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OBSERVATIONS ON THE BREEDING BIOLOGY OF SOME CRABS FROM THE SOUTHWEST COAST OF INDIA*

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ABSTRACT

Annual reproductive cycles were studied of 12 species of crabs from different habitats of the south-west coast of India on the basis of the incidence of ovigerous females in monthly samples. The swimming crabs such as *Scylla serrata, Portunus sanguinolentus, Charybdis cruciata* and *Charybdis hoplites pusilla* show a tendency to breed continuously with distinct periods of peak reproductive activity during the annual reproductive cycle. The shore crabs such as *Uca annulipes, Uca marionis nitidus, Sesarma quadrata, Ilyoplax gangetica Metopograpsus messor* and the bottom species such as *Matuta lunaris* and *Dorippe astuta* and the swimming crab *Portunus pelagicus* do not breed all round the year though their breeding season, periods of intensive activity can be noticed.

The shore crabs of this area apparently start breeding and attain peak activity earlier than the swimming forms. Laboratory observations indicate that shore crabs do reberry during one reproductive season.

There is a steady increase in the number of eggs produced as the mature female grows and after attaining a certain size the number of eggs produced tend to remain more or less constant. The medium size groups of mature females are the active spawners among shore as well as swimming crabs.

INTRODUCTION

THE breeding in marine invertebrates has been a topic of intensivestudy by several investigators. Notwithstanding the considerable amount of data that have accumulated in the past on this subject, our information regarding the details of the reproductive cycles of representative forms of even major groups of invertebrates in the tropical region is still far from complete to draw definite conclusions. While some information is available on the breeding of marine invertebrates of the east coast of India (Panikkar and Aiyar, 1939; Paul, 1942; Subrahmanyam, 1963; Rao, 1965; Rahaman, 1966, 1967; Krishnaswamy and Krishnan, 1967) practically very little is known about the breeding of those of the west coast bordering the Arabian Sea, where the meteorological and hydrological conditions are different from those prevailing along the east coast, on account of the strong influence of both the south-west and north-east monsoons. This conspicuous lack of information on the breeding of invertebrates of the west coast of India has for a long time necessitatd detailed studies.

The available information on the breeding of crabs of Indian waters stems mostly from investigations upon those with economic value (Menon, 1952; Prasad and Tampi, 1953; George and Nayak, 1961). It may be pointed out here that

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detailed and systematic studies on the different aspects of the reproductive cycles extending over all the months of the year of even economically important species have never been attempted.

The present work was, therefore, undertaken with a view to throwing some light on the breeding biology of certain common species of crabs that occur along the south-west coast of India. Studies on the reproductive cycles of crabs have been chiefly based on the incidence of ovigerous (berried) females in the population (Churchill, 1918; Stephenson, 1934; Broekhuysen, 1936, 1941; Hiatt, 1948; Bloolootian *et al.*, 1959). The twelve species of crabs included in this study are *Uca annulipes* (Latreille) *U. marionis nitidus* (Dana), *Sesarma quadrata* (Fabricius), *Ilyoplax gangetica* (Kemp), *Metopograpsus messor* (Forsskål), *Matuta lunaris* (Forsskål), *Scylla serrata* (Forsskål), *Portunus pelagicus* (Linnaeus), *P. sanguinolentus* (Herbst), *Charybdis cruciata* (Herbst), *C. hoplites pusilla* Alcock and *Dorippe astuta* Fabricius. The information thus yielded by noting the incidence of ovigerous females in different months will serve as a foundation for more detailed observations on the reproductive cycles of crabs.

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MATERIALS AND METHODS

The shore crabs such as *Uca annulipes, U. marionis nitidus, Sesarma quadrata* and *Ilyoplax gangetica* were collected from their burrows by digging and examining the mud or sand, from selected localities along the shores of Cochin Backwater (Lat. 9° 58′ N, Long. 76° 17′ E). The swimming crabs, *Portunus pelagicus, P. sanguinolentus, Scylla serrata, Charybdis cruciata, C. hoplites pusilla* and the bottom species, *Dorippe astuta* were obtained chiefly from the trawlers operating off Cochin, on the shelf region and also from the fish markets of Ernakulam and Cochin where these arrived from the inshore areas. The shallow water burrowing crab, *Matuta lunaris* was collected from the shore seines operated off Cochin. *Metopograpsus messor* was collected from the under surface and crevices of large boulders along the Cochin Backwater. These crabs were brought to the laboratory in the live condition for further study. Random sampling was made. At least ten females of each species were examined every month to represent a sample following the precedure adopted by Boolootian *et al.* (1959). The size of the crabs examined was measured accurately to a millimetre across the carapace — the width of the carapace — and in species where the carapace had lateral spines, they were also included.

In all cases the abdomen of the females was lifted and examined for the presence of eggs since in the case of a partly spawned crab the eggs are hidden beneath the broad abdomen. The egg mass referred to as "sponge' or 'berry' contained a variable number of eggs depending on the size of the individual and the size of the berry. The number of eggs contained in it was noted. The percentage of the females carrying the eggs was noted in each month of the year. The stage of development of the eggs in the 'sponge' was also recorded.

