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Feeding behaviour and food selection in the horseshoe crab, *Tachypleus gigas* (Müller)

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Abstract

The Indian horseshoe crab, *Tachypleus gigas* (Müller), is a benthic feeder which subsists mainly on molluscs, decayed organic matter and polychaetes, in order of prevalence. A strong and positive preference was recorded for molluscs over other food organisms. The intensity of feeding was maximum during the north-east monsoon (November to January) in females and during the intermonsoon season (February to May) in males. It was minimum during the south-west monsoon (June to September).

Introduction

The horseshoe crab – a living fossil – is represented by two species along the north-east coast of India. One of these, *Tachypleus gigas* (Müller) is abundant in the shallow nearshore waters off Balramgari coast. It has also been reported from Malaysia, Singapore, Gulf of Siam, Sarawak, Kudat and Torres Straits (Sekiguchi *et al.*, 1976). Yet, little is known about its biological features. Here, we report the results of a study on food, feeding habits and food selection in *T. gigas* in relation to its maturation cycle.

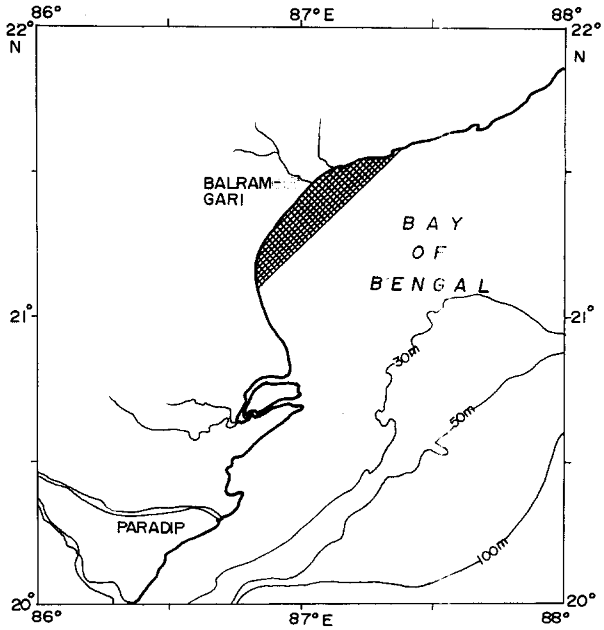

Fig. 1. Map of the area of study (hatched zone).

Materials and methods

A total number of 306 specimens of *T. gigas*, ranging in size from 90–170 mm were collected from March 1988 to April 1989 from 4–10 m depth off Balramgari (Lat 21° 17′ N; Long 87° 00′ E) (Fig. 1). A mechanized boat (40 feet length) fitted with a bottom trawl (mouth width 8.5 m) was operated twice a month, coinciding with full/new moon. During these phases, maximum number of horseshoe crabs move towards the shore. The speed of the boat (1 knot) and duration of each haul (2 hours) was kept constant. Per day, the total number of crabs collected during three hauls were pooled.

Each crab was measured for carapace length by a Vernier Caliper, weighed to 0.1 g, and sexed. The samples were grouped in eight size groups of 10 mm each (I: 90–100; II: 101–110; III: 111–120; IV: 121–130; V: 131–140; VI: 141–150; VII: 151–160 and VIII: 161–170 mm). The digestive tract was removed from the foregut (oesophagus and gizzard) to the hind gut (ventriculum), weighted to 0.5 g, and preserved in 10% formalin.

The contents of the digestive tract were transferred to 10% ethanol. The method of Chatterji *et al.* (1977) was followed for the analysis of the food items. The gut content was sorted under a stereoscopic microscope, identified to the lowest possible taxon, and counted. The relative abundance of each food item was expressed as a percentage of total number of food items in the sample. Percentage of decayed organic matter and sand particles were determined by eye estimation. The intensity of feeding was studied by determining the gastro-somatic index (gut weight expressed as percentage of body weight) as described by Chatterji *et al.* (1977). The number of crabs with empty guts was also noted per month and expressed as a percentage of the total number of crabs examined that month.

