SIZE DISTRIBUTION AND REPRODUCTIVE BIOLOGY OF THE MUD CRAB *SCYLLA SERRATA* AT COCHIN DURING THE MONSOON PERIOD

DISSERTATION SUBMITTED BY
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CERTIFICATE

This is to certify that this Dissertation is a bonafide record of the work done by Smt. Sheeba K. Thariyan, under my supervision and that no part thereof has been presented before for any other degree.

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C O N T E N T S

P R E F A C E

The mud crab Scylla serrata is the largest among edible crabs of India. Constituting a traditional fishery of sustenance level in the country, this crab has assumed considerable importance in recent years on account of its growing popularity as a gourmet's favourite. It is also a good export commodity. At present the crab is underexploited in our waters and the catches could be increased many fold by improved devices and techniques of capture. In view of its euryhaline nature and many other favourable factors it is also considered as a candidate species for coastal aquaculture. Realising the potentialities for its culture, attempts are being made in many countries of the Indo-Pacific for commercial culture and propagation of this species.

It is well known that the development of any fishery largely depends on a sound knowledge of the biology of the constituent species. The capture fisheries are often threatened by depletion of stocks due to overfishing and culture fisheries by operational failures for want of proper management principles. Management of fisheries is a complex problem which could be solved only if adequate information is available on the characteristics of stocks, structure of population, recruitment, growth, reproduction and behavioural responses to fishing/ culture operations. A perusal of literature on the mud crab

would reveal that in India no serious attempts have been made so far to throw light on these aspects although several reports are on record pertaining to its fisheries from different centres along the coasts.

Cochin is an important centre for the production of mud crab. The vast stretches of backwater system and the extensive inshore areas of the sea bordering this cosmopolitan city is an important reserve for this crab which supports a lucrative fishery under the artisanal sector. Besides being sold in large quantities in the local markets, considerable amount of the mud crab is also processed and exported from here during the peak fishing season. The increasing demand for the mud crab calls for proper exploitation of the wild stock and also culturing it on commercial scale in order to augment production. For achieving success in such ventures reliable data on the biology and population characteristics of the species is essential.

In the present study, an attempt is made to throw light on some aspects of the biology of the mud crab occurring in Cochin waters during the southwest monsoon period (June-September), which is the peak crab fishing season of the area, based on commercial landings. The coastal waters of this region during the monsoon period is characterised by marked changes in the hydrographic conditions due to the influence of rain and

upwelling (Ramamirtham and Rao, 1973). The most striking change in the backwater is the steep decline in salinity as a result of freshwater influx. Relatively cooler waters also prevail at the bottom. Devasia and Balakrishnan (1985) recorded the range of salinity, temperature and dissolved oxygen content of the crab fishing grounds as 1.5-21.0 ‰, 24.1-27.3°C and 2.9-6.5 ml/L respectively during the monsoon period. Though not so pronounced as in the backwater relatively low salinity and temperature conditions prevail in the inshore areas of the sea also during this period (Ramamirtham and Rao, 1973).

The dissertation embodies mainly two important aspects, namely, size distribution and reproductive biology of the two forms of mud crab that have been identified in the commercial catches. The size range, modal sizes and mean sizes of the population occupying the marine and estuarine environments have been dealt with sex-wise. Monthly pattern of size frequency distribution in the two different ecosystems has been elucidated to understand the structural variations and behaviour of crab population in time and space. Under the section on reproductive biology, details of sex differentiation, sex ratios and maturation of female crabs and distribution pattern of spawning population are described.

Though the study is only for a short period of four months the information that could be gathered may be taken to generalise the conditions since the observations pertain to the peak season of the fishery.

I wish to express my sincere gratitude to my supervising teacher Dr.C.Suseelan for his guidance and encouragement in this work. Grateful acknowledgements are due to Dr.P.S.B.R.James, Director, Central Marine Fisheries Research Institute, Cochin for the facilities provided for carrying out the work. My thanks are due to Shri K. Narayana Kurup, Scientist for the help rendered in statistical analysis of the data, I wish to thank Mr. A.Nandakumar, Technical Assistant for rendering laboratory help. I am greatly indebted to all my class mates, senior and junior research fellows for their help and co-operation at various stages of work. I am grateful to the Indian Council of Agricultural Research for offering me a Junior Research Fellowship during the tenure of my study.

INTRODUCTION

Crabs form an important constituent of the crustacean fishery resources and an excellent source of cheap protein-rich food. They support significant fisheries in the sea as well as brackishwater areas along the entire coastline of India. Available catch statistics (Anon., 1986) show that an average of about 25,000 tonnes of crabs are landed every year from the inshore waters of our coast, and the magnitude of the fishery from the brackishwater areas is comparable with that of the inshore waters (Rao et al., 1973). Though the bulk of the catch is utilised for local consumption in coastal areas, some quantity is also exported to foreign countries like Belgium, U.S.A., Japan, Singapore etc. in the form of frozen crab meat. A perusal of trends in the export of frozen crab meat from the country for the part few years (Anon, 1987, 1988) would reveal that the export has increased tremendously since 1982. The quantity of the frozen crab meat exported to foreign countries increased from 4.6 tonnes in 1982 to 87 tonnes during the year 1987-'88, realising a corresponding increase in value from Rs 0.2 million to Rs 4 million. This evidently shows that apart from its growing importance in supplementing the nutritional requirements of the people in the country the crab resource offers vast scope for augmenting our export earnings.

Though the crab fauna of India is enormously rich and varied (George and Rao, 1967) only about eight species belonging to the families Portunidae (6 species), Calappidae (1 species) and Grapsidae (1 species) are commercially important (Rao, et al., 1973). The fishery, however is mainly supported by the portunid crabs. Among these the mud crab Scylla serrata (Forskal) is the largest and hence in greater demand than the rest of the species. Other added advantages of this species from the commercial point of view are the high quality of meat and its ability to remain alive out of water for a long period (Thomas, 1971). Though it is a marine crab, it invariably invades the esturies and backwaters where it forms a lucrative fishery. It is capable of withstanding wide range of salinities and temperature.

The mud crab was first described by Forskal in 1755 under the name Cancer serratus. Later, de Haan (1833) established the genus Scylla and assigned this species as Scylla serrata (Forskal). Crabs of the genus Scylla exhibit a lot of variations in colouration, size, spination and habitat. Several forms, varieties, and species have been described under this genus by various authors in the past contributing to much confusion about their true identity. However, most carcinologists have been considering all of them to be synonymous with only one species i.e., Scylla serrata (Forskal) until Estampador (1949) through his

comparative external morphological and gametogenetical studies of various forms of the genus Scylla de Haan has revised the genus, recognising three distinct species namely, Scylla oceanica (Dana), Scylla tranquebarica (Fabricius), Scylla serrata (Forskal) and its variety Scylla serrata Paramamosain Estampador. According to Stephenson (1972), however, these separate species are "probably differently pigmented forms of S.serrata".

From India, the genus Scylla de Haan has been referred to by several workers like Henderson (1893); Alcock (1899); de Man, (1908); Kemp, (1915); Gravely, (1927); Pearse, (1932); Hora, (1935); Chopra and Das, (1937); Panikkar and Aiyar, (1937); Pillai, (1951); Naidu, (1953); Chacko et al., (1953); Chacko, (1955-'56 & 1956-'57), Chhapgar, (1957, 1962); Balasubramanian, (1966); Rekha, (1968); Thomas, (1971); Premkumar, (1971); Joel and Raj, (1980); Kathirvel, (1981); Radhakrishnan and Samuel (1982) and Devasia and Balakrishnan (1985). All of them refer to only Scylla serrata.

Kathirvel (1981) pointed out that there may species or variety also existing under this species backwaters and in the adjacent inshore sea indicating the important distinguishing characters found in colour pattern, sizes of the frontal teeth, spination on the carpus of chelipeds, size of the animals and the sizes at first maturity.

Later, Radhakrishnan and Samuel (1982) also came across two forms of the species in Cochin backwaters. By comparing some of the important morphological features such as the structure of the carapace, chelate leg and the first abdominal pleopod of male and the colour pattern of the body they (Radhakrishnan and Samuel, 1982) established the existence of a sub-species which they named as Scylla serrata serrata in addition to the regular form Scylla serrata (Forskal).

Joel and Raj (1980) recorded two distinct species of the genus, namely Scylla serrata (Forskal) and Scylla tranquebarica (Fabricius) in Pulicat lake along the east coast of India. Since the different species created under the genus are still to be established for their validity as already mentioned, the occurrence of two different species in Pulicat lake needs further confirmation.

Scylla serrata is an Indo-Pacific species. It enjoys a wide distribution in this region occurring in the east coast of Africa, Red Sea, Madagascar, Mauritius, Seychells, Pakistan, West and East coast of India, Sri Lanka, Andaman and Nicobar islands, Singapore, Malaysia, Indonesia, Philippines, Fiji, New Caledonia, Australia, Newzealand, Tahiti and Japan. It supports traditional fisheries in most of these countries. In Indian waters, it is found commonly in the inshore sea, backwaters, estuaries, saltwater lakes, mangrove swamps and lagoons through out the west and east coasts.

The mud crab supports flourishing fisheries along with other portunid crabs in the Gulf of Mannar and Palk Bay (Jones. 1967; Rao, 1968), the estuaries of the rivers Ganges, Mahanadi, Godavary, Krishna and Cauvery and the brackishwater lakes of Chilka and Pulicat on the east coast and the estuaries of Narmada and Tapti and the backwaters of Kerala on the west coast (Jones and Sujansingani, 1952; Chacko, et al., 1953; George and Rameshnayak, 1961; Jones, 1967; Thomas, 1971; Datta, 1973; Rao et al., 1973; Joel and Raj, 1980, 1987; Devasia and Balakrishnan, 1985). In most of these places crab is fished by lines baited with pieces of dead fishes. The other types of gear used include gill nets, drag nets, stake nets and baited traps.