In the case of shore crabs, females were kept in the laboratory to study their breeding activity. The swimming crabs could not be studied thus on account of the lack of aquarium facilities and circulating sea water. The size at maturity of females was ascertained by collecting large samples consisting of several individuals of different sizes and noting the carapace width of the smallest carrying eggs on their pleopods. Since the incidence of ovigerous females is a clear indication of the breeding activity, it was presumed that observations of females alone could furnish important clues regarding the reproductive cycles.

In *U. annulipes* it was possible to make some more detailed field observations such as an analysis of population samples collected at fortnightly intervals and display activity of the males.

TABLE 1. *Habitat, colour of newly laid eggs and colour of eggs at hatching of twelve species of crabs from the southwest coast of India*

Name of species	Habitat	Colour of newly laid eggs in the berry	Colour of eggs at hatching
U. annulipes	Burrows in sandy and muddy shores of brackish water areas.	deep purple	dirty grey
U. marionis nitidus	Same as above; but towards the lower reaches of the intertidalzone.	do	do
S. quadrata	Same as in *U. annulipes*	dark brown	ashy grey
I. gangetica	do	dirty brown	do
M. messor	Crevices of boulders and beneath stones	do	yellowish black
M. lunaris	Sandy and muddy areas of the shelf near the shore.	reddish brown	bluish black
S. serrata	Shelf: Known to migrate to rivers	orange red	black
P. pelagicus	Shelf: swimming crab migrates to brackish water areas during pre-monsoon.	do	do
P. sanguinolentus	do	do	do
C. cruciata	Shelf: swimming crab	orange red	black
C. hoplites pusilla	do	yellow	light bluish black
D. astuta	Shelf: bottom away from the shore.	brown	deep bluish black

RESULTS

In Table 1 is presented the habitat, colour of the freshly laid eggs and the colour of the eggs at hatching of the twelve species of crabs studied with a view to indicating the representative nature of the different species. The data regarding the range in

carapace width, the minimum size of the females which carry eggs and the size of eggs expressed as diameter of the respective species collected for this study are presented in Table 2. It may be seen that the minimum size of a breeding female shows difference in different species and this may have a correlation with the diffe-

TABLE 2. *Range in carapace width, minimum size of females carrying eggs and size of eggs of twelve species of crabs from the south-west coast of India*

Name of species	Number collected	Range of carapace width (mm)	Minimum size carrying eggs (carapace width) (mm)	Egg-diameter (μ)	No. of eggs in berry
U. annulipes	257	10.2–18.0	10.5	384	420–1150
U. marionis nitidus	122	15.0–28.0	15.5	295	680–1910
S. quadrata	134	13.5–24.0	14.0	315	515–1270
I. gangetica	186	5.5–10.0	6.0	220	150–400
M. messor	152	11.0–22.0	14.0	380	500–1250
M. lunaris	153	44.0–60.0	45.0	308	1100–2580
S. serrata	118	115.0–250.0	120.0	350	318720–521450
P. pelagicus	242	95.0–164.0	95.0	343	180400–463730
P. sanguinolentus	163	85.0–128.0	90.0	328	151780–307500
C. cruciata	142	65.0–110.0	67.0	298	117820–243210
C. hoplites pusilla	196	26.0–48.0	27.5	287	2370–5060
D. astuta	148	20.0–35.0	20.0	390	1550–3190

rence in the maximum size attained by the adults. Similarly the egg diameter also shows difference in the various species and this may be correlated with the habitat of the crab and several other factors such as the number of eggs produced, the amount of yolk present and the duration of planktotrophic life of the larvae.

Uca annulipes

An examination of the females extending over a period of two years, starting from October 1963, reveals that they are in berry between September and April with the peak in December. From Fig. 1 b, it will be seen that during the first year ovigerous females were collected from October to February. In the second year, however, (Fig 1c) samples from the higher reaches, five kilometers upstream showed

Fig. 1. The incidence (percentage) of ovigerous females of *Uca annulipes* - a. average for two yeas; b. for the first year, October 1963- September 1964; and c. for the second year, October 1964–September 1965.

that ovigerous females occur even during April,representing probably a few stragglers. After April no ovigerous female was encountered in the population of this habitat till September. During the first year the peak incidence of ovigerous females was noted in January. However, during the second year the peak was attained a little earlier, in December. From this it may be concluded that this species breeds along the south-west coast of India from September to April with the peak period of activity during December-January.

Copulative activity was frequently noticed in the field during October-November as well as during March-April.