Simultaneously, duplicate benthic samples were collected along the tract of trawling by deploying a 0.04 m^2 Van Veen grab. Processing and analysis of meio and macrobenthic samples followed the method of Parulekar *et al.* (1976). A plexi-glass core of 0.75 cm dia with a penetration of 12.7 cm was used to collect undisturbed samples from the grab for analysis of meiobenthos. The samples were preserved in buffered formalin containing Rose Bengal and sieved through 45 μm mesh in the laboratory. Macrobenthos samples were sieved through a 0.5 mm mesh screen. The animals retained on the screen were preserved, identified and counted.

The electivity index (E) was used as a measure of food selection (Ivlev, 1961):

$$E = \frac{r_i - p_i}{r_i + p_i}$$

'r_i' is the relative amount of any food item in the gut (expressed as a percentage of the total amount of food items) and 'p_i' the relative abundance (%) of the same food items in environment.

Results

Food selection

In the environment, bivalves were the most abundant potential macrobenthic food item encountered throughout the period of study. They accounted for 34.4% of the total (Table 1). The electivity index calculated for the four most frequent food items, during different seasons, is presented in Fig. 2. Maximum electivity was found for all food items during the south-west monsoon, except for 'miscellaneous' (Foraminifera, Nema-

Table 1. Abundance of different benthic organisms in the study area.

Groups	March 1988	April	May	June	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan 1989	Feb.	March	April	Mean
Mollusca	42.4	62.4	7.7	3.2	0.8	3.4	–	–	19.1	6.5	3.4	3.4	8.7	10.2	14.2
Arthropoda	27.5	12.0	1.2	1.4	2.6	6.1	2.8	10.9	1.0	0.4	1.5	1.6	0.8	1.2	5.0
Annelida	14.0	13.1	1.2	1.0	0.8	2.0	–	–	0.5	0.4	0.9	1.7	1.0	1.0	3.1
Miscallaneous	16.1	12.5	89.9	94.4	95.8	11.5	97.2	89.1	79.4	92.7	94.2	93.3	89.5	87.6	74.5

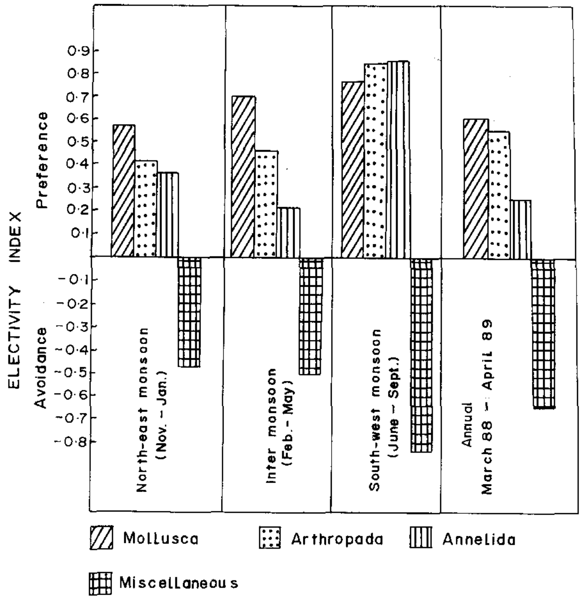

Fig. 2. The electivity indices of different major food items during March, 1988 to April, 1989.

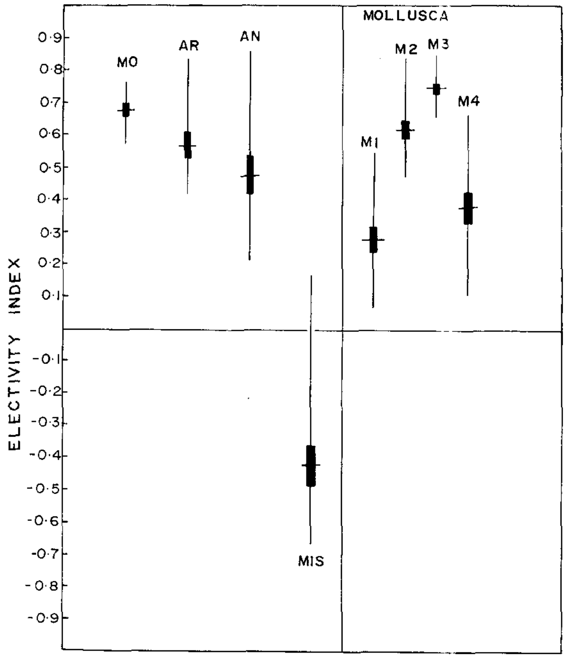

Fig. 3. Values of electivity index (E) for four of the most frequently occurring food items in *T. gigas* guts. Horizontal lines represent the mean, dark rectangles the standard error and vertical lines the range of the electivity index. (The groups are abbreviated as follows: MO = Molluscs; AR = Arthropods; AN = Annelida; MIS = Miscellaneous food items; M1 = *Mya* sp; M2 = *Perna* sp; M3 = Unidentified bivalves; M4 = Unidentified gastropods).