According to Rao, et al., (1973), the crab fishery of Vembanad lake in Kerala is mainly contributed by S.serrata, with an annual production ranging from 18 to 35 tonnes. Though the crab occurs in this environment through out the year, the main fishing season extends from May to September. Devasia and Balakrishnan (1985) reported that commercial fishing for the mud crab commences in Cochin backwater with the onset of south west monsoon and lasts till the end of north east monsoon, with maximum landings during the peak monsoon period. During September-October period the fishery experiences decline. In a lesser intensity a second season starts in November and lasts

till the middle of February. During the active fishing season 4000-5000 crabs are supplied to the processing industry.

The biology of Scylla serrata has been the subject of several investigations in recent years from different parts of the Indo-Pacific. Some of the notable contributions from abroad are the studies of Atkinson (1971), Varikul, et al., (1972), Brick (1974), Hill (1974, 1975, 1976, 1978, 1979 a, 1979 b, 1980) and Hill et al., (1982). Various aspects of reproduction and life history of the species have been dealt with in the works of Arriola (1940), Ong (1966), Haesman (1980), Haesman and Fielder (1983), and Quinn and Kojis (1987). From India, much work has been done on the endocrine control and physiology of gametogenesis (Bhattacharya, 1931; Ezhilarasi and Subramoniam, 1980; 1984; Ezhilarasi, 1982; Pannerselvam and Subramoniam, 1982; Nagabhushanam and Farooqui, 1984; Sarojini et al., 1985). The biochemical and histochemical characteristics of seminal plasma and spermatophores have been studied by Uma and Subramoniam (1979, 1982) and Ezhilarasi (1982), while Sudha (1982) estimated carotenoids in the ovary. Pillai and Nair (1968, 1973) and Mercy Thomas (1984) touched upon the reproductive cycles and breeding biology, and Naidu (1955) studied the early development. Though many workers have thrown light on the fishery potential of this species from different parts of the country, studies on population characteristics and bionomics are extremely limited. Amont the few investigations made on these aspects are the works of Mohanty (1975) from Chilka Lake, Joel and Raj (1980) and Srinivasagam and

Raman (1985) from Pulicat Lake and Kathirvel (1980, 1981), Mercy Thomas (1984) and Devasia and Balakrishnan (1985) from Cochin backwaters. Some biological information such as growth, survival and mating behaviour of this crab is also documented by Bensam (1986) and Marichamy et al., (1986) by rearing studies.

In view of the increasing demand for crab meat in the world markets it has become necessary to develop culture techniques for this important species for augmenting production. Experiments to rear larval stages to juveniles have been conducted in Sri Lanka and Philippines (Arriola, 1940), Malaysia (Ong, 1966 a, 1966 b),and India (Naidu, 1955; Marichamy and Rajapandian, 1979). Of late, attempts have been made to culture young crabs to marketable size on moderate scale in Philippines (Escritor, 1970; Pagcatipunan, 1970), Thailand (Varikul et al., 1970), Sri Lanka (Raphael, 1970), India (Marichamy, 1979; Marichamy et al., 1986; Bensam, 1986) and Singapore and Thaiwan fill it. The above studies have shown that S.serrata could be cultured profitably in ponds and cages.

Cochin backwater is the most productive part of the Vembanad Lake from the fishery point of view. Every year considerable quantity of the mud crab is exploited from the backwater as well as from the adjoining inshore waters, and there is plenty of scope for further expansion of the fishery through proper management and judicious exploitation of the

natural population. The easy availability of seeds in the backwater (Kathirvel, 1980) and breeding population locally (Kathirvel, 1980; Mercy Thomas, 1984) makes it possible to develop a culture fishery for this species in the area. For all these developmental programmes adequate information on the biology and population characteristics of the animal is an essential pre-requisite. But from the foregoing review of literature it is evident that the available information on these aspects are very meagre This has prompted a detailed study of the size distribution and reproductive biology of the mud crab at Cochin during the peak fishing season of the southwest monsoon period and the results are presented in this work.

MATERIAL AND METHODS

The material for the present study was obtained from the commercial catches of Cochin backwater and the adjoining inshore sea lying between Latitudes 9°55'N and 10°05'N. After a preliminary survey of the important landing centres and their nearest markets for the mud crab, three observation centres, namely, Vypeen, Thevara and Champakkara were fixed for regular sampling and monitoring of the catch (Fig.1). For convenience, these three centres have been named as Observation Centre I, II and III respectively for all practical purposes. The crabs landed at Vypeen were all caught from the sea and the Cochin bar mouth, while those landed at Thevara were caught from the open backwater and Champakkara from the interior of the backwater.

Each observation centre was visited in the morning once a fortnight and size measurement were taken sex-wise for a random sample of 25 to 50 crabs of each form (species and its variety) depending on their availability. The carapace width (C.W), measured between the tips of the ninth antero-lateral spines to the nearest millimetre using a vernier caliper, was taken to represent the size of the crab. In all, 815 crabs were measured from the three observation centres together. The female specimens contained in the random sample were brought to the laboratory for detailed study of reproductive aspects. Each animal, after noting down the ovigerous

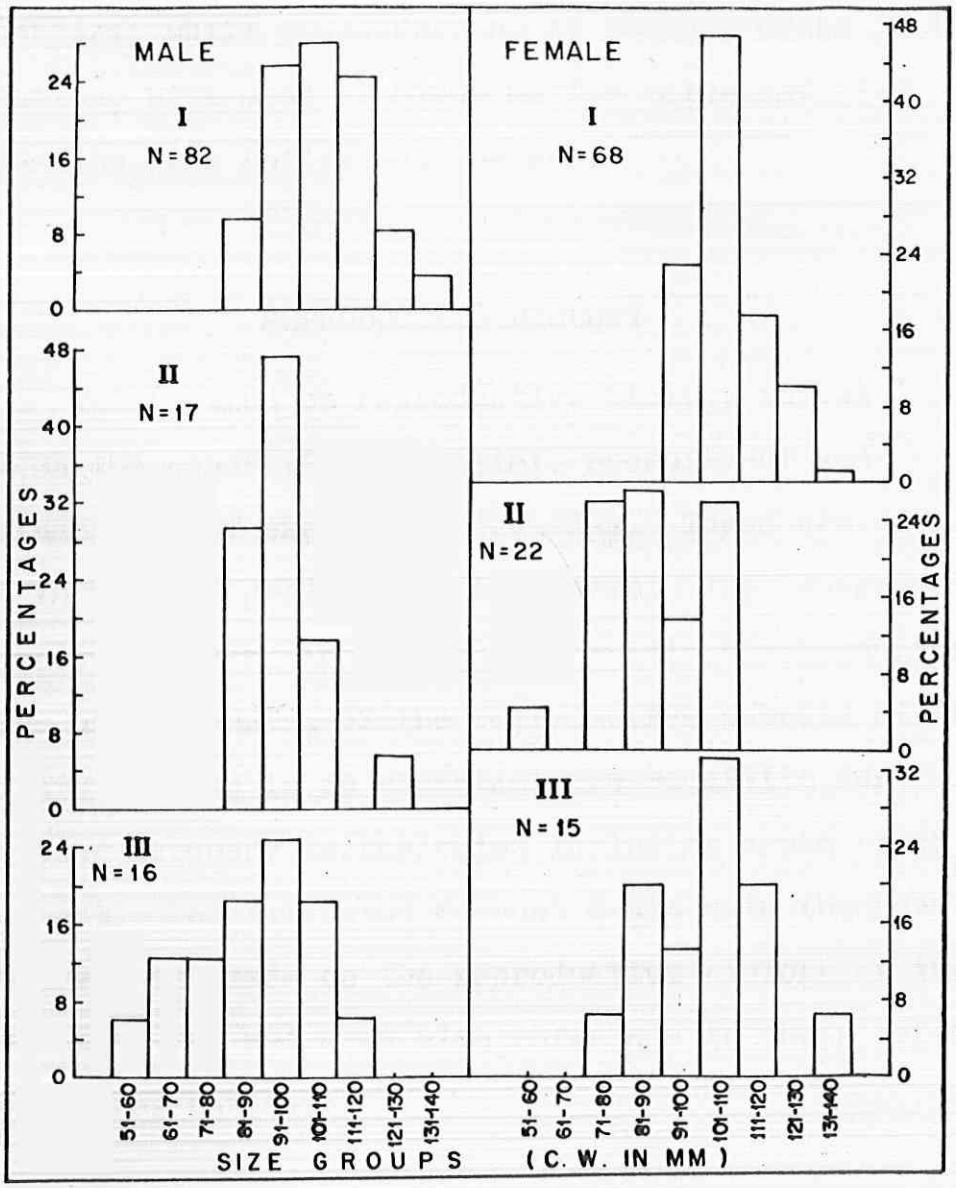
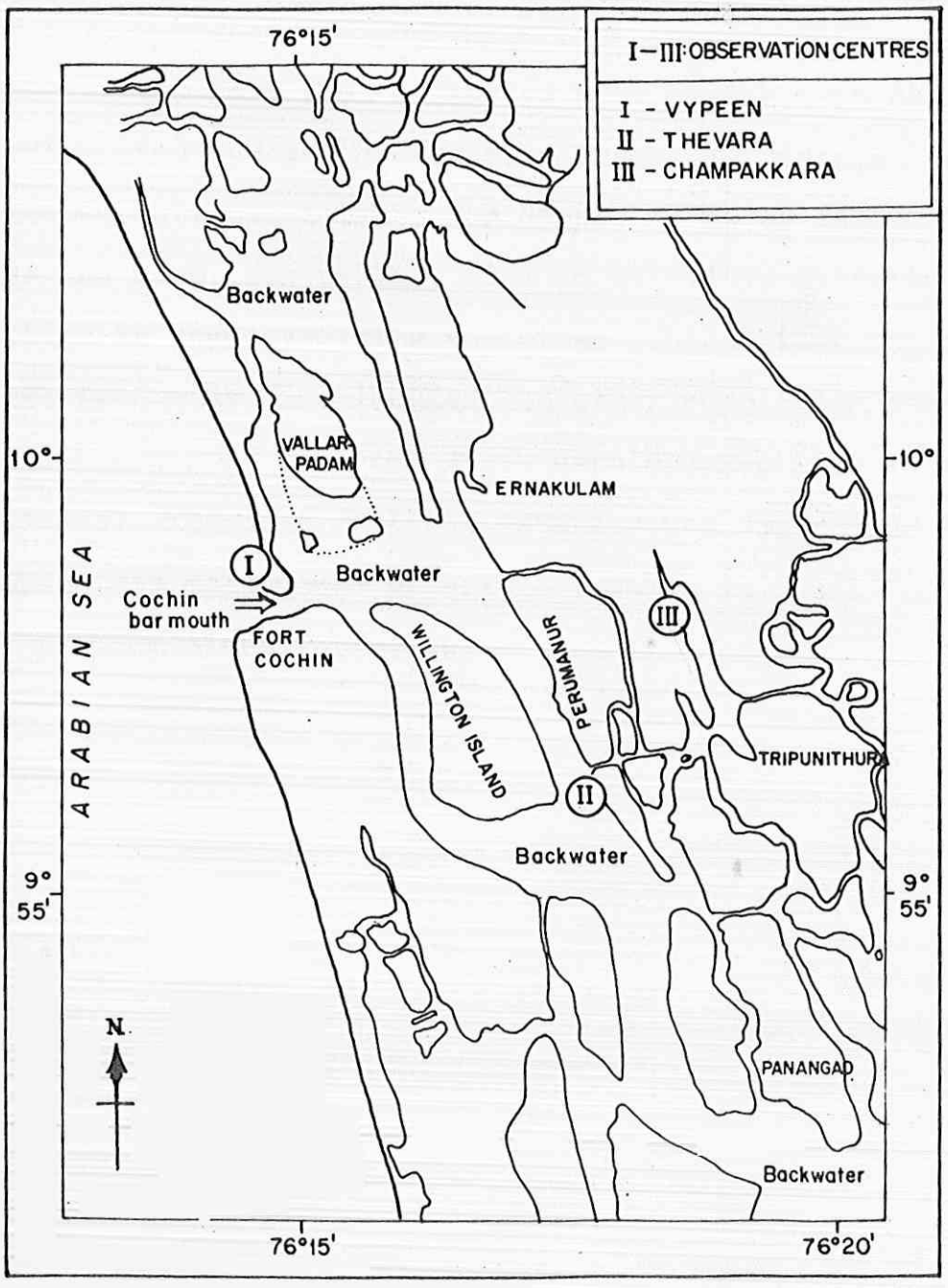