Observations of ovigerous females of *U. annulipes* reared in the laboratory indicated that the eggs of 'sponge' usually have an incubation period of 15-20 days. In all the breeding months, females reared in the laboratory normally reberried only after a fortnight. However, in the month of October an interesting case of a

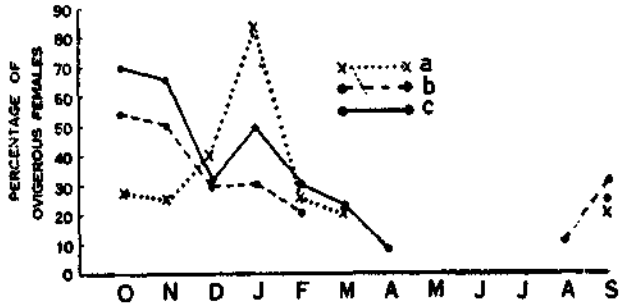

Fig. 2. The incidence (percentage) of ovigerous females of–a. *Uca marionis nitidus;* b. *Sesarma quadrata,* and c. *Ilyoplax gangetica* during October 1963 - September 1964.

crab laying a fresh batch of eggs within four days of shedding the first brood of zoeae was noticed. Similar rapid berry formation was also noticed in the peak breeding month — December. It is, therefore, obvious that even during the breeding season there are periods when gonadal activity is accelerated to produce broods in rapid succession. The different individuals that constitute a population generally represent individuals with different reproductive potentialities and periodicities, the comparatively younger ones having the ability to produce quicker broods. Thus, the frequency of gonadal activity showed difference not only during different stages of a crab's life but also at different periods such as the onset, during the course, at the

TABLE 3. *The incidence of ovigerous females (percentage) in the samples of different species of crabs collected during 1963-1965*

Name of species	S	O	N	D	J	F	M	A	M	J	J	A
U. annulipes	13	25	32	36	33	16	10	8				
U. marionis nitidus	20	27	25	40	82	25	20					
S. quadrata	30	54	50	30	31	20						10
I. gangetica	25	70	65	31	50	30	23	8				
M. messor	20	66	50	75	27	18						
M. lunaris	10	40	58	35	28	30	13					
S. serrata	25	30	28	40	46	33	20	10	20	10	10	30
P. pelagicus	18	23	23	48	56	46	31	20				10
P. sanguinolentus	12	10	19	25	54	65	40	53	27	8		10
C. cruciata	33	40	35	41	57	52	30	12	16	10	7	20
C. hoplites pusilla	31	45	27	53	75	50	58	30	33	10	14	20
D. astuta	28	46	33	58	53	80	66	20	10			

peak and at the termination of the breeding cycle. Preliminary observations indicated that during the breeding period of this species from September to April an adult female was likely to produce at least one brood per month. Therefore, it is presumed that a mature female may be able to produce about 8 broods of eggs during a breeding season. This conclusion was, however, tentative and could be conclusively proved

only after close and continuous observations throughout the breeding season of several individuals in the field. In crabs kept within the confined space of the laboratory, after the second brood of eggs had been released, no instance of a third batch of eggs could be recorded. This may be attributed to the inadequate living conditions within the crabbery.

A population of *Uca annulipes* was examined by collecting fortnightly samples and the incidence of different size groups is given in Table 4 and Fig. 3. It will be seen that there is a preponderance of small size groups comprising immature and young forms in January-February and also during April-August. These months follow the breeding months when large numbers of females were found in the ovigerous condition.

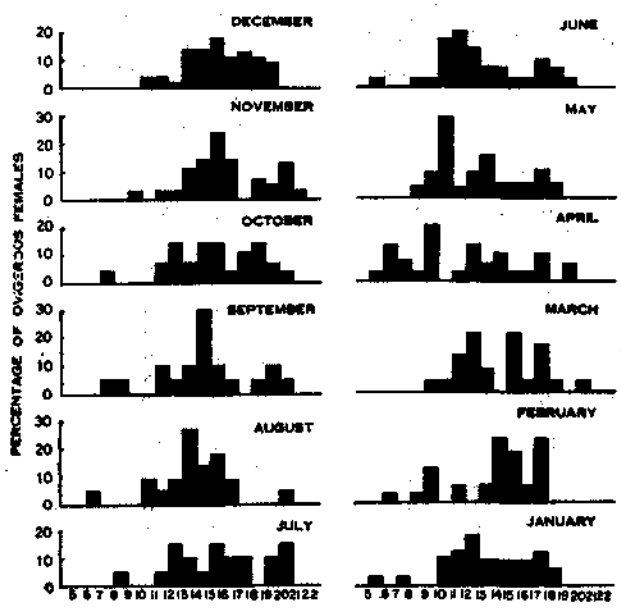

Fig. 3. Histograms showing the incidence of various size groups in the monthly samples of *Uca annulipes* from January 1964 to December 1964.

In the population sampled, males dominated in numbers over the females, and the sex ratio was 5 males to 3 females. In the males one of the chelipeds, either the right or the left being much larger than that of the other side, attained such enormous proportions as to weigh about a third of the total body weight. This enlargement might be effected either in the left or in the right one and in the population examined they were found in the ratio of 50 : 50 as was already reported by Pillai (1951).

This large cheliped of the crabs of the genus *Uca* is waved during the display activity and the exact significance of this curious behaviour is not clearly understood and this has aroused the interest of several investigators since the first half of the last century. These studies led to quite different and sometimes contradictory, opinions as to the meaning and function of waving (Altevogt, 1955).