toda, Turbellaria, Euphausiaceae, Tanaidaceae, Penaeidea, Cumacea, Sipunculida, Hydrozoa and Ophiuroidea). A 2-way analysis of variance (ANOVA) was used to determine if seasons contributed to variability in the selection of the four major food items in the guts. During the south-west monsoon, electivity indices were significantly different from those in other seasons (ANOVA, $p > 0.05$).

The electivity index was positive for all items in all seasons except for the miscellaneous group (Fig. 3). Among molluscs, bivalves (*Mya* sp, *Perna* sp) and unidentified bivalves were preferred over gastropods (Fig. 3). A strong avoidance of gammarid amphipods was observed, although these occurred in almost all months in the environment (22.5%). Similarly, electivity of polychaetes was lower than for molluscs and contributed to only 5.2% of the gut content, against 18.5% in the environment.

Food composition

Seasonal variations in food composition showed that molluscs form the main item. They contributed 24.7% of the total food consumed (Table 2). Amongst molluscs, bivalves contributed most (34.4%) and occurred in most of the months. The maximum percentage (23.7%) of bivalves was encountered in the month of March, and the minimum (5.3%) in June. The maximum number of gastropods were observed in January (16.2%) and the minimum in July (4.5%).

Insects and unidentified crustaceans constituted 9.8% of the diet. Insects and unidentified crustaceans were highest in April 1988 (16.7%) and March 1989 (9.8%) (Table 2). Other food items encountered were harpacticoid copepods (2.7%) and cirripeds (1.6%). This group, consisting also of *Nereis*, *Glycera*, Oligochaeta, Phyllodocidae and unidentified polychaetes, formed 8.4% of the total diet. Polychaetes (5.2%) were consumed during most months with maximum intake in December (11.6%) and minimum in July (2.2%).

Foraminifera, nematoda, fish, turbellaria and

Table 2. Monthly variations in the percentage composition of different food items in the gut of *T. gigas* (data based on prey percentages).