MALE
I
N = 82
II
N = 17
III
N = 16
FEMALE
I
N = 68
II
N = 22
III
N = 15
PERCENTAGES
PERCENTAGES
0
8
16
24
32
40
48
51-60
61-70
71-80
81-90
91-100
101-110
111-120
121-130
131-140
SIZE GROUPS (C. W. IN MM)

Fig. 1 Topography of the study area and location of observation centres.


I–III: OBSERVATION CENTRES
I - VYPEEN
II - THEVARA
III - CHAMPAKKARA
76°15'
76°20'
10°
9° 55'
ARABIAN SEA
Backwater
VALLAR-PADAM
ERNAKULAM
Backwater
Cochin bar mouth
FORT COCHIN
WILLINGTON ISLAND
PERUMANUR
TRIPUNITHURA
Backwater
PANANGAD
Backwater
N
I
II
III

or non-ovigerous state, was dissected out in fresh condition and the maturity stage of the ovary was recorded on the basis of growth and colour of the gonad.

The data thus collected were analysed in detail for centre-wise and month-wise size frequency distribution, mean size variations, t-tests for sample means of the two forms of the mud crab, sex ratios, size at maturity, maturity distribution in space and time and other reproductive aspects. For size frequency distribution and other population studies the measurements of carapace width were grouped into 10 mm size classes. The size at first maturity was determined from the percentage occurrence of gravid females in total females at every 5 mm class intervals.

R E S U L T S

IDENTIFICATION OF THE MUD CRAB

A detailed study of the taxonomic characters of the mud crabs occurring in the marine and brackishwater areas of Cochin, prior to the commencement of routine observations, has revealed the existence of two distinct groups of crabs as noticed by earlier workers (Kathirvel, 1981; Radhakrishnan and Samuel, 1982). One group closely agreed with the original description of Scylla serrata (Forskal) while the other group showed noticeable variations in the structure of carapace and chelate leg and in the colour pattern based on which Radhakrishnan and Samuel (1982) created the sub-species Scylla serrata serrata. The diagmostic features of these two forms of the mud crab are as follows.

SCYLLA SERRATA (PLATE I A):

Carapace convex, frontal teeth slightly pointed and anteriorly projected, anterolateral teeth not anteriorly truncated, a deep 'H' shaped furrow in the cardiac region, posterior border broad and less convex; chelate legs massive, merus bearing three stout spines in the anterior border (inner angle) and two on the posterior border (outer angle) of which one terminal and the other one sub median in position, carpus with a strong spine at the inner angle and two stout spines

at the outer angle, propodus with one stout spine at the front of the apex of the wrist joint and two small ones located side by side behind the finger joint; colouration of carapace predominently greenish on the dorsal side and creamy on the ventral sides; swimming legs, upper portion of chelate legs and abdominal flap of mature females with numerous mosaic-like yellow or white patches.

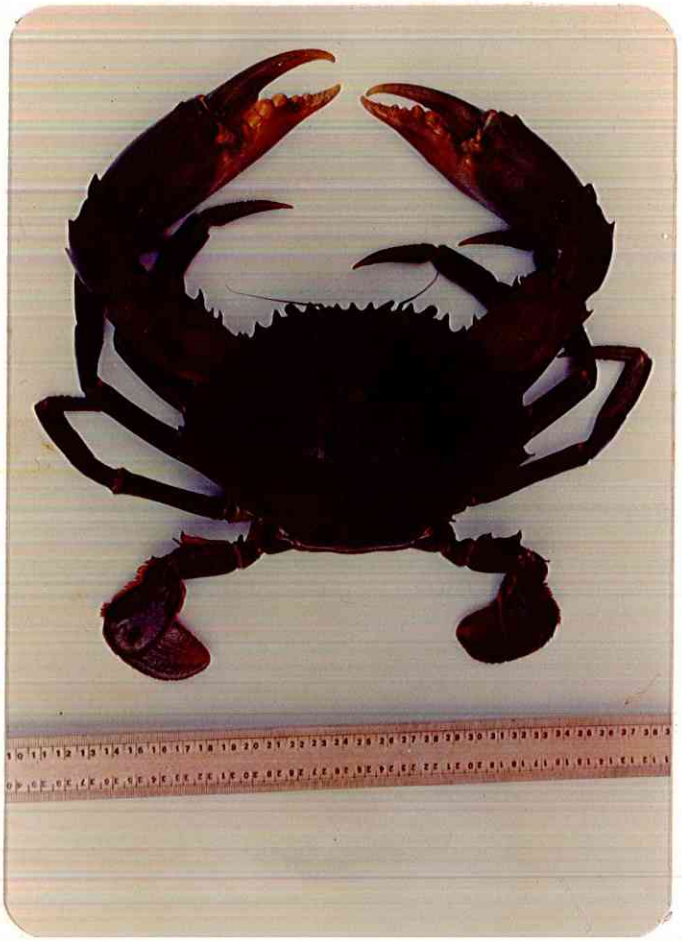
SCYLLA SERRATA SERRATA (PLATE I B):

Carapace more convex, frontal teeth blunt and arranged in a row, anterolateral teeth compactly arranged and anteriorly truncated, a moderately deep 'H' shaped furrow in the cardiac region, posterior border narrower and more convex; spination on merus and propodus of chelate legs similar to that of the former one, carpus with a strong spine at the inner angle and a single spine at the outer angle, lateral region of propodus with a tubercle; colouration of carapace shyny green with a smooth surface dorsally and bluish pink ventraly; mosaic-like patches visible only on carapace, chelate legs orange coloured with a brownish green tinge, abdominal flap of mature females brownish black in colour with dark bands.

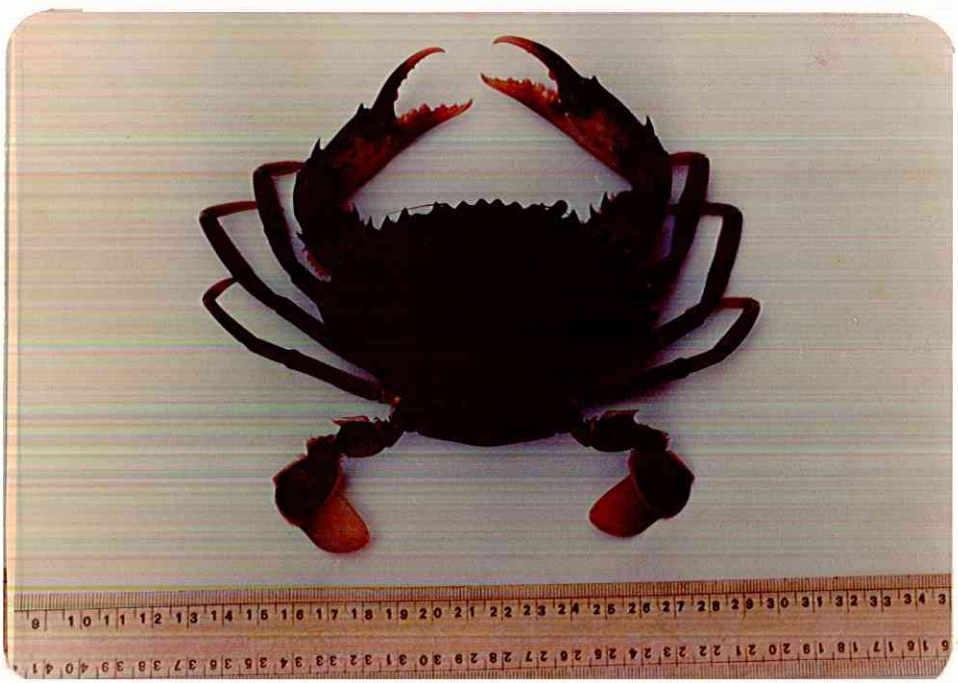
In the field, S.serrata serrata could be easily distinguished from S.serrata based on the characters such as the presence of only a single spine (as against two) on the

Plate I The mud crabs. A. *Scylla serrata*; B. *Scylla serrata serrata*

PLATE I



A



B

outer angle of the carpus of chelate leg and the brownish black colour of abdomen with dark cross bands in mature females and in the absence of mosaic-like patches on the distal part of swimming legs.