During the course of the field study, at the test site near the Oceanographic Laboratory, Ernakulam, some interesting observations were made of the waving activity of *Uca annulipes*. It was noticed several times in the field that during the peak period of activity of the crabs after the tide had, ebbed several males (5-7) waved against a single female which was 'beckoned' towards the burrow of the males. A male chasing a female was also observed to be in the act of waving Several instances were noticed of a single male waving against a female approaching the burrow of the former. Two males were found rapidly advancing towards each other even in the absence of females and this ultimately led to an open fight between the males who used the large cheliped as weapons. Occasionally during the peak periods of display activity, a band of 8-10 males collected together in a circle and all of them waved for a long time synchronously without any inducement from females. Gordon (1958) observed synchronous claw waving in African fiddler crabs. This gesture is probably a means of communication between individuals, for conveying specific information in the form of signals. These observations tend to show that waving is an action not solely meant for attracting the female.

TABLE 4. *Incidence of different size groups (percentage) in the monthly samples of* Uca annulipes *from January* 1964 *to December* 1964

Carapace width mm	Jan.	Feb.	Mar.	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
5–6	3			3		3						
6–7	0	3		13		0		5				
7–8	3	0		7		0		0	5	4		
8–9	0	3		3	4	3	5	0	5	0		
9–10	0	12	4	20	9	3	0	0	0	0	3	
10–11	10	0	4	0	29	17	0	9	0	0	0	4
11–12	12	6	13	3	4	20	5	5	10	7	3	4
12–13	18	0	21	13	9	14	15	9	5	14	3	2
13–14	9	6	8	6	15	7	10	27	10	7	11	14
14–15	9	23	0	10	5	7	5	14	30	14	14	14
15–16	9	18	21	3	5	3	15	18	10	14	24	18
16–17	9	6	4	3	5	3	10	9	5	4	14	11
17–18	12	23	17	10	10	10	10	0	0	11	0	13
18–19	6		4	0	5	7	0	0	5	14	7	11
19–20			0	6		3	10	0	10	7	5	9
20–21			4				15	5	5	4	13	
21–22											3	

Generally a copulating male holds the female in between the palm of the large chela and the body. However, whether its function is to hold the female during the copulative process was doubtful since it was noticed in the laboratory that a male who autotomised its large cheliped was copulating with a female. Therefore, the large cheliped does not seem to be essential for holding the female in the copulative process which can be effected by the interlocking of the walking legs.

In the course of these observations it was noticed that this large cheliped was waved at a greater frequency during the reproductive season and this may be due to sexual excitement. From Table 5 it may be seen that greater frequency of waving is during the months from October to May. These values were obtained as the averages of weekly readings of daily waving activity of 3 individuals on every Wednesday at the time of low tide. The months showing greater frequency were periods prior to peak breeding activities of females. During this period copulative activity was noticed in the field. However during the rainy season, June to August, a general slackening of this activity was evident.

Therefore, based on the observations in the present study, it can be concluded that while this large cheliped is an organ of multiple function expressing different feelings, used for a variety of purposes such as beckoning of the female, conveying of specific information to others, for holding the female during sexual congress, for territory demarcation as well as for offence and defence. Its role in the display of sexual excitement is no less important. This is evidenced by a greater frequency of waving activity during the reproductive season.

TABLE 5. *Frequency of waving activity of male* Uca annulipes *in different months*

Month	Frequency of waving in a minute (average)	Month	Frequency of waving in a minute (average)
October	18	April	19
November	17	May	17
December	18	June	8
January	16	July	4
February	15	August	5
March	18	September	10

Uca marionis nitidus

The data presented in Fig. 2 a show that *U. marionis nitidus* breeds from September to March. The incidence of ovigerous females shows a fall in November after the initial increase in October, and the peak is reached in January. This is followed by a steady fall and the low value in March is indicative of the end of the breeding period.

In *Uca marionis nitidus* laboratory observations show that the eggs have an incubation period of about 25-30 days and in no case a female was seen to re-berry in the laboratory during the course of one year's observation. The eggs of this species were found to be comparatively smaller in size than those of *U. annulipes* (with a longer period of incubation). Examination of several ovigerous females with eggs even in advanced stages of development revealed only a very slow regeneration of the spent ovary. This apparently slow rate of reproductive activity of this species is probably one of the reasons for its rarity in this area.

It is interesting to note that the dominant species *U. annulipes* shows a fairly uniform distribution in the intertidal belt while *U. marionis* is found only occasionally moving about the lower reaches of the intertidal zone.

Sesarama quadrata

In Fig. 2 b, is illustrated the reproductive cycle of this species. Ovigerous females appeared in the population from August to February. The peak was attained in October with a steady increase in the number of ovigerous females. With only 10 per cent in August the ovigerous females showed an increase to 54 per cent in October and thereafter a gradual decline was noticeable until February.

Ilyoplax gangetica

Ovigerous females appeared in the population from September to April (Fig. 2c). The peak month October recorded 70 per cent of ovigerous females. Therefore, it can be presumed that this species breeds along the south-west coast of India from September to April with peak in October.