Food items	March 1988 (29)	April (28)	May (23)	June (21)	July (22)	Aug. (19)	Sept. (8)	Oct. (11)	Nov. (15)	Dec. (18)	Jan. 1989 (32)	Feb. (28)	March (30)	April (22)	Mean (306)
Hya	3.4	2.3	2.5	0.7	1.9	–	–	–	3.8	3.6	1.6	2.8	3.1	1.0	1.9
Mytilus	6.2	5.8	2.5	0.1	–	–	–	–	–	–	2.2	1.9	2.7	0.8	2.7
Unidentified bivalve	10.8	9.2	8.2	4.5	4.8	–	–	–	18.5	19.5	16.2	13.5	17.9	15.8	12.6
Unidentified gastropods	5.2	6.5	5.3	7.2	4.5	–	–	–	7.2	8.9	12.5	10.2	6.5	9.2	7.5
MOLLUSCA	25.6	23.8	18.5	12.5	11.2	–	–	–	29.5	32.0	32.5	28.4	30.2	26.8	24.7
Copepoda	6.8	3.8	2.8	1.9	2.8	–	–	–	2.8	3.8	1.5	1.8	0.8	1.2	2.7
Insecta	6.7	6.2	1.9	2.8	3.4	–	–	–	2.5	4.8	3.9	1.5	3.3	1.9	3.3
Cirripedia	2.5	3.8	1.2	–	0.8	–	–	–	3.9	1.7	–	0.9	0.9	0.2	1.6
Unidentified crustaceans	4.8	10.5	8.9	5.6	5.8	–	–	–	7.8	10.2	3.2	2.4	6.5	5.9	6.5
ARTHROPODA	20.8	24.3	14.8	10.3	12.8	–	–	–	17.0	20.5	8.6	6.6	11.5	9.2	14.2
Nereis	0.9	1.9	2.0	2.6	0.8	–	–	2.0	2.1	3.1	1.0	0.9	1.2	1.0	1.5
Glycera	0.6	–	1.2	–	0.7	–	–	1.2	2.8	1.8	–	–	0.8	0.6	1.0
Oligochaeta	2.5	3.2	2.8	–	0.6	–	–	2.8	1.3	1.0	0.4	0.3	0.8	0.7	1.5
Phyllodocidae	1.0	0.8	0.3	1.6	–	–	–	1.0	0.9	2.1	0.2	1.0	0.2	0.3	0.7
Unidentified polychaete	3.5	4.7	5.8	2.8	1.4	–	–	8.0	3.4	8.5	1.8	2.1	2.8	1.9	3.7
ANNELIDA	8.5	10.6	12.1	7.0	3.5	–	–	15.0	10.5	16.5	3.4	4.3	5.8	4.5	8.4
Foraminifera	2.8	4.3	8.7	10.5	10.7	–	–	1.0	2.4	1.8	1.1	2.8	2.9	4.8	4.5
Nematoda	2.5	4.2	3.2	10.2	7.0	–	–	1.5	1.8	0.1	1.8	1.8	0.8	3.5	3.2
Unidentified fishes	1.1	2.3	2.8	4.5	6.8	–	–	5.0	3.5	1.3	4.2	3.2	3.7	2.3	3.4
Turbellaria	3.1	3.1	3.2	–	2.6	–	–	2.5	–	–	1.2	1.5	2.1	1.9	2.0
Plant material	1.8	2.6	2.9	3.0	2.8	–	–	20.0	2.8	5.8	9.2	10.5	3.2	3.4	5.6
MISCELLANEOUS	11.4	16.5	20.8	28.2	29.9	10.0	–	30.0	10.5	9.0	17.5	19.8	12.7	15.9	17.1
Decayed organic matters	28.5	20.5	30.2	38.5	39.8	10.0	5.0	50.0	20.0	13.0	30.0	35.5	33.3	38.4	28.0
Sand particles	5.2	4.3	3.6	3.5	2.8	80.0	90.0	5.0	12.5	9.0	8.0	5.4	6.5	5.2	7.8

