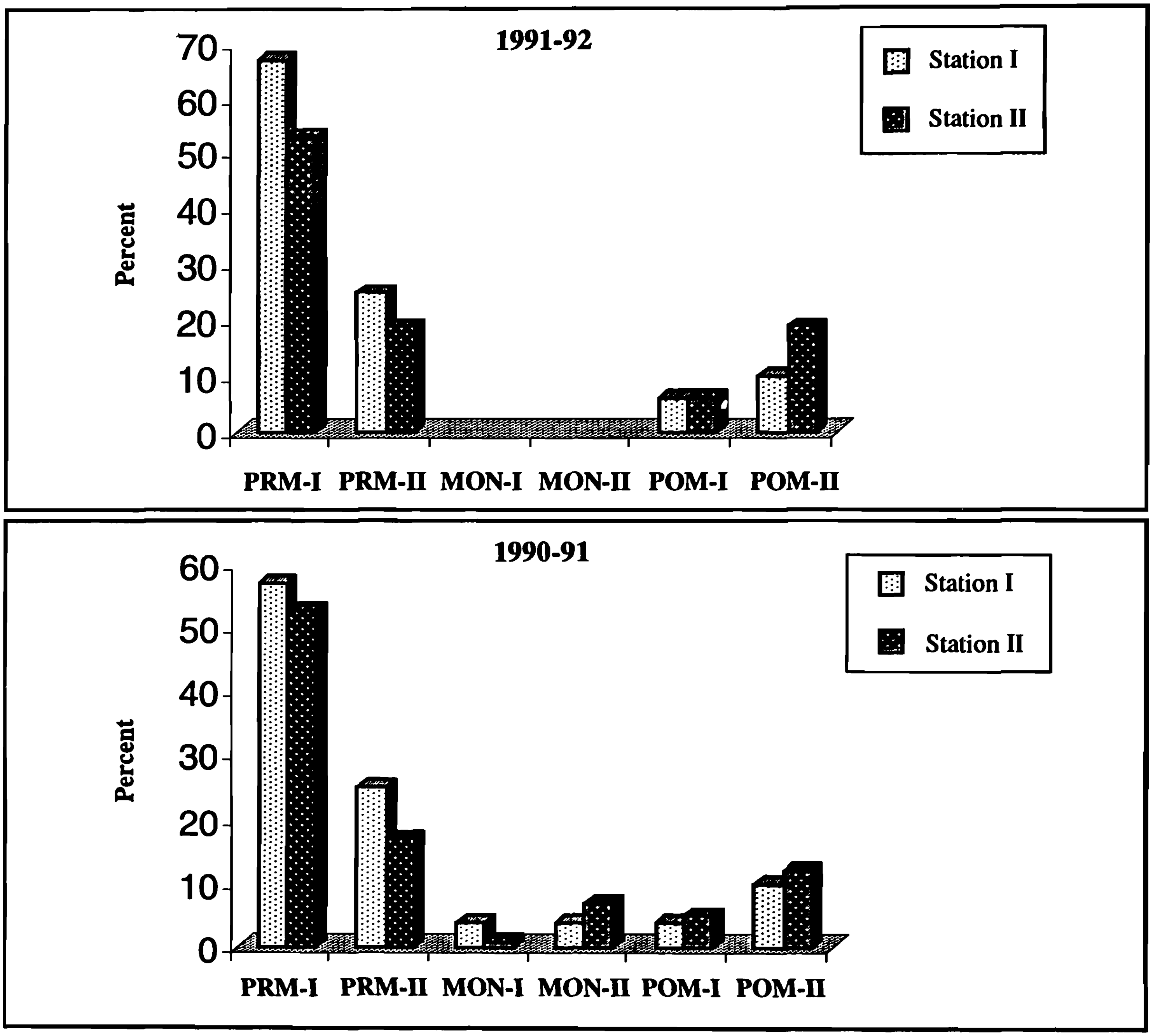

Fig. 8. Frequency of occurrence (percent) of spawning couple of *C. rotundicauda* during different months.

Occurrence of juveniles

During the period of study, juveniles were not seen on mudflats except at site –6, Kishori Mohanpur. The island gets totally submerged during high tides. It indicates the occurrence of juveniles in nearby waters but these generally do not come out of water. The occurrence of juveniles in the fishermen's nest also confirms this conclusion.

(iii) Fecundity

The fecundity of 120 specimens in the size range of 151 to 190 mm, varied between 3540 and 13490 eggs with a mean of 7942.5. The fecundity increased with increasing length and body weight. A significant relationship was observed between log-fecundity and log-body weight.