Other interesting phenomena noticed in this species were the characteristic bumping action of the male, with their chelipeds and a preponderance of juveniles in the field after the peak occurrence of ovigerous females. Continued field observations indicated that the bumping act of the males takes place at a rapid rate during the height of the breeding season. A preponderance of juveniles was noticed in the population during the period January to April. This is an additional indication of the probable breeding period of this species.

Metopograpsus messor

September to February (Fig. 4 a) seems to be the period of breeding of this species in this area. An initial increase to 66 per cent was seen in October followed by a fall during the next month and December registered the peak period with 75 per cent ovigerous females. This was followed by a fall to 18 per cent in February.

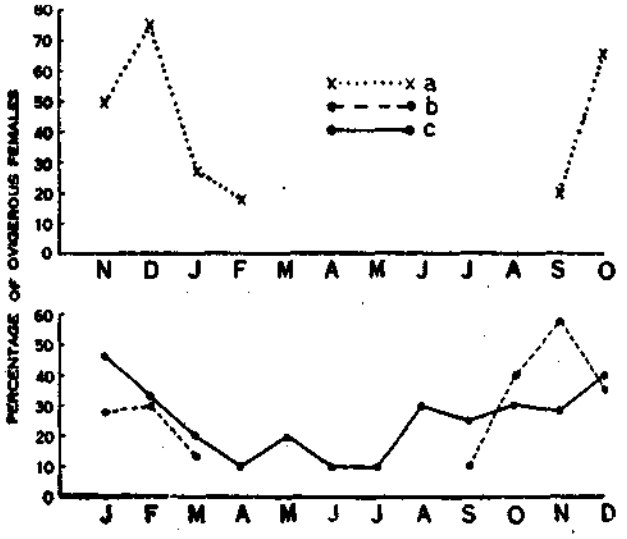

Fig. 4. The incidence (percentage) of ovigerous females of - a. *Metopograpsus messor* from November 1963 to October 1964; b. *Matuta lunaris* and c. *Scylla serrata* January to December 1964.

Matuta lunaris

Ovigerous females occurred in the population from September to March (Fig. 4 b). September registered only 10 per cent, the peak was attained in November, then a fall in December and in January followed by a slight increase in February and a decline in March which represented the end of the breeding period since no ovigerous females were encountered in the collections thereafter.

Scylla serrata

The occurrence of ovigerous females during all the months of the year gives the impression that this species in this area is a continuous breeder with one period of peak activity. In the course of this study a distinct peak was discernible in January (Fig. 4 c) with 46 per cent ovigerous females. The period of least activity was

noticed in June and July. In August the values showed an upward trend and this continued till the attainment of the peak in January.

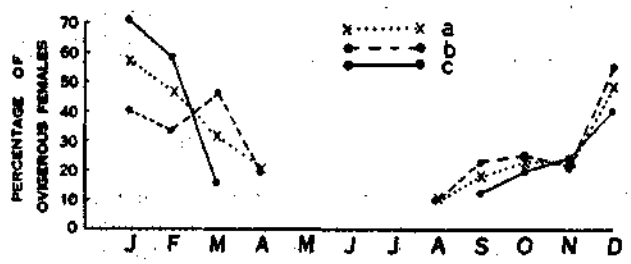

Fig. 5. The incidence (percentage) of ovigerous females of *Portunus pelagicus*—a. average for two years; b. for the first year, January to December 1964 and c. for the second year, January to December 1965.

Portunus pelagicus

Two years' data regarding this species are plotted in Fig. 5. Ovigerous females occur in the population from August to April with the peak in January. During the first year, 1964, ovigerous females were present from January to April and then from August to December. Though January registered 40 per cent ovigerous females, during February there was a fall to 33 per cent. Again in March there

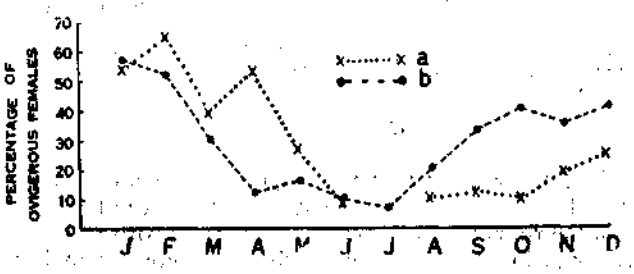

Fig. 6. The incidence (percentage) of ovigerous females of – a. *Portunus sanguinolentus* from January to December 1965 and b. *Charybdis cruciata* from January to December 1964.

was an increase to 46 per cent and this was followed by a low value in April. Thereafter ovigerous females were not encountered in the population till August when 10 per cent of the females were berried. Through the subsequent months the values reached the peak in December. During the year 1965, January registered 71 per cent. This is contrary to the results of the previous year. February also registered a higher percentage of ovigerous females in the samples than that of the previous year.

Portunus sanguinolentus

In Fig. 6 a, are presented the data regarding *P. sanguinolentus*. Ovigerous females were found in the collections in all the months of the year except July. But the period of low activity was June to August. November to March registered a high percentage of ovigerous females in the population with a peak in February.