In parentheses – number of samples analysed

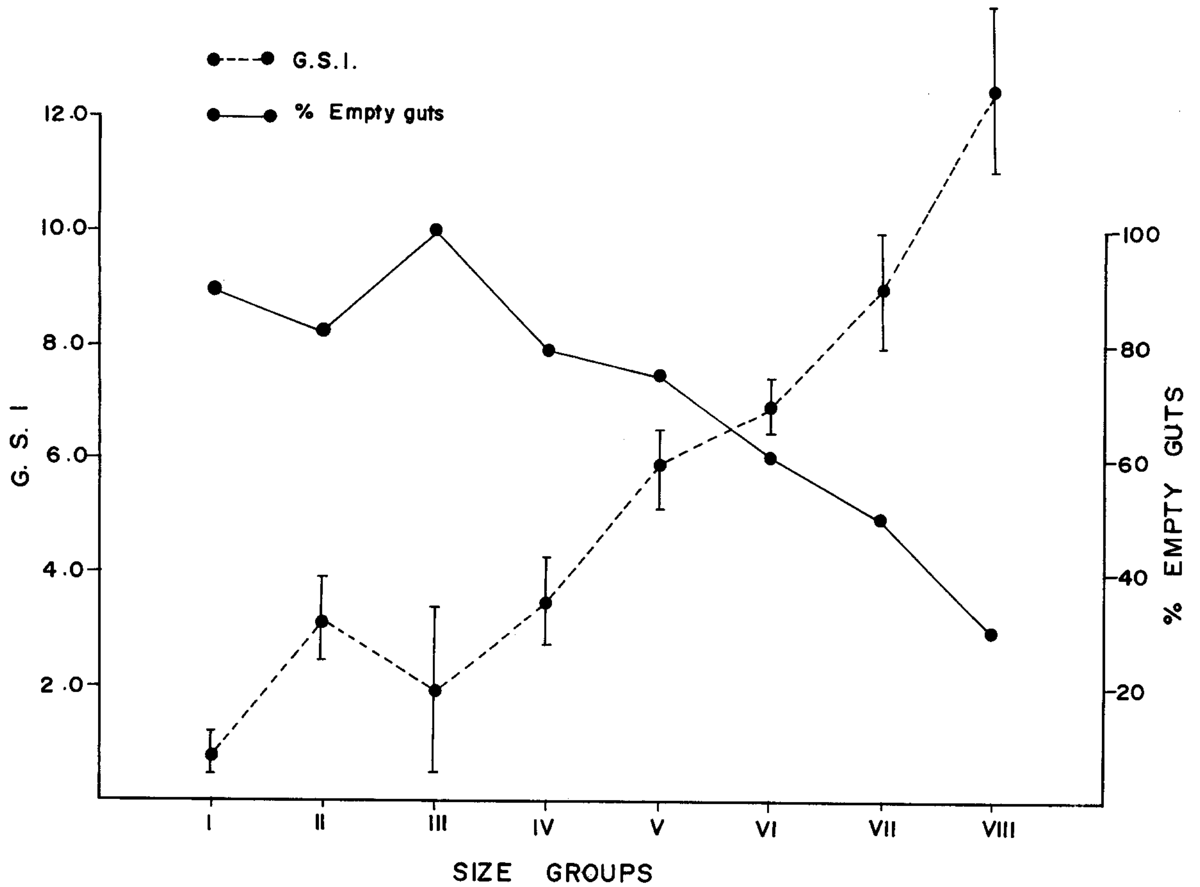

Fig. 4. Intensity of feeding at different size groups of *T. gigas* (Vertical bars indicate ± SE).

pieces of plant material were also encountered (Table 2). These items together formed 17.8% of total gut content with maximum abundance in October (30.0%) and minimum in December (9.0%).

Unidentified organic matter (mostly plant material) in decayed condition constituted about 28.0% of the total diet. It occurred regularly and throughout the year with a maximum contribution in October (50%), and minimum in September (5.0%).

Sand particles formed 7.6% of the total diet and occurred in the gut content throughout the year.

Intensity of feeding

The value of the gastro-somatic index, and the percentage of empty guts in different size groups of *T. gigas* are presented in Fig. 4. A gradual increase in feeding was observed with increasing size. Maximum values of gastro-somatic index in females were observed from November 1988 to January 1989 (north-east monsoon season) and minimum during June to September 1988 (south-west monsoon season). In males, a maximum gastro-somatic index was obtained during December 1988 to March 1989 and a minimum from August to October (Fig. 5). Females fed more intensely than males.

Discussion

The relative percentage of food items varied from month to month and a particular type of food item tended to be maximum at a particular time in the stomach, in line with the abundance