DISCUSSION

The occurrence and abundance of *C. rotundicauda* on mudflats of Sunderban were highly restricted as the species was recorded from only few specific locations, out of vast area covered under the region. The occurrence of other species of horse-shoe crabs on mud and sand flats at specific places and absence from several other places in the same region/area has also been reported by several earlier workers. Botton *et. al.* (1988) observed the occurrence of *L. polyphemus* in large numbers along the coasts of Delaware but its almost total absence from north beach, just a kilometer away and indicated the existence of very specific reasons for selecting a particular beach. This has been generally assigned to their inherent capabilities of distinguishing between suitable and unsuitable beaches/flats as the ground is to be used for a highly specific purpose of breeding. This innate mechanism of area selection ensures the animals for the survival of their young ones on mud flats. It has been suggested that such characteristics might be responsible for providing evolutionary advantages to the animals for their very long survival.

However, contrary to other species of the group, which occur in great abundance in the areas/ beaches of their occurrence, both in this country and other region of the world, the population density of *C. rotundicauda* in Sunderban region was extremely low, which was evident from very poor and almost rare occurrence as compared to vast area covered. Except during peak spawning season of early premonsoon (PRM-1), the number of individuals per transect, hardy exceeded 10 during full moon phase. In case of the other species occurring in Indian region, *T. gigus*, Chatterji *et. al.* (1992) reported the existence of a very dense population on sandy beaches of Balramgarhi, Orissa (Bay of Bengal), both during full moon and new moon. Since, *C. rotundicauda* occurs only in this area of the country, their extremely low population density is of great concern. Earlier reports (Annandale, 1909, Roonwal, 1944) indicate the occurrence of species even in River Hugly upto 60 Km upwards. This definitely indicates that the population density of the species has considerably gone down during last 50 years. The factors responsible for their decline are probably the exploitation of the animals by local people for their use in faith healing, besides the changing conditions of estuarine water and soil of mudflat due to degradation of main feeder river Hugly. As already indicated these animals are highly sensitive and select the beaches/flats for spawning with great degree of precession. The other factor which appears to contribute somewhat to their decline may be the wanton destruction by fishermen when caught in their nets, because of the damage they cause to their nets.

Though not very strictly, like other aquatic animals, the length-weight relationship of *C. rotundicauda* followed the cube law roughly as the weight of the body grew at an approximate rate of cube of length, at least in some stages of the life. The value of 'n' in LW curve (2.846 in females) was very close to theoretical 3. Although the analysis of variance did not show any significant differences in LW relationships of males and females, males were slightly heavier at lower size/age groups but reverse was the case in higher size or age group individuals. Curves of both males and females crossed at a point near 160 mm carapace length and this point of intersect in LW relationship generally signifies the onset of maturity in animals (Olsen and Merriman, 1946 in case of fish). It may be assumed that C. *rotundicauda* matures around this size range. However, as remarked by Chatterji *et. al.* (1988), in case of both, *T. gigus* and *C. rotundicauda*, it may not be safe to conclude definitely in the absence of smaller sized individuals in sufficient numbers.

Like many of the species of horse-shoe crabs, the molluscs (both gastropods and bivalves) alongwith decayed organic matter and polychaetes constituted the main food of *C. rotundicauda*. Botton (1984a) and Botton and Rope (1989) found that nearly 87% of the total diet of *L. polyphemus* was constituted by molluscs. Among the Indian species, *T. gigus*, Chatterji *et. al.* (1992b) also reported similar food composition, where molluscs and decayed organic matter contributed more than 50% of the diet. However, there were significant differences in the dietary composition of the two species. While molluscs, both gastropods and bivalves, constituted nearly 40% of the diet of *C. rotundicauda*, their share in the diet of *T. gigus* was only 25%. The contribution of arthropods, comprising mainly crustaceans and few insects was higher in *T. gigus* as compared to other species. The consistent occurrence of decayed organic matter comprising mainly of vegetative matters in considerably high quantities, revealed that the species fed actively upon detritus, besides animal matters. Both, *L. plyphemus* (Botton, 1984a) and *T. gigus* (Chatterji *et. al.*, 1992b) also subsisted heavily on vascular plants and detritus. The other food items were of almost no significance and their occurrence in the gut might be due to chance rather than intentional feeding. It appears that while both species feed on similar type of food, the relative share of different groups vary considerably. Probably this was an adaptation to avoid competition for food in the areas where the two species exist together. The occurrence of certain food items in insignificant quantities and others in considerably high quantities as compared to their availability in the environment exhibited the definite food selectivity of the species. Out of nine major categories, the electivity indices were positive for only gastropods, bivalves and polychaetes. Of these, the electivity indices of bivalves were very high. The occurrence of bivalves in Sunderban region is highly patchy and their overall relative density in macrobenthic composition was only 6.5%. It is quite evident that the horse-shoe crabs have to make tremendous efforts in search of this food item. Contrary to this, the electivity indices for other preferred food like gastropod (0.211) and polychaetes (0.255) were considerably lower than bivalves which indicated that these items were opted for only due to non-availability of bivalves in sufficient numbers. It was also noted that the most abundant component of meiobenthos, the nematodes and copepods were almost completely avoided by the species.