SIZE DISTRIBUTION

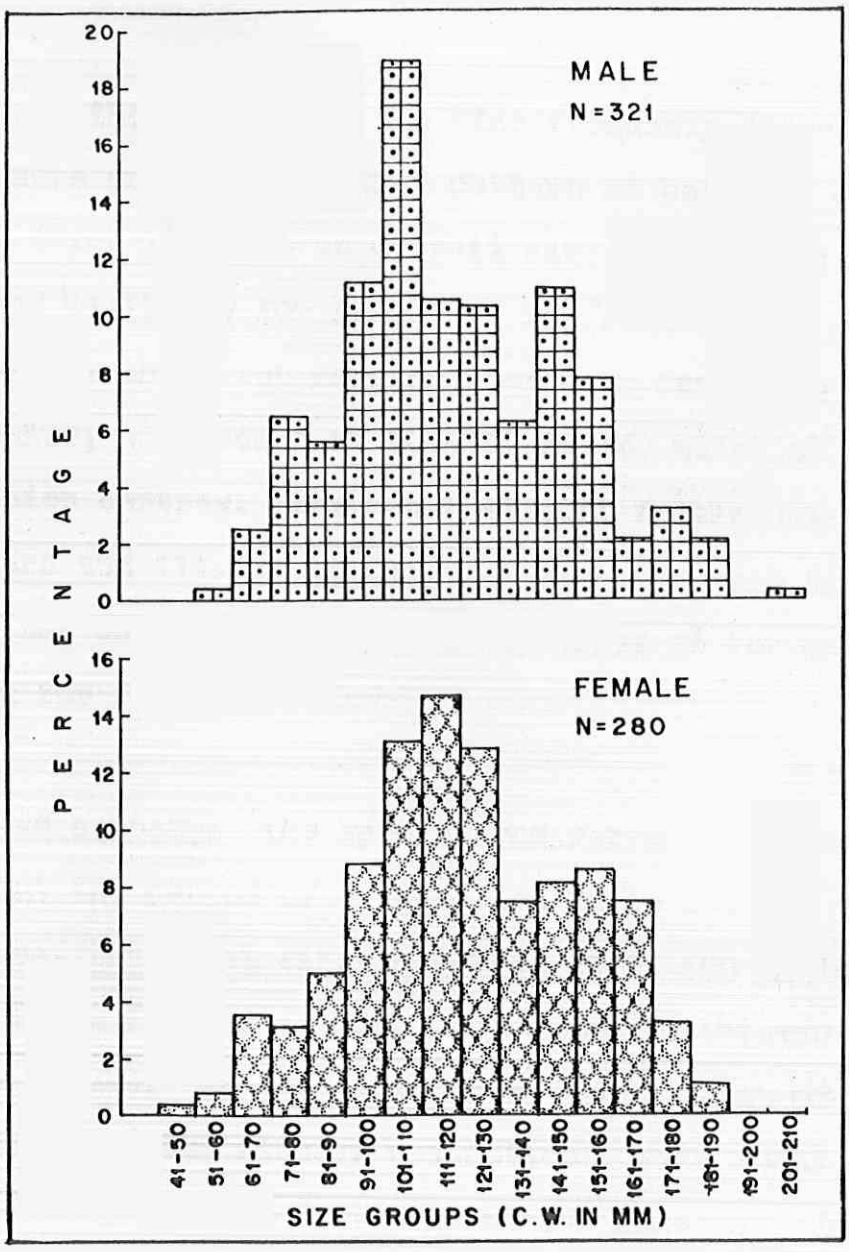
The commercial fishery of the mud crab was constituted by both the forms described above at all the three observation centres in varying proportions. On the whole, S.serrata was more numerous in the population than S.serrata serrata in the marine as well as backwater environments.

SCYLLA SERRATA (Fig. 2, 3 & 4)

of 601 crabs including 321 males and 280 females measured have indicated a size range of 41-210 mm carapace width. The fishery was predominantly constituted by the size groups 91-150 mm for males and 91-130 mm for females. The overall size frequency distribution was of unimodal pattern with the modes at 101-110 mm in males and 111-120 mm in females (Fig. 2). The mean size of males worked out to 119.2 mm and that of females to 118.6 mm.

Spatial distribution: Significant variations were noticed in the size distribution of the crab in the sea and backwater. The size range in the marine catch was 71-210 mm for males and

Fig. 2 Size frequency distribution of *Scylla serrata* (Pooled data)


MALE
N=321
FEMALE
N=280
PERCENTAGE
SIZE GROUPS (C.W. IN MM)
41-50
51-60
61-70
71-80
81-90
91-100
101-110
111-120
121-130
131-140
141-150
151-160
161-170
171-180
181-190
191-200
201-210

91-190 mm for females, with modes at 101-110 mm for both the sexes. Over 70 % of the males and 65 % of the females were constituted by the sizes ranging 101-160 mm and 101-170 mm respectively. The mean sizes worked out to 131.7 mm for males and 134.1 mm for females.

In the backwater, the size frequency distribution showed more or less a similar pattern at both the observation centres (Fig. 3), with an overall size range of 51-190 mm for males and 41-190 mm for females. The bulk of the fishery was supported by the sizes ranging 71-130 mm for males and 61-130 mm for females, with modes at 101-110 mm for males at both the observation centres. The modal size of female was at 91-100 mm at Thevara and 111-120 at Champakkara. The mean size of the crab in the backwater worked out to 105.2 mm for males and 105.5 mm for females.

Month-wise pattern: The species was represented in the fishery throughout the period of observation in both the environments. In the sea, the modal sizes observed at 91-100 mm in males and 101-110 mm in females in June progressed to 141-150 mm for both sexes by August. In September fresh recruitment of younger population into the fishery was noticed, with modal sizes at 101-110 mm for males and 111-120 mm for females. In the back-water, the crab landings showed modes at 91-100 mm for males

Fig. 3 Size frequency distribution of *Scylla serrata* at different observation centres