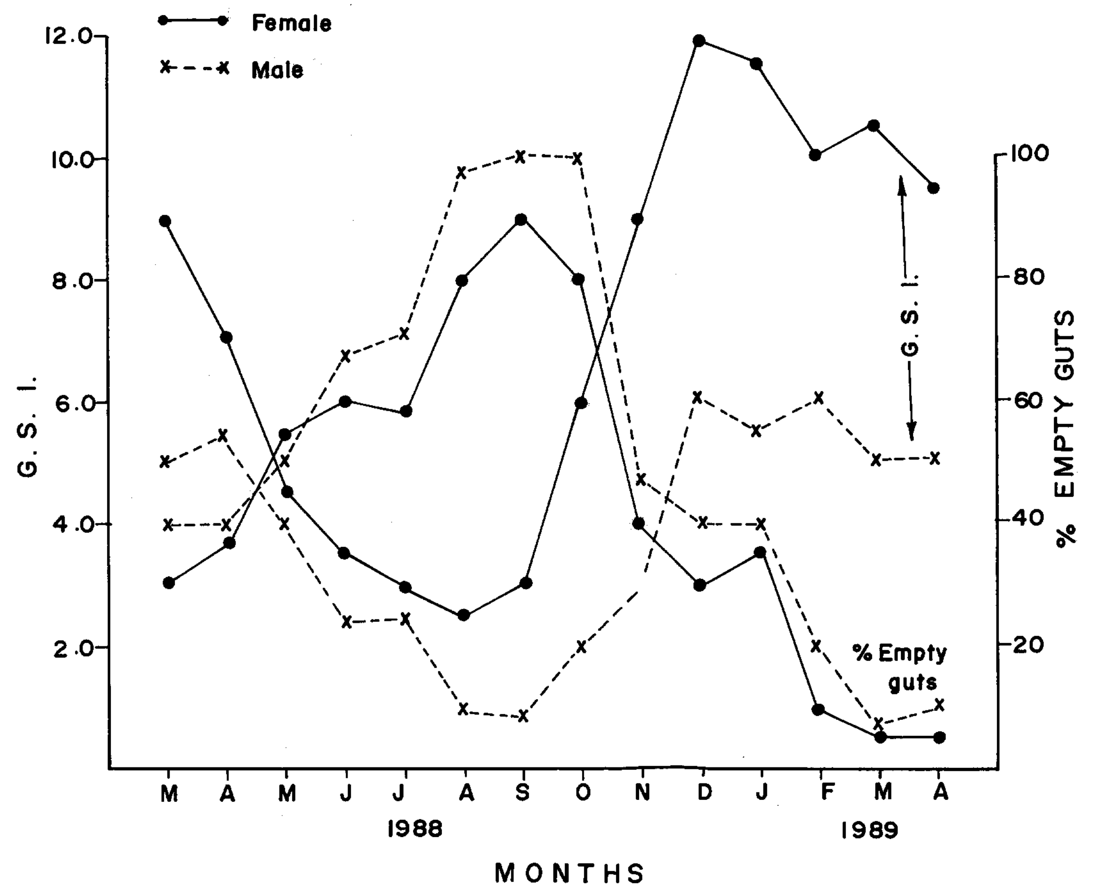

Fig. 5. Seasonal variations in the intensity of feeding of *T. gigas*.

of that food item in the environment at that time.

Despite multiple feeding strategies, including filter feeding, deposit feeding and hunting, many marine animals are selective feeders (Hughes, 1980). No previous information was available on the feeding behaviour and food preference of the adult Indian horseshoe crab, in spite of its growing importance in medical research (Cohen, 1979).

Tachypleus gigas is a selective feeder and analysis of its gut content in different months showed that molluscs and decayed organic matter were the main constituents of its diet. The major portion of the mollusca was contributed by bivalves. In the habitat, scaphopods and gammarid amphipods prevailed throughout the study period, but these were hardly encountered in the guts of the crab examined. Maximum electivity for the four most frequently occurring food items was recorded during the south-west monsoon (June–October 1988), when the abundance of food items in the environment was relatively low. Similarly, the feeding habit of *L. polyphemus* has also been reported as selective, with bivalve species being selected by the animal on the basis of prey length and shell strength (Botton, 1984b). However, one bivalve, *Gemma gemma*, in spite of its overwhelming dominance of 99.4% in the macrofauna in an inshore intertidal flat, was completely avoided (Botton, 1982). Elsewhere, the soft clam *Mya arenaria* was preferred as prey by *L. polyphemus* (Smith, 1953). The dietary habits of *L. polyphemus* collected on the continental shelf between North Carolina and New Jersey again showed that various molluscs constituted about 87% of the total diet (Botton & Ropes, 1989).

The mechanism of feeding in horseshoe crab has been reported by many workers beginning with Lockwood (1970). The pieces of food, initially captured with the help of chelate walking legs, are grouped by chitinous gnathobases before their consumption (Shuster, 1982). In the present study, plant material and detritus were encountered in the guts of almost all *T. gigas*. Similar observations have been reported previously; 90% of *L. polyphemus* consumed vascular plant and detritus (Botton, 1984a).

No significant difference in food composition and preference was noticed between males and females. The female is larger, and has been assumed to consume larger prey than males (Shuster, 1989). Females dig deeper than males especially during the breeding season, and as such, they have more access to benthic fauna than males. But in the present study, no sex-linked differences in diet were observed. Food selection by *L. polyphemus* in an aquarium experiment showed no significant difference in the electivity indices of male and female either (Botton, 1984a).

From July to October, the percentage of decayed organic matter, sand particles and pieces of plant material was high in the stomach of the crab. In the environment, during this period, the relative percentage of preferred prey (molluscs) was also low, and hence the animal has to subsist on decayed organic matter and plant debris. The nutritional value of these items has not been ascertained (Botton, 1984a). Maximum intensity of feeding during December–January is in conformity with an increased availability of preferred food items in the environment. In contrast, the percentage of crabs with empty guts was high during February–April 1989. During these months, maximum breeding activity is found along the Balramgari coast (Chatterji *et al.* unpublished work).

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