The choice of a particular species or set of species as food from the preferred category depends upon a number of factors of which the prey size is very important. The species fed all types of bivalves, provided their sizes were within its reach. Species with large shells like *Crossostrea, Saccostrea* and *Placuna* etc. were not found in the gut. Instead, small form like *Meretrix meretrix, Anadora granulosa, Solen brevis* etc. were of common occurrence. Similarly in case of gastropods, smaller individuals like those of *Assimina, Cerithidia* and *Ellobium* were found in the gut.

The preference of bivalves to such a degree, signifies their ability to meet the dietary requirements of *C. rotundicauda* to the maximum, because selection in aquatic organisms can only be expected, as pointed out earlier (Khan and siddiqui, 1973), if energy lost due to not utilising certain food resources is negligible in comparison to that gained by selection. Thus a predator will feed in a manner to get maximum reward of energy expended (MacArther and Levins, 1964). The other species of horse-shoe crabs from different parts of the world have also been reported to be selective in their feeding habits. Among preferred category of food items, species specificity has also been observed. Botton (1984a) reported that *L. polyphemus* selected certain species of bivalves and at the same time avoided the other species which was most abundant in the environment. Similarly *T. gigus* (Chatterji *et. al.*, 1992b) preferred *Perna* sp. amongst bivalves.

The breeding activities of *C. rotundicaua* was almost similar to other species of horse-shoe crabs. As reported for *L. polyphemus* (Rudloe, 1980, 1985; Howard *et. al.*, 1984 and Cohen and Brockmann, 1983) and for *T. gigus* (Chatterji *et. al.*, 1992a), the spawning activity of *C. rotundicauda* was also found to be governed by lunar cycle, as maximum number of spawning couples were seen on the day of full moon. In all species of horse-shoe crabs, definite migration takes place from sea and estuaries to shores for spawning activity and *C. rotundicauda* was no exception. However, differences in specific patterns were visible in different species. Mating in *L. polyphemus* was recorded during high tides as against *C. rotundicauda* where it took place during low tides with sufficiently exposed mud flats. Further, spawning in the latter took place during daylight as against the observation of certain authors in case of *L. polyhemus*, which was found to spawn during night (Cavanaugh, 1975). *T. gigus* was also found to spawn during day time. The spawning season of horse-shoe crabs has been reported to vary from region to region and species to species (Sekiguchi and Nakamura, 1979, Rudloe, 1980). *T. gigus* on Balramgarhi coasts was found to breed throughout the year. Mating couples of *C. rotundicauda* were mainly seen during premonsoon-1 season which extended to premonsoon-II season. During rest of the period the activity was minimum, indicating the restricted spawning season. Since no other period of increased activity was noticed, it can be concluded that the species on Sunderban mud flats spawns only once in a year during premonsoon period. Contrary to this, Sekiguchi and Nakamura (1979) observed the breeding activity of this species on muddy sides of river beds in Gulf of Siam and Thailand throughout the year.

The selection of nesting sites by horse-shoe crabs is not well understood and it could also not be assessed during the present investigations. It was not clear which factor stimulated the animals to select one point and reject the other, when there were no apparent differences in the physico-chemical and biological nature of water or soil of mud flats in lower Sunderban region (Khan, 1995). Botton *et. al.* (1988) observed that animals detect the beach characteristics on the rising tides and avoid migration towards unsuitable beaches. Chatterji *et. al.* (1992a) related the migration and spawning activities to general sediment characteristics (grain size) in case of *T. gigus*. Many earlier workers have already pointed out the importance of this factor (Willams 1987, Botton and Haskin 1984). Further studies are required in case of *C. rotundicauda* on such lines.