Charybdis cruciata

This species seems to breed throughout the year in this locality (Fig. 6 b). The period which registered low activity was from April to July. But from August onwards the number of ovigerous females showed an increase. Though the peak period of breeding activity was January with 57 per cent ovigerous females, February also showed a high value.

Charybdis hoplites pusilla

Crabs of this species also seem to breed throughout the year along this coast (Fig. 7 a) with a peak period in January. The period indicating a low incidence of ovigerous females was from June to August. Though there was a gradual increase from August to October, November registered a low value. The activity increased in December to reach the peak during the next month.

Fig. 7. The incidence (percentage) of ovigerous females of – a. *Charybdis hoplites pusilla* and b. *Dorippe astuta* from January to December 1964.

Dorippe astuta

From Fig. 7 b, it is evident that the ovigerous females occur in the population from January to May and also during September to December. January registered 53 per cent and in February the peak period was noticed with 80 per cent. The lowest percentage was noted in May. Ovigerous females were absent in the collection of June, July and August. The period September to December showed the presence of a fairly large number of ovigerous females.

OTHER OBSERVATIONS

Table 6 and Fig. 8, provide data on the percentage of ovigerous females of *Uca annulipes, U. marionis nitidus, Portunus pelagicus, P. sanguinolentus* and *Charybdis hoplites pusilla* in different size groups. It will be seen that the middle size groups in all the species represent the most active spawners as evidenced by the greater percentage of ovigerous females in this group. In the small size groups the incidence of ovigerous females was comparatively low and the same was the case with larger individuals in the population. Thus, it is clear that in these species of crabs, the medium size groups are the active spawners.

In Table 7 and Fig. 9, the percentage of ovigerous females of *Uca annulipes* of different size groups are presented for different months of the breeding season. During September and October which represent the early part of the breeding period,

the middle size groups with carapace ranging from 13 to 16 mm were found in increased numbers in breeding conditions whereas about the middle of breeding period freshly maturing individuals of small size groups also joined the breeding stock. By February again a greater number of medium sized females appear showing breeding activity.

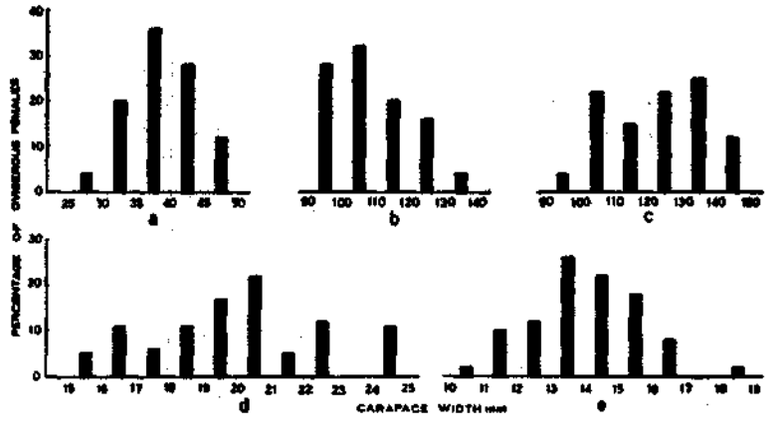

Fig. 8. The frequency of occurrence (percentage) of ovigerous females in different size groups of five species of crabs - a. *Charybdis hoplites pusilla*; b. *Portunus sanguinolentus*; c. *P. pelagicus*; d. *Uca marionis nitidus* and e. *U. annulipes*.

While assessing the fecundity of these crabs, it has been found that in all species of crabs examined, there is a steep increase in the number of eggs as the mature animal grows and after attaining a certain size the number of eggs produced remain more or less constant.

DISCUSSION

The species of crabs whose reproductive cycles have been presented above are representatives of different habitats of the marine environment. *Uca annulipes, Uca marionis nitidus, Sesarma quadrata* and *Ilyoplax gangetica* are inhabitants of typical muddy and sandy estuarine areas. But *Metopograpsus messor* is found among the boulders along the intertidal region. All these species occur along the Cochin Backwater. *Portunus pelagicus* and *Portunus sanguinolentus* though typically marine crabs move into the backwater. *Scylla serrata* is another estuarine swimming crab, which has been reported even from rivers (Panikkar and Aiyar, 1939). *Matuta lunaris* is confined to the coastal muddy bottom, living often buried in the mud. *Dorippe astuta* is a bottom dwelling form of comparatively deeper waters while crabs of the genus *Charybdis* mentioned here are capable of undertaking long journeys.

Uca annulipes and *U. marionis nitidus* are related species of fiddler crabs inhabiting the intertidal estuarine sand and mud along the coasts of Cochin Backwater. Of these *U. annulipes* is smaller but more common almost uniformly distributed in the intertidal region but *U. marionis nitidus* is only occasionally found constituting 4 - 5 per cent of the *Uca* population of this locality and seems to have a preference for the lower reaches of this zone. This disparity in the incidence of *U. marionis nitidus* and *U. annulipes* may be the result of competition.