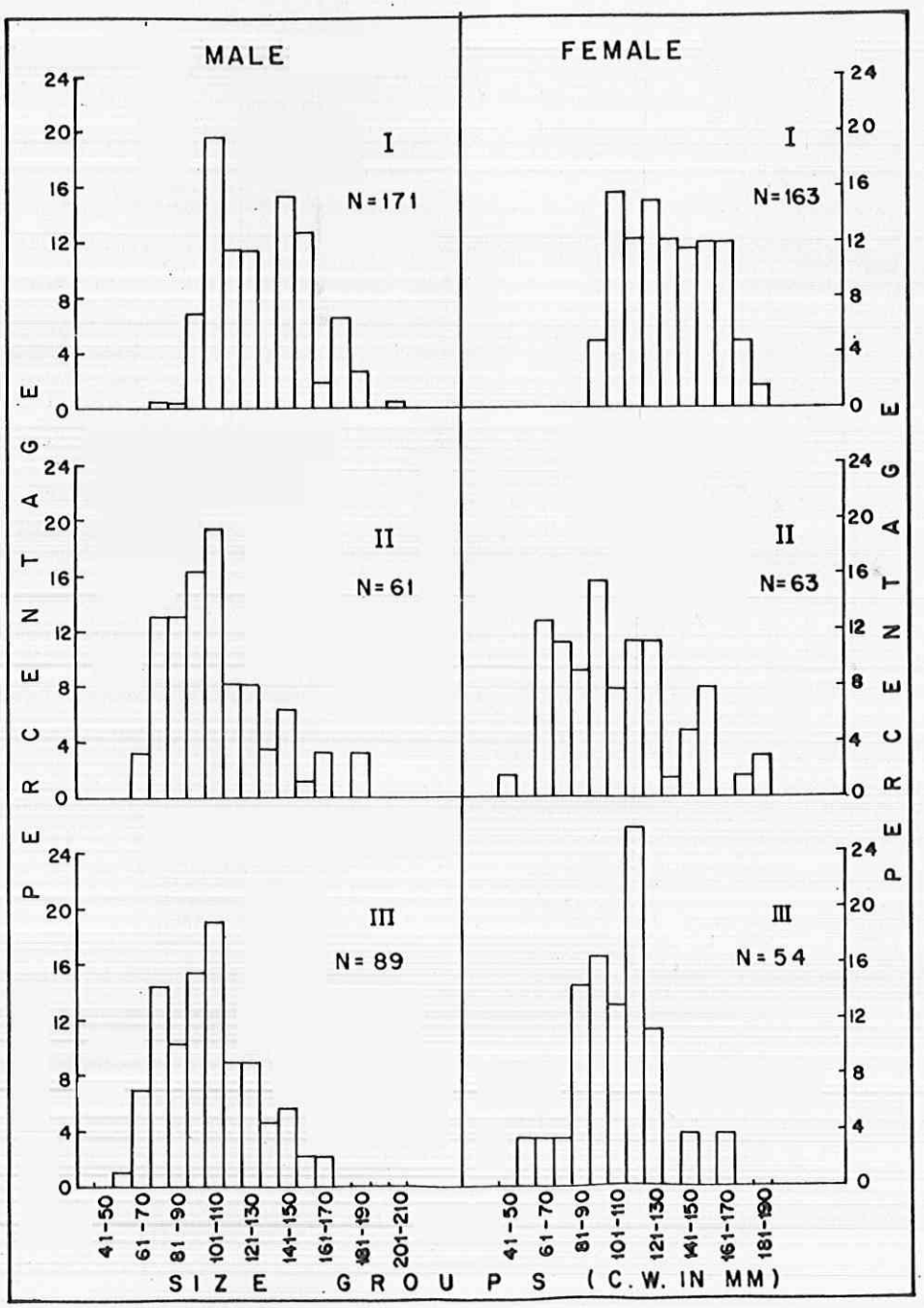
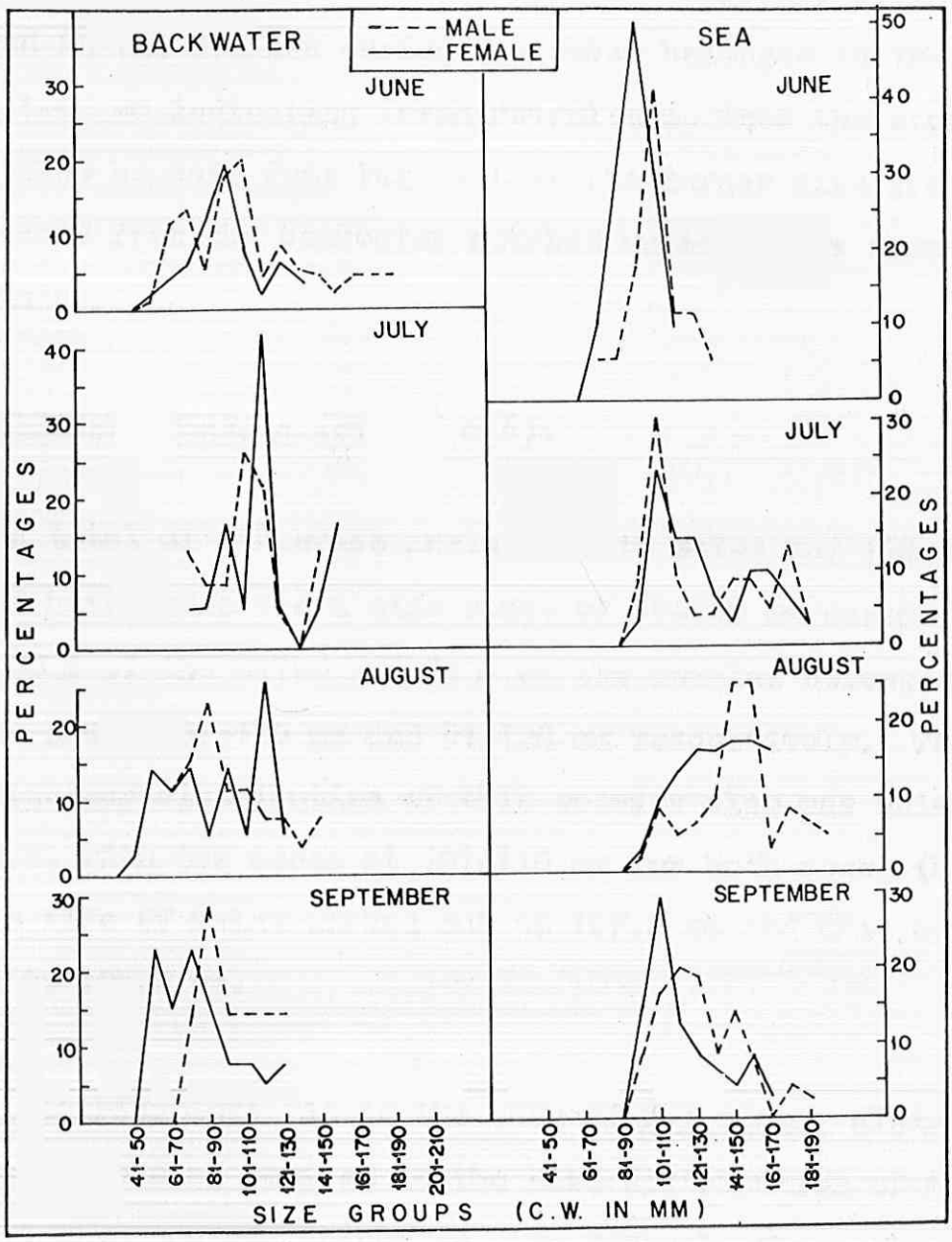

MALE
FEMALE
I
N=171
I
N=163
II
N=61
II
N=63
III
N=89
III
N=54
PERCENTAGE
0
4
8
12
16
20
24
41-50
61-70
81-90
101-110
121-130
141-150
161-170
181-190
201-210
SIZE GROUPS (C.W. IN MM)

Fig. 4 Size frequency distribution *Scylla serrata* month-wise.


BACKWATER
MALE
FEMALE
SEA
JUNE
JUNE
JULY
JULY
AUGUST
AUGUST
SEPTEMBER
SEPTEMBER
PERCENTAGES
PERCENTAGES
41-50
61-70
81-90
101-110
121-130
141-150
161-170
181-190
201-210
SIZE GROUPS (C.W. IN MM)

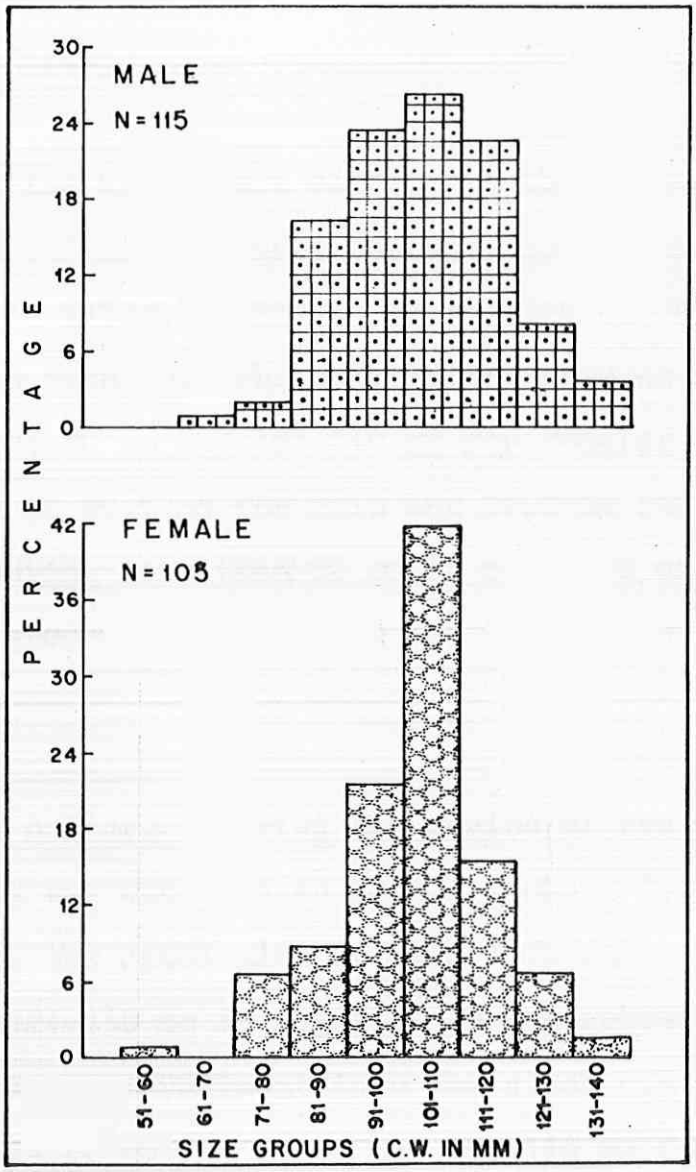
and 101-110 mm for females in June. While the modal size of male progressed to 111-120 mm in July and remained to be so in August, the principal mode of female stayed at 101-110 mm in July and thereafter shifted to 81-90 mm. Majority of the males observed in the catches during September belonged to the size group 51-80 mm indicating fresh recruitment into the stock. It can also be seen from Fig. 4 that the larger size groups disappeared from the backwater catches successively from July to September.

SCYLLA SERRATA SERRATA (Fig. 5 & 6):

A total of 214 crabs including 115 males and 105 females measured have indicated a size range of 51-140 mm carapace width. Nearly 90 % of the males and 80 % of the females belonged to the size groups 81-120 mm and 91-120 mm respectively. The overall size frequency distribution of this species also was unimodal in nature, with the modes at 101-110 mm for both sexes (Fig. 5). The mean size of males worked out to 107.8 mm and that of females to 104.0 mm.

Spatial distribution: As in the case of S.serrata, clear cut variations could be noticed in the size distribution of the subspecies in the sea and backwater. In general, the crab population of the sea was constituted by larger individuals as compared to that of the backwater. The size range in the former

Fig. 5 Size frequency distribution of *Scylla serrata serrata* (Pooled data).