The fecundity and clutch size of horse-shoe crabs differed widely between the species and within species between individuals, depending upon various environmental and biological factors. Novitsky (1984) found that *L. polyphemus* laid about 80,000 eggs in different nests with each nest having approximately 300 eggs. In case of *T. gigus,* Chatterji and Parulekar (1992) reported that total number of ova varied between 1242 and 6565 with a mean of 3748 and there was significant relationship of fecundity with carapace length and body weight. In case of *C. rotundicaua,* these authors reported the range of fecundity as 4217 to 10,982 with a mean of 7438. The fecundity of the species observed during present investigations varied between 3540 and 13490 with a mean of 7942, which was very close to those observed by Chatterji and Parulekar (1992).

SUMMARY

(1) Out of four extant species of horseshoe crabs, one species, *Carcinoscorpius rotundicauda* (Laterille) occur only in Sunderban estuarine region and adjoining coastal waters of Bay of Bengal in Indian region. The occurrence, abundance, seasonal variation, length-weight relationship, food and feeding habits and reproduction of the species were studied on mud flats of the estuarine system between the period 1988-92.

(2) In the vast area of estuarine mud flats surveyed, the species occurred only at few specific sites and that too in small numbers. Out of 40 randomly selected sites, the species was recorded, one time or other, at 14 sites and only at 3 sites it occurred regularly in all seasons.

(3) Detailed studies on their occurrence and abundance were carried out at two study stations for two years, 1990-1991 and 1991-1992. Maximum density was noticed during early premonsoon (March-April), followed by late premonsoon (May-June). During other seasons its abundance was very low. Most of the individuals observed on mud flats were adult pairs. Juveniles were not recorded from these study stations.

(4) Although length-weight relationship of the two sexes did not differ significantly, males were found to be slightly heavier than females at early size groups and reverse was the case at higher size groups.

(5) The food of the species mainly consisted of bivalves, gastropods, polychaetes and decayed organic matter. The intensity of feeding was not generally good except during late post monsoon and early premonsoon seasons. Species was found to feed selectively as electivity indices were considerably higher for certain categories of food items like bivalves, gastgropods and polychetes. All other categories were avoided as exhibited by negative indices.

(6) Spawning season of the species was generally confined to early premonsoon season or at the most extending to late premonsoon. Spawning couples migrated to shores, specially during daylight of full moon period, with females carrying the males on their top. After courtship females dug nests, approximately 12-15 cm deep and laid eggs and males fertilized. The entire activity was

completed before the onset of next high tide. Neither adults nor their eggs could be traced during following low tides. The fecundity of the species as determined by the examination of specimen in laboratory varied between 3450 and 13490 with a mean of 7942.

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REFERENCES

Annandale, N. 1909. The horse-shoe crab, *Tachypleus gigus* (Muller). *Rec. Indian Mus.*, **3** : 294-295.

Barber, S. D. 1956. Chemoreception and proprioreception in *Limulus. J. experimental Zool.*, **131** : 51-69.

*Botton, M. L. 1982. Perdition of adult horseshoe crab, *Limulus polyhemus* (L) and its effects on benthic intertidal community structure of breeding beaches in Delaware Bay. New Jersy. *Ph.D. thesis*, Rutgers Univ. N.J. : 466 pp.

Botton, M. L. 1984a. Diet and food preferences of adult horse-shoe crab, *Limulus polyhemus* in Delaware Bay, New Jersy, USA. *Mar. Biol.*, **81** : 199-207.

Botton, M. L. 1984b. The importance of predation by horse-shoe crab, *Limulus polyhemus* to an interidal sand flat community. *J. Mar. Res.*, **42** : 139-161.

Botton, M. L. 1984c. Pattern of abaundance of horse-shoe crab, *Limulus polyhemus* in Delaware Bay and coastal New Jersy. *Bull. N.J. Acad. Sci.*, **27** : 39.

Botton, M. L. and Haskin, H. H. 1984. Distribution and feeding of horseshoe crab, *Limulus polyhehemus* on the continental shelf, New Jersy. *Fish. Bull.*, **82** : 383-389.

Botton, M. L., Loveland, R. E. and Jacobsen, T. R. 1988. Beach erosion and geochemical factors : influence on spawning success of horseshoe crab (*Limulus polyphemus*) in Delaware Bay. *Mar. Biol.*, **99** : 325-332.

Botton, M. L. and Ropes, J. W. 1989. Feeding ecology of horseshoe crabs on the continental shelf, New Jersy to North Carolina. *Bull. Mar. Sci.*, **49** : 737-647.

Cavanaugh, C. H. 1975. Observation on mating behaviour in *Limulus polyhemus. Bio. Bull.*, **149** : 419-453.

Chatterji, A., Vijayakumar, R. and Parulekar, A. H. 1988. Growth and morphometric characteristic in horseshoe crab, *Carcinoscorpius rotsundicauda* (Latreille) from Canning, West Bengal, India. *Pak. J. Sci. Ind. Res.*, **31** 352-353.