The size of eggs of shore crabs is larger when compared with that of swimming crabs. This may be due to the greater accumulation of organic reserves in the eggs in the form of yolk, ensuring a ready food supply for the developing embryos and the subsequent early larval stages. Thus, the quantity of the organic matter that has gone into the production of ova is proportionately greater in the case of shore crabs. The largest size of egg has been noticed in a bottom living species, *Dorippe astuta*. This may be due to the fact that this crab gets plenty of rich food in the form of decaying organic matter, a large quantity of which may be further utilised in the form of yolk for the developing embryo in the egg. The presence of a large quantity of yolk in the egg is also attributable to the fact that generally the bottom forms seem to have a shortened life history and the yolk may be utilised for rapid development in the egg.

TABLE 6. *Carapace width range and percentage of ovigerous females in different size groups of crabs*, Uca annulipes, Uca marionis nitidus, Portunus pelagicus, Portunus sanguinolentus *and* charybdis hoplites pusilla

Carapace width mm	Percentage of ovigerous females	Carapace width mm	Percentage of ovigerous females
1. *Uca annulipes*		2. *Uca marionis nitidus*	
10 - 11	2	15 - 16	5
11 - 12	10	16 - 17	11
12 - 13	12	17 - 18	6
13 - 14	26	18 - 19	11
14 - 15	22	19 - 20	17
15 - 16	18	20 - 21	22
16 - 17	8	21 - 22	5
17 - 18	-	22 - 23	12
18 - 19	2	23 - 24	-
		24 - 25	11
3. *Portunus pelagicus*		4. *Portunus sanguinolentus*	
90 - 100	4	90 - 100	28
100 - 110	22	100 - 110	32
110 - 120	15	110 - 120	20
120 - 130	22	120 - 130	16
130 - 140	25	130 - 140	4
140 - 150	12		
5. *Charybdis hopltes pusilla*			
25 - 30	4		
30 - 35	20		
35 - 40	36		
40 - 45	28		
45 - 50	12		

A relationship between egg size and habitat can also be seen, the largest being noticed in the bottom living species, *Dorippe astuta*, the shore crabs coming second and the swimming crabs having comparatively much smaller types of eggs. Egg size is dependent on the amount of nutritive substance present in it and has a relation to the duration of the planktotrophic life of the larva, the size of the egg being inversely proportional to the duration of the free swimming period. Therefore, it can be inferred that the swimming crabs have comparatively longer periods of free swimming larval period when compared with those of the shore crabs or the bottom living species.

The breeding of these west coast crabs seems to have a relation to the conditions prevailing in the habitat. *U. annulipes* breeds from September to April along these backwater. The peak season of breeding activity is during December-January. *U. marionis nitidus* breeds from September to March with a peak in January. In *S. quadrata* the season extends from August to February with a peak in October.

I. gangetica breeds from September to April with peak activity in October. In *M. messor* the breeding season extends from September to February and here the peak activity is in December. From this it is evident that these shore crabs have an extended breeding period with a distinct peak in the breeding activity. The breeding period extends from August to April and there is practically no breeding activity during May, June and July. Some of the swimming crabs such as *S. serrata, C. cruciata* and *C. hoplites pusilla* show a tendency to breed continuously throughout

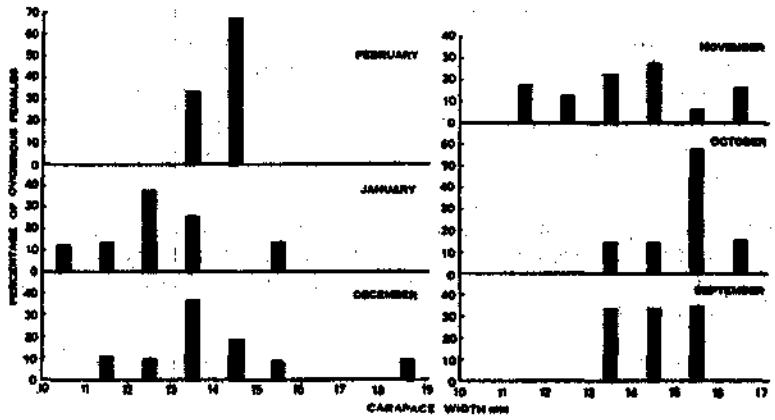

Fig. 9. The frequency of ocurrence (percentage) of ovigerous females in various size groups of *Uca annulipes* in different months of the breeding season.

the year with a low activity between May and August. In *M. lunaris* breeding extends from September to March with a peak in November, in *P. pelagicus* from August to April with peak in the month of January and in *P. sanguinolentus* breeding is almost continuous throughout the year (with the exception of July) with a peak activity in February. The two species of the genus *Charybdis* have a continuous breeding season with peak in the month of January. *D. astuta* the bottom dwelling crab breeds from September to May with a peak activity in February. Thus, among the crabs of the west coast of India, while a few of the swimming crabs have a continuous breeding season, others seem to have an extended breeding season and in both the cases a distinct peak during the season is discernible. It may be noted that though the breeding activity in both shore and swimming crabs gains momentum at the beginning of the post-monsoon period, the shore crabs attain the peak activity first during the period October to January, and the swimming crabs reach this condition a little later from December to February. This may be explained by the fact that the comparatively higher temperature of the habitat of the shore crabs may accelerate the rate of gonad development and reduce the incubation period of the eggs in berry. Thorson (1946) has noticed among Danish bottom invertebrates that there is a tendency for earlier spawning among those inhabiting the shallower waters which warm up earlier in the year; the deep waters being slower to warm up have inhabitants which spawn correspondingly later in summer.