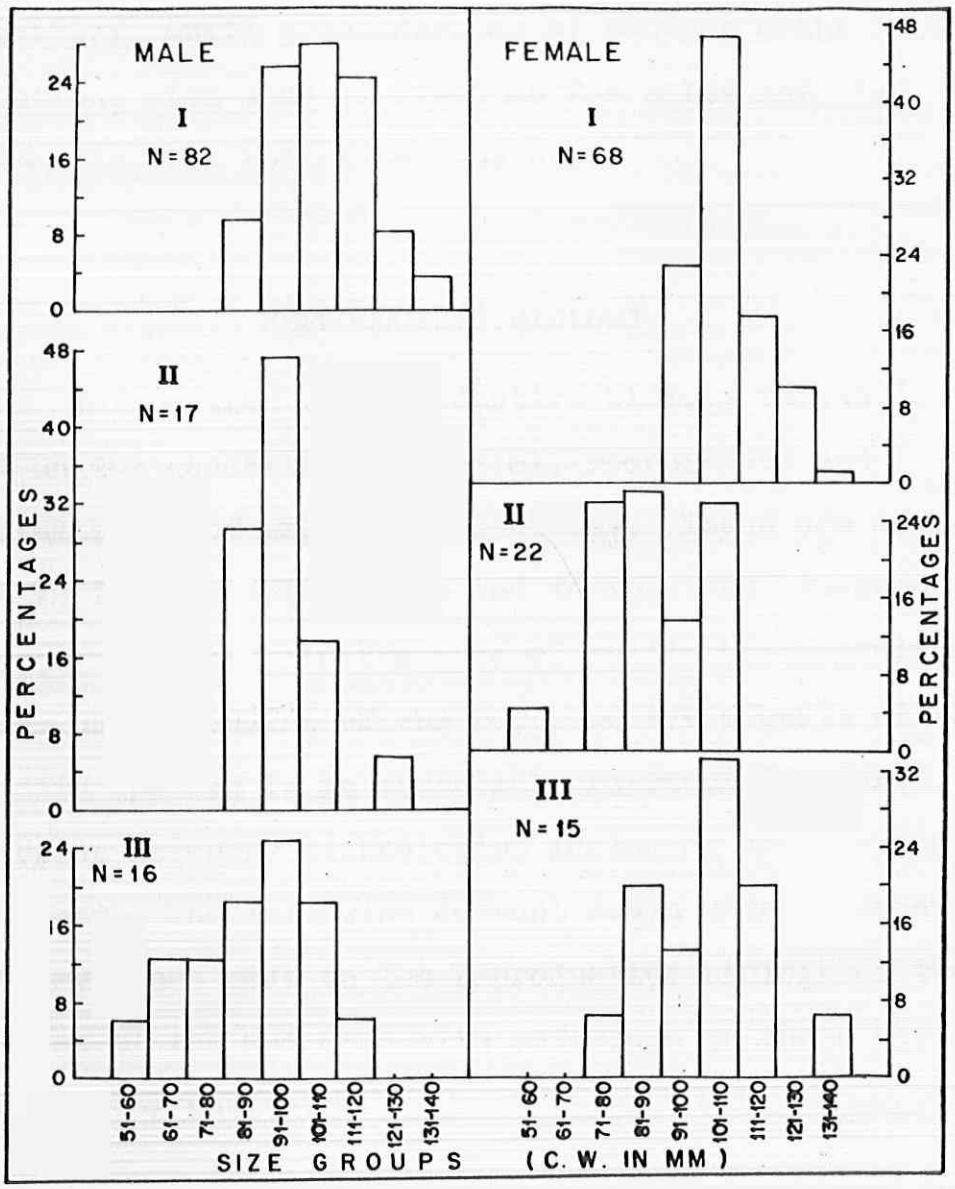

MALE
N = 115
FEMALE
N = 105
PERCENTAGE
0
6
12
18
24
30
36
42
51-60
61-70
71-80
81-90
91-100
101-110
111-120
121-130
131-140
SIZE GROUPS (C.W. IN MM)

environment was 81-140 mm for males and 91-140 mm for females, with modes at 101-110 mm for both sexes (Fig. 6). Over 75 % of the males and females were formed by the size group 91-120 mm. The mean sizes worked out to 106.2 mm for males and 107.1 mm. for females.

In the backwater, almost all the size classes ranging from 51 to 140 mm size were encountered of which the size group 81-110 mm in males and 71-120 mm in females constituted the bulk of the fishery. The modal sizes were at 91-100 mm for males and 71-80 mm and 101-110 mm for females. The mean size worked out to 95.1 mm for male and 97.1 mm for female. Younger crabs measuring less than 80 mm in carapace width were met with in fairly good numbers at both the observation centres of the backwater.

Month-wise pattern: During the period of the present study the sub-species was encountered in the fishery from July to September. In the sea, the modal size of male crab was at 111-120 mm and female at 121-130 mm in August. In the subsequent month, however, fresh recruitment into the stock was noticed, with modes at 91-100 mm for males and 101-110 mm for females. In the backwater, majority of the crabs were in the size range 101-110 mm for males and 81-110 mm for females during July and August at Champakkara. The modal sizes at Thevara during

Fig. 6 Size frequency distribution of Scylla serrata serrata at different observation centres.


MALE
I
N = 82
II
N = 17
III
N = 16
FEMALE
I
N = 68
II
N = 22
III
N = 15
PERCENTAGES
PERCENTAGES
0
8
16
24
32
40
48
51-60
61-70
71-80
81-90
91-100
101-110
111-120
121-130
131-140
SIZE GROUPS (C. W. IN MM)

August were at 91-100 mm for males and 81-90 mm for females. In September, relatively larger crabs of both sexes ranging 91-120 mm dominated in the fishery at Champakkara, while preponderance of younger crabs in the population, with mode at 81-90 mm for males and 71-80 mm for females, was noticed at Thevara.

REPRODUCTIVE BIOLOGY

Information on reproductive biology throws light on the generative potential, recruitment and sustainability of exploited resources. These are of great value in fishery predictions and formulating management measures. Further, in the case of cultivable organisms, a clear understanding of the reproductive aspects of the candidate species is an essential pre-requisite for developing hatchery technologies including brood stock management. The following account deals with the results of observations made on the reproductive biology of the two forms of the mud crab with reference to their marine and estuarine habitats.

SEX DIFFERENTIATION

The male and female crabs can be easily distinguished by the size and shape of abdominal flap

and the number and structure of abdominal appendages. The female has a broader abdomen than in the male. There are only two pairs of abdominal appendages in males (on first and second somites), which are modified to form rod-like copulatory organs. In females there is one pair of appendages on each of the second. third, fourth and fifth abdominal somites. These form the pleopods or 'swimmerets' to which the eggs are attached during incubation.

In both forms of the mud crab, the abdomen of mature female assumes a semicircular shape with well developed pleopods to hold the eggs. In S. serrata the abdominal flap develops a green colour, with full of yellow or white mosaic-like patches, while in S. serrata serrata the colour of the abdomen at breeding stage is brownish black with dark bands across the flap.

SEX RATIOS

The average condition of sex ratios in the fishery indicates preponderance of males in both the environments for S. serrata, the overall sex composition being 51 : 49 in the sea and 56 : 44 in the backwater. In the case of S. serrata serrata also males outnumbered the females in the marine catch (55 : 45), whereas in the backwater fishery the females were slightly in excess of males (47 : 53).

The distribution of sex ratios with reference to different size classes (Tables 1 & 2) indicates no definite pattern either in the sea or in the backwater. Analysis of sex ratios monthwise has shown that in S. serrata (Table 3) females occur in greater proportion than males in the sea during July and August, which may be due to the gradual migration of spawning population from the backwater (vide infra) during that period. In S. serrata serrata, however, the two sexes were almost equally represented in the backwater population throughout July - September (Table 4) although the males slightly dominated in the marine catch in August and September.

CLASSIFICATION OF MATURITY STAGES OF FEMALE

The maturation of crab involves a series of changes in the morphology, histology and colouration of the gonad. In the present study, based on colour change and morphological features such as size, shape and the space it occupies in the body cavity, the ovary has been classified into five maturity stages viz. Immature, early maturing, late maturing, mature or ripe and spent recovering.

Stage I - Immature: Ovary colourless, thin and flimsy. Restricted to only the cephalathoracic region, Ovary is hidden in the hepatopancreatic tissue.

Stage II - Early maturing: Ovary light yellow. Ovarian tubules distinct from hepatopancreas.

Stage III - Late maturing: Ovary orange colour, Opaque in nature. Ovarian tubules are greatly enlarged.

Stage IV - Mature or ripe: Ovary deep orange and fills up the whole body cavity of carapace. Hepatopancreas is concealed.

Stage V - Spent recovering: Ovary colourless and flaecid. Distinctly larger than immature overy and the arms extend to posterior part of carapace.

In the ripe condition the ovary of S. serrata serrata is more brilliantly coloured than in S. serrata.

SIZE AT FIRST MATURITY

According to Edwards (1978) the maturity in female crab is identified by characters such as (a) the presence of eggs on the abdomen, (b) the presence of sperm

in the spermatheca and (3) the ripeness of the ovaries. In the present investigation, crabs with ovaries in III and IV stages of development have been considered to be sexually mature for normal reproductive functions.

In S. serrata the smallest crab observed in sexually mature state measured 100 mm carapace width. As could be seen from Fig. 7, the size at first sexual maturity at 50% level is found to be 109.0 mm C.W. In the case of S. serrata serrata the corresponding sizes were much smaller, the observed minimum size being 83 mm and the size at 50% level being 90.0 mm in carapace width (Fig. 8).

DISTRIBUTION AND ABUNDANCE OF BREEDING POPULATION

The crabs in general reproduce in their usual habitats. Often the breeding is protracted as in other members of decapod crustaceans occuring in tropical regions. After spawning the fertilised eggs are carried by the mother crab as 'berry' underneath the abdominal cover for a few days (ovigerous period) before they hatch out as zoea larvae. In the case of the mud crab, Kathirvel (1981) reports that although berried females are encountered in estuarine systems and culture ponds, the newly hatched zoea larvae have never been recorded from such environments. It is therefore presumed that the

Fig. 7 Size at first sexual maturity at 50 % level of *Scylla serrata* females.