Chatterji, A. and Parulekar, A. H. 1992. Fecundity of Indian horseshoe crab, *Carcinoscorpius rotundicauda* (latreille). *Tropical Ecology*, **33** : 97-102.

Chatterji, A., Vijayakumar, R. and Parulekar, A. H. 1992a. Spawning migration of Indian horseshoe crab, *Tachypleus gigus* (Muller) with lunar cycle. *Asian Fisheries Sci.* **5** : 123-128.

Chatterji, A., Mishra, J. K. and Parulekar, A. H. 1992b. Feeding behaviour and food selection of Indian horseshoe crab, *Tachypleus gigus* (muller), *Hydrobiologia,* **246** : 41-48.

Cohen, E. (Ed.) 1979. *Biomedical Application of the Horseshoe Crab (Limulidae*). Alan R. Liss. Inc., New York : 688 pp.

Howard, H. A., Fiordalice, R. W., Camara, M. D., Kass, L., Powers, M. K. and Barlow, R. B. Jr. 1984. Mating behaviour of *Limulus* : relationship to lunar phase, tide height and sunlight. *Biol. Bull.,* **167** 527.

Khan, R. A. 1995. Ecology of Hugly-Matla estuarine system. In *Zool. Survey of India, Estuarine Ecosystem series, Part 2 : Hugly-Matla Estuary* : 417-464.

Khan, R. A. and Siddiqui, A. Q. 1973. Food Selection by *Labeo rohita* (Ham.) and its feeding relationship with other major carps. *Hydrobiologia*, **43** : 429-442.

MacArther, R. and Levins, R. 1964. Competition, habitat selection and character displacement in a patchy environment. *Proc. Nat. Acad. Sci.*, **51** 1207-1210.

Mikkelsen, T. 1988. *The Secret of Blue Blood.* Science Press, Beijing : 124 pp.

Novitsky, T. J. 1984. Discovery to commercialization : The blood of horseshoe crab. *Oceanus,* **27** : 13-18.

Olsen, Y H. and Merrinam, D. 1946. Studies on the marine resources of Southern New England. IV The biology and economic importance of the ocean part *Macrozoarees americanus* (Bloch and Scheneider). *Bull. Bingham. Oceanogr. Collect,* **9** : 1-184.

Price, J. T 1971. *The Origin and Evōlution of life*. The English Univ. Press Ltd. London : 113 pp.

Rama Rao, K. V and Surya Rao, K. V 1972. Studies on Indian King Crab (Arachnida : Xiphosura). *Proc. Indion Nat. Sec. Acad.*, **38** : 206-211.

Roonwal, M. L. 1944. Some observation on the breeding biology and on swelling weight, water content and embryonic movement in the developing eggs of the Moluccan King Crab, *Tachypleus gigus*, Muller) *Proc. Indian. Acad. Sci.*, **20**(B) : 115-119.

Rudloe, A. 1980. The breeding behaviour and patterns of movement of horseshoe crab, *Limulus polyhemus* in the vicinity of breeding beaches in Apalache Bay, Florida, *Estuaries,* **3** : 177-183.

Rudloe, A. 1979. *Limulus polyhemus.* A review of the ecologically significant literature. In : *Biomedical Application of Horseshoe crab (Limulidae*). E. Cohen (ed.) Alan. R. Liss. Inc. New York : 27-35.

Rudloe, A. 1981. Aspects of the biology of juvenile horseshoe crab, *Limulus polyhemus. Bull.Mar. Sci*, **31** : 125-133.

Rudloe, A. 1985. Variation in the expression of lunar and tidal behavior rhythms in the horseshoe crab, *Limulus polyhemus*, *Bull. Mar. Sci.*, **36** : 388-395.

Sekiguchi, K., Nakamura, K., Sen, T. K. and Sugita, K. 1976. Morphological variations and destribution of horseshoe crab, *Carcinoscorpius rotundicauda* from the Bay of Bengal and Gulf of Siam. *Proc. Jap. Soc. Syst. Zool.*, **15** : 24-30.

Sekiguchi, K. and Nakamura, K. 1979. Ecology of extant horseshoe crab. *Progr. Clin. Biol.*, **29** 37-45.

Willams, K. L. 1987. A study of horseshoe crab egg distribution with respect to intertidal depth and geographical gradients on three Delaware Bay beaches in New Jersey. *Rep. New Jersy Bept. Environ. Prot., Div. Of Fish, Game and Wildl.*

*Not consulted in original