In *Portunus sanguinolentus, Charybdis cruciata, C. hoplites pusilla* and *Scylla serrata* the occurrence of a small number of ovigerous females may be noted even during the off-season. This off-season spawning tends to show that the species is a continuous breeder. Off-season spawning is not uncommon among the decapod Crustacea. Herrick (1909) has noted it in the lobster, and Broekhuysen (1936,

1941) has found it to be characteristic of two other shore crabs, *Carcinus maenas* and *C. punctatus*. Hiatt (1948) reported a similar case in *Pachygrapsus crassipes*. In the case of *Uca annulipes* though the incidence of ovigerous females could be noted from September to February, observations in the next year however, gave evidence of the presence of a few individuals with berry in March and even in April.

Comparable data on the breeding of crabs from Indian waters are very few. Panikkar and Aiyar (1939) have concluded that shore crabs breed mostly from September to January, along the Madras Coast. In the Bombay waters Chhapgar (1959) stated that the majority of the crabs of Bombay breed from November to March. But the data are incomplete since only dates on which ovigerous females had been encountered in the collection were noted without methodically collecting data and studying the details of the breeding in any one species. Among the economically important crabs, *Portunus pelagicus* is a continuous breeder with maximum intensity during the period September to March near Mandapam on the south-east cost of India (Prasad and Tampi, 1953). *Portunus sanguinolentus* breeds on the Malabar Coast during February-March (Menon, 1952) and on the Mangalore Coast from December to April with maximum activity during the March-April period (George and Nayak, 1961). Chhapgar (1959) reported that these two species are irregular breeders in Bombay waters.

TABLE 7. *Carapace width and percentage of ovigerous females in different breeding months from September - February, in* Uca annulipes

Carapace width mm	September	October	November	December	January	February
10 - 11	—	—	—	—	12	—
11 - 12	—	—	17	10	13	—
12 - 13	—	—	12	9	37	—
13 - 14	33	14	22	36	25	33
14 - 15	33	14	27	18	—	67
15 - 16	34	57	6	8	13	—
16 - 17	—	15	16	—	—	—
17 - 18	—	—	—	—	—	—
18 - 19	—	—	—	9	—	—

Though there is general agreement regarding the fact that these tropical crabs have an extended breeding period, the onset and peak period of activity may vary from place to place and even from year to year. This fact may be seen from the results on *P. sanguinolentus* (Menon, 1952; Chhapgar, 1959; George and Nayak, 1961). Similarly the breeding of *P. pelagicus* reported from the wide range of its distribution in the Indo-Pacific region also varies considerably (Stead, 1898; Delsman and De Man, 1925; Thomson, 1951; Prasad and Tampi, 1953; Chhapgar, 1959). Stephenson (1934) noted *Thalamita stimpsoni* in the berried condition in every month from August to June and inferred that at least some reproduction occurred during the greater part of the year. Hiatt (1948) observed ovigerous females of *Pachygrapsus crassipes* between April and September in the Pacific area. A recent detailed study comparable to these on the incidence of ovigerous females is avaiable from the west coast of America (Boolootian *et al.*, 1959).

Another interesting point is that the peak activity is never attained in the tropical crabs with all the adult females attaining berried condition, whereas in temperate regions the peak is recorded with 100 per cent in berried condition (Boolootian *et al.*, 1959). This may probably be due to longer incubation period and also to a tendency towards synchrony in the reproductive activities in the

temperate forms as distinct from the tropical forms where the incubation period is comparatively shorter owing to the higher temperature of the environment. The reproductive population here is of a heterogeneous nature and therefore, the spawning is naturally asynchronous.

The reproductive cycles of marine invertebrates are to some extent influenced by environmental factors so that the release of the young takes place at a period most favourable for their survival (Giese, 1959). The majority of the crabs of the west coast of India have a breeding season extending for several months and in a few species a tendency for continuous breeding may be noted. But in both cases a well marked peak period of reproductive activity is unmistakably discernible. One among the many factors influencing this peak breeding activity of these crabs seems to be an abundance of rich planktonic food in the inshore area. This area is under the influence of 'mud banks' occurring during the closing phase of the south-west monsoon (Panikkar and Jayaraman, 1966). This affords a rich phytoplanktonic bloom early in the post-monsoon period. The occurrence of planktonic bloom in the inshore waters of this area is continued through the post-monsoon and the early part of the pre-monsoon as a result of upwelling of the bottom water rich in organic nutrients (Banse, 1959; Panikkar and Jayaraman, 1966). It is, therefore, quite probable that the breeding of these species of crabs is effectively attuned to the availability of the food for the young during their planktotrophic life as was suggested by Boolootian *et al.* (1959) in regard to some crabs of the west coast of America.

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