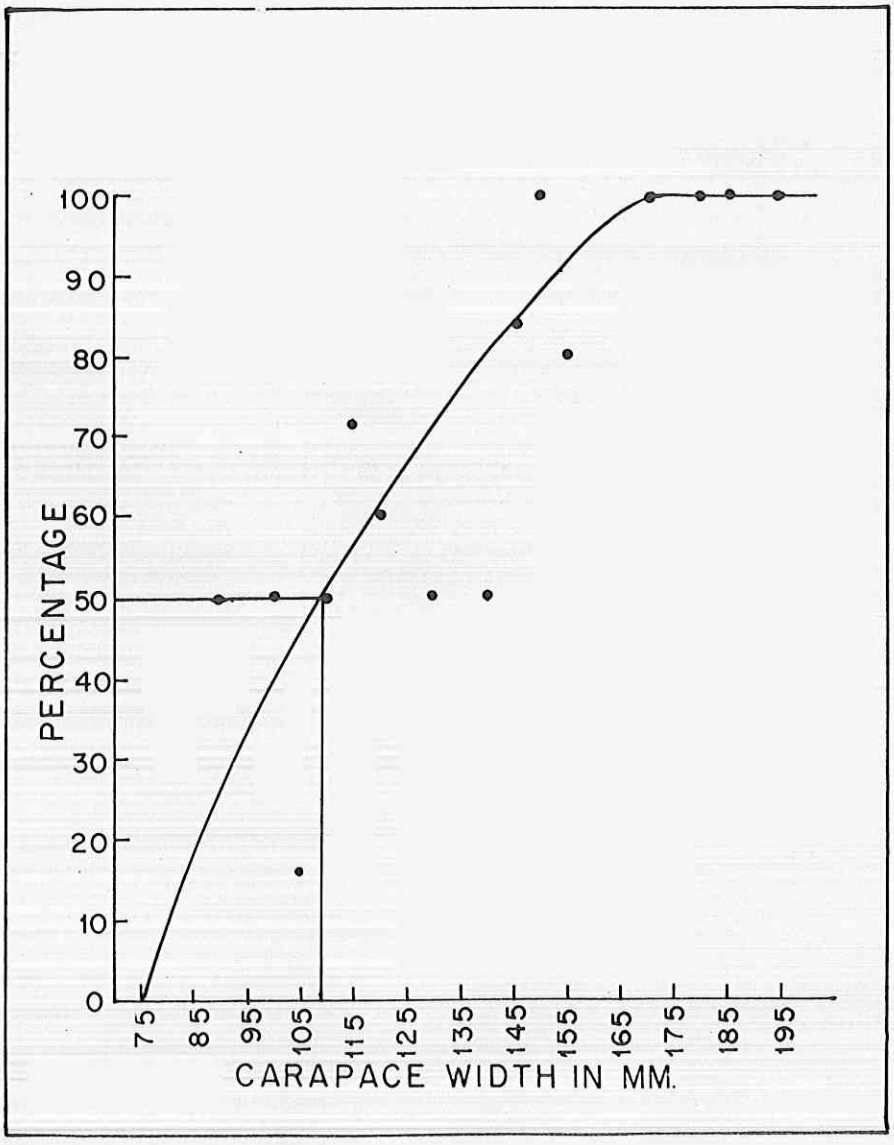
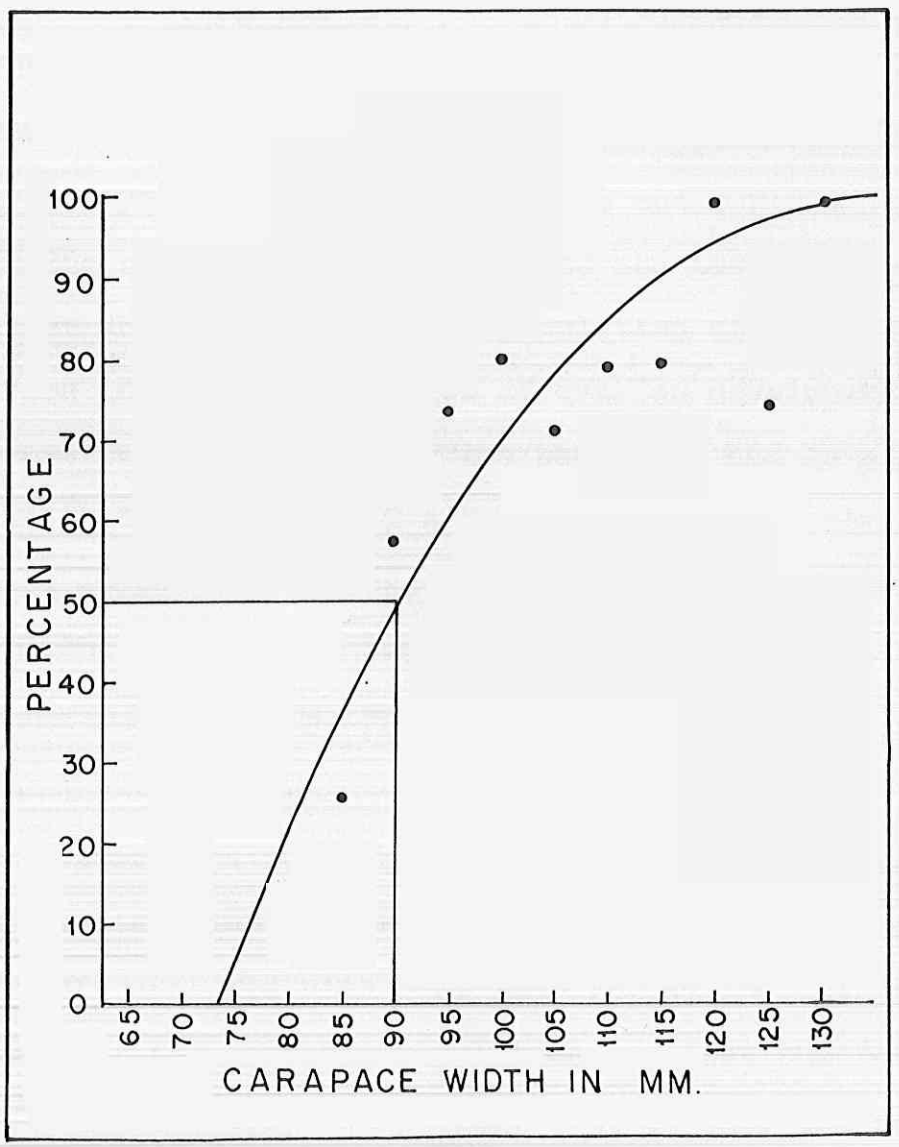

100
90
80
70
60
50
40
30
20
10
0
PERCENTAGE
75
85
95
105
115
125
135
145
155
165
175
185
195
CARAPACE WIDTH IN MM.

Fig. 8 Size at first sexual maturity at 50 % level of *Scylla serrata serrata* female.

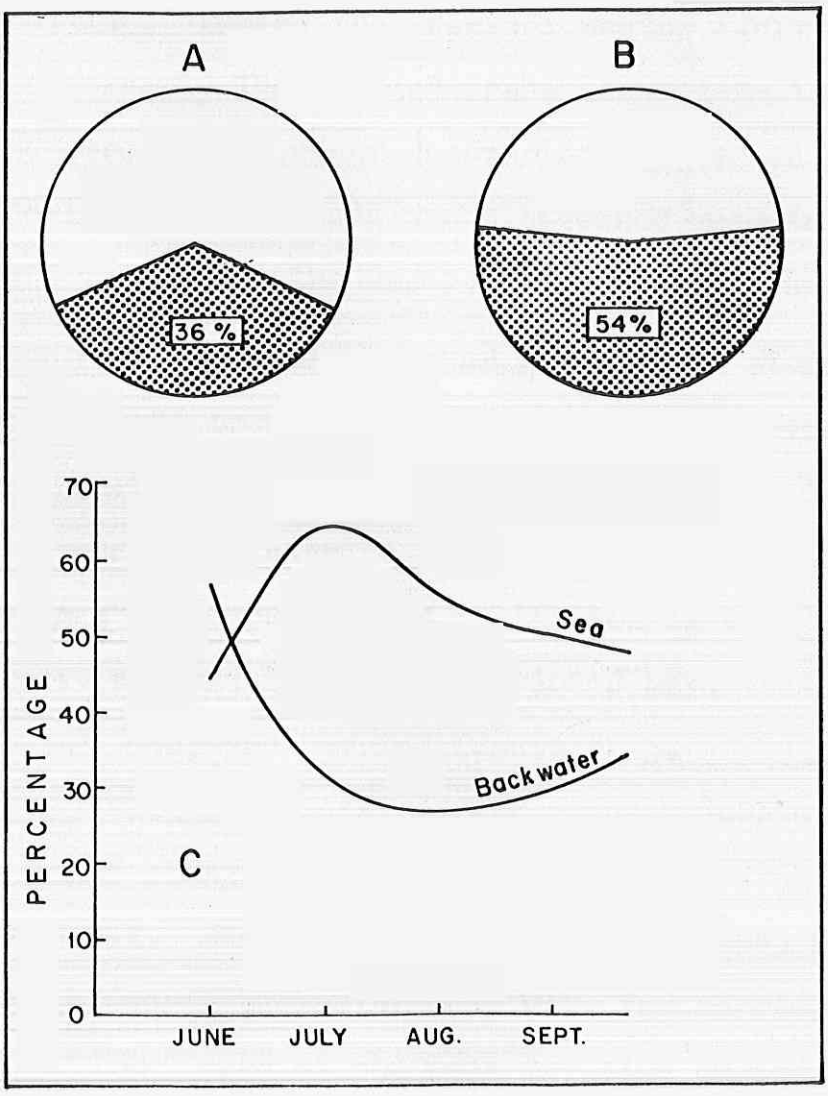

PERCENTAGE
100
90
80
70
60
50
40
30
20
10
0
65
70
75
80
85
90
95
100
105
110
115
120
125
130
CARAPACE WIDTH IN MM.

larvae may undergo metamorphosis only in the marine region where suitable salinity conditions exist. The brackishwaters are not favourable for larval development and hence egg-hatching may not take place there.

During the present study, crabs in all the five stages of gonadal development were noticed in both the environments (Table 5). In S. serrata, more than half of the population was in immature and early maturing stages in the backwater, whereas in the sea these stages formed about 18.3%. The spawning population comprising of crabs in III and IV stages of ovarian development constituted about 36% in the backwater and as high as 54% in the sea (Fig. 9 A & B). Spent recovering stages were comparatively less represented in the backwater (10.3%) than in the sea (11.7%).

Fig. 9 C depicts the monthly trends in the abundance of reproductive females for S. serrata. In the backwater, the peak occurrence of spawners was recorded in June and thereafter the percentage of mature crabs sharply declined with some improvement in September. In the sea. the spawning population was less numerous than in the backwater during June. But in July the percentage of spawners shot up to a much higher level than in the backwater, and thereafter gradually declined.

Fig. 9 Distribution of spawning population of Scylla serrata. A, Percentage of spawning population in total females in the backwater; B, Percentage of spawning population in total females in the sea; C, Monthly abundance of spawners in the sea and backwater.


A
B
36 %
54%
70
60
50
40
30
20
10
0
PERCENTAGE
Sea
Backwater
C
JUNE
JULY
AUG.
SEPT.

In S. serrata serrata mature females were noticed in the backwater fishery only in September when more than 60% of the animals had ovaries in ripe condition. During the previous months (July and August), though fairly large sized crabs occured in this environment they were all in spent recovering stage. In the sea, vast majority of the female crabs examined were in gravid state throughout the monsoon period.

During the course of the present study no berried female could be observed in the fishery. However, it was understood from local fishermen engaged in crabbing that berried females do occur sometimes in stray numbers during the monsoon period in the sea as well as backwater. In this context it may be mentioned here that during October 1988, one berried female of S. serrata serrata was met with in a local market. The colour of the berry was light orange and the crab was caught from the bar mouth by dip net. Devasia and Balakrishnan (1985) have noticed that in Cochin backwater only very few berried females are obtained even at the peak breeding periods.

Table 2: Size-wise sex ratios (in percentage) of *Scylla serrata serrata*.

Size classes (mm)	Backwater		Sea	
	Male	Female	Male	Female
51-60	-	100.0	-	-
61-70	100.0	-	-	-
71-80	22.2	77.8	-	-
81-90	43.7	56.3	100.0	-
91-100	68.7	31.3	56.7	43.3
101-110	38.8	61.2	41.8	58.2
111-120	50.0	50.0	62.5	37.5
121-130	100.0	-	50.0	50.0
131-140	-	100.0	75.0	25.0

TABLE 3: Monthly sex composition (in percentage) of *Scylla serrata* in the commercial catches during the monsoon period.

Months	Backwater		Sea	
	Male	Female	Male	Female
June	63.3	36.7	62.9	37.1
July	53.5	46.5	43.4	56.6
August	45.5	54.5	42.8	57.2
September	53.8	46.2	59.2	40.8

TABLE 4: Monthly sex composition (in percentage) of *Scylla serrata serrata* in the commercial catches during the monsoon period.

Months	Backwater		Sea	
	Male	Female	Male	Female
June	-	-	-	-
July	50.0	50.0	-	-
August	48.5	51.5	53.6	46.4
September	48.2	51.8	54.5	45.5

TABLE 5: Percentage composition of the different maturity stages of *Scylla serrata* females in the backwater and sea during the monsoon period (Pooled data)

Environment	Im.	EM	LM	M	Sp.
Backwater	41.5	12.7	27.2	8.3	10.3
Sea	7.6	10.7	38.5	15.5	27.7

TABLE 6: Comparative statistical analysis of the sample means of *Scylla serrata* and *Scylla serrata serrata*.

Name of animal	n	mean	S	se	t
MALE					
S. serrata	215	122.50	31.44		
S. serrata serrata	75	107.29	12.93	3.73	4.06
FEMALE					
S. serrata	260	123.85	29.37		
S. serrata serrata	95	102.56	16.96	3.19	6.66

D I S C U S S I O N

The occurrence of more than one form of mud crab under the genus Scylla de Haan has been reported from many regions of the Indo-Pacific, but the validity of specific status assigned to the different forms (Estampador, 1949; Serena, 1952) is still being debated. Radhakrishnan and Samuel (1982), while erecting the sub-species S.serrata serrata demonstrated many morphological features to compare S.serrata and S.serrata serrata that co-exist in the Cochin backwater. Statistical analysis of the data on size measurements separatel for males and females of these two forms of mud crab by t-test (Table 6) showed that the meas sizes differed significantly at 5 % level.

The present study shows that both the forms of mud crab utilize the marine as well as estuarine environments to complete their life, as is generally believed. There are however differences between the younger population and adult crabs in the extent to which the two types of habitats are utilized. The former is relatively more restricted to the estuarine environments, whereas the latter tend to move out to the open sea. However, in the case of S.serrata serrata though the younger population is met with only in the backwater, the adult crabs are found admixed with the juveniles in

greater proportion than in S.serrata in this ecosystem. Kathirvel (1980) observed the occurrence of early juveniles of S.serrata (11-60 mm size) in Cochin backwater throughout the year, with peak abundance during May-October. Studying the distribution of S.serrata on the tidal flats in Australia, Hill et al., (1982) came across considerable variations in the preference of habitats by different size groups. They observed that juveniles (20 to 99 mm c.w.) were resident in the mangrove zone, remaining there during low tide. The majority of sub-adult crabs (100 to 149 mm) migrated into the intertidal zone to feed at high tide and retreated to subtidal waters at low tide. Adults (above 150 mm) were caught mainly subtidally and only small numbers were captured in the intertidal zone. According to Reste et al., as quoted by Devasia and Balakrishnan (1985), the young crab which enters the estuary migrate to the mangrove and from there back to the sea.

The size frequency distribution of the two forms of mud crab clearly indicate that S.serrata grows to a much larger size than S.serrata serrata. The maximum carapace width recorded is 210 mm for the former and 140 mm for the latter. Male attains larger size than female, with a difference of about 10 mm c.w. in S.serrata as also noticed by Srinivasagam and Raman (1985) in Pulicat Lake. The greatest size attained by this crab, as reported by Estampador (1949) is about 229 mm c.w. Mohanty (1973) recorded a maximum size of 215 mm from Chilka Lake, while Kathirvel (1981) came across 202 mm and 198 mm for male and female specimens respectively from Cochin backwaters and 210 mm for a male specimen from Kovalam back-waters (Madras).

Available information on the size distribution of mud crabs in the commercial fishery of India pertains to only the estuarine systems. The major size groups supporting the exploited fishery do not differ significantly from one system to the other. In Cochin backwater the present investigation shows that the dominant size groups are 61-130 mm for S.serrata and 71-120 mm for S.serrata serrata. Not separating the two forms of the mud crab, Devasia and Balakrishnan (1985) recorded the size group 9-11 cm constituting the bulk of this fishery. In Chilka Lake (Mohanty, 1975) the modal sizes range from 77.5 mm to 150.7 mm for male and 81.3 mm to 132.3 mm for female, whereas in Pulicat Lake (Srinivasagam and Raman, 1985) the mean sizes range from 90.9 mm to 115.9 mm for male and 93.4 mm to 112.8 mm for female. In the marine region the present study reveals that the crab population is almost exclusively constituted by adult crabs which are undoubtedly getting recruited from the backwater.

The preponderance of males in the crab population in respect of S.serrata in both the environments and of S.serrata serrata in the sea is in conformity with the observation of Mohanty (1975) in Chilka Lake. Kathirvel (1981) and Srinivasagam and Raman (1985) however noticed higher proportion of females in the population of Cochin backwater and Pulicat Lake respectively, which is the condition noticed in S.serrata serrata in the backwater during the present study.

From the spatial distribution pattern of the mature population of the mud crabs it is quite evident that though mature and spent recovering females do occur in the backwater indicating possibility of their spawning in that environment there is a strong tendency for seaward migration *en masse* associated with spawning and other related activities. Breeding migration towards the sea has been reported from Philippines (Arriola, 1940), Malaysia (Ong, 1966), Hawaii (Brick, 1974) and South Africa (Hill, 1974). It is presumed that seaward migration is to maximise survival of the larvae (Brick, 1974), because for successful metamorphosis of larvae a minimum salinity of atleast 29 ‰ salinity for zoeal stages and 22 ‰ for megalopal stage is required as restablished by Ong (1964 a) through rearing experiments.

The mud crab is known to breed throughout the year with definite peaks in most of the Indo-Pacific regions studied including India (Arriola, 1940; Pillai and Nair, 1968; Devasia and Balakrishnan, 1985; Quinn and Kojis, 1987). The peak season for the reproductive activity is reported to be May to September in Philippines (Arriola, 1940), July to December in Thailand (Varikul *et al.*, 1972), October to February in the southwest coast of India (Pillai and Nair, 1973), May to October in Hawaii (Brick, 1974) and November to March in South Africa (Hill, 1975). In Cochin backwater, Devasia and Balakrishnan (1985) noticed two peaks, one in July and the other

in January. During the present investigation, maximum percentage of reproductive females among the crab population was noticed in June in the backwater and July in the sea, which almost agrees with the primary peak recorded by the previous workers (Devasia and Balakrishnan, 1985).

As far the occurrence of ovigerous females in Cochin backwater, Radhakrishnan and Samuel (1982) had come across gravid females of S.serrata serrata near the bar mouth, while no gravid females of S.serrata could be noticed in the backwater. Devasia and Balakrishnan (1985) reported that even at the peak breeding periods only very few berried females were observed in this ecosystem and attributed this rarity to the passive mature of the crabs. During the period of the present study no ovigerous female could be noticed in the backwater although one egg-laden female was found to have been caught in the dip, net at the bar mouth in October, '88. It is obvious that the ovigerous females abound in higher saline areas and the single specimen encountered in October represents a population of ovigerous females that started appearing with the increase in salinity along the coastal waters after the cessation of monsoon season. However, more data is needed to establish this finding.

supporting the fishery in the sea and backwater are respectively 101-170 mm and 61-130 mm for S. serrata and 91-120 mm and 71-120 mm for S. serrata serrata.

5. In S. serrata, active recruitment of younger population into the backwater fishery is observed in August and September. A successive disappearance of larger size classes noticed in the backwater catches from July to September suggests migration of the same to marine environment.

6. Distribution of sex ratios indicates preponderance of males in both the environments for S. serrata and in the sea for S. serrata serrata.

7. The size at first sexual maturity at 50% level in female crab is found to be 109.0 mm C.W. for S. serrata and 90.0 mm C.W. for S. serrata serrata.

8. In S. serrata, spawning population is observed to be in greater proportion in the sea (54%) than in the backwater (36%). Monthwise distribution of spawning population indicates peak occurrence of the same in June in the backwater and July in the sea, which would suggest gradual shifting of reproductive females seaward when monsoon is most active.

9. In the case of S. serrata serrata, vast majority of the females are in gravid state in the sea throughout the monsoon period and more than 60% in the backwater during September.

10. No ovigerous female could be noticed in the study area between June and September in both forms of the mud crab.

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