TITLE : FECUNDITY AND REPRODUCTIVE OUTPUT IN THE BRACHYURAN CRABS *Scylla serrata* **(Forsskal, 1755) AND** *Thaiamita orenata* **(H. Milne Edwards, 1834) AT THE KENYA COAST.'**[1]

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A THESIS SUBMITTED IN PART FULFILMENT FOR THE DEGREE OF MASTER OF SCIENCE (HYDROBIOl.OGY) IN THE UNIVERSITY OF NAIROBI (1995).

DECLARATION

This is my original work and has not been presented for a degree in any other University. All sources of information have been specifically acknowledged by means of references.

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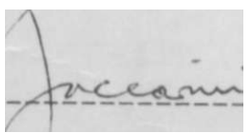
DORCUS AUMA ONYANGO DATE

This thesis has been submitted for examination with my approval as University supervisor.



Prof. ^TCTOR JACCARINI DATE.

DEDICATION

This work is dedicated to my parents, the late Mr. Simeon Onyango Oyugi and Mrs. Zipporah Were Onyango.

TABLE OF CONTENTS

L1ST OF FIGURES

LIST OF TABLES

LIST OF PLATES

ACKNOWLEDGEMENTS

I wish to express my sincere thanks to Dr. W. M. Kudoja for suggesting the topic and supervising the field work, and to Prof. V. Jaccarini for supervising me at the stage of the writing up of this work.

I also wish to thank the Director of Kenya Marine and Fisheries Research Institute Dr. Ezekiel Okemwa for providing the facilities for this study. I am also grateful to all technicians at the research institute who were helpful in one way or another especially Mr. Boaz Orembo who accompanied me to the sampling sites. I also cannot forget the services of the fisherman Issa Kombo for his dedication during the sampling period.

Special thanks to my colleagues for their valuable assistance during the writing up of the work, not forgetting Dr. R. Okello and Dr. Vanden Berghe for their statistical advice during analysis of this work, Mr. M. Odido of the RECOSCIX -WIO for the literature and Mr. R. Oswaggo for the drawings.

I am very grateful to the University of Nairobi for awarding me a scholarship and the National Council for Science and Technology for providing a grant which made the execution of this project possible.

Lastly, I wish to express my sincere gratitude to my husband Apollo W. O. Sigana, my sister Ruth and my children Stella and Lynnette for their patience during this study period and not forgetting my cousin Judith for material assistance.

ABSTRACT

Scylla serrata and *Thalamita crenata* are crustaceans belonging to the class Malacostraca, Order Decapoda and infra-order Brachyura (the true crabs). Both belong to the family Portunidae, (the swimming crabs) and occur both intertidally and subtidally along the coast of Kenya especially in estuaries and mangrove areas. Along the Kenyan coast *S. serrata* is known as Kaa mkubwa and *T. crenata* is known as chanje.

Scylla serrata (Forsskal) was sampled at Kiwambale near Shimoni using madema traps between January 1990 to December 1990. *Thalamita crenata* (H. Milne Edwards) was sampled at Gazi using a scoop net between April 1990 to March 1991.

The ovarian maturity stages were described as stage zero - Virgin / Resting, stage one - Developing, stage two - Well developed, stage three - Ripe. In *S. serrata*, maturity stage zero was only obtained once during the study period, while maturity stages one and three were obtained in low numbers in some months. The most abundant was maturity stage two which occurred in large numbers in each sample. The developmental phases of embryos were grouped into 10, only three phases, one, two and three were observed in the five ovigerous *S. serrata* obtained. in the study, smallest ovigerous crab had a carapace width of 139.75 mm and a crab of

77.1 mm carapace width was found to have an active ovary (stage one). ft positive relationship exists between fecundity and carapace width (t = 3.546; d.f. = 3 ; P < 0.05) and embryo-mass weight (t = 3.251; d.f. = 3; P < 0.05) respectively while no significant relationship was found between fecundity and embryo-size (t = 0.029; d.f, = 3; P > 0.1). A test of homogeneity of the binomial distribution of the sex ratio showed homoscedasticity (X^2 = 14.615; d.f. = 13; P > 0.05) and the overall sex ratio did not differ from a 1:1 (X^2 = 0.776; d.f. = 1; P > 0.25). The variance test of homogeneity of the binomial distribution of sex in relation to size shows a very significant heterogeneity (X^2 = 32.83; d.f. = 9; P << 0.05). There was no significant difference when the overall mean sizes for males and females were compared using the t-test (t = 4.26; d.f. = 18; P > 0.001). The relatively high numbers of females with stage two ovaries indicates that spawning probably takes place throughout the year with a possible peak in the second half of the year.

T. crenata occurs subtidally in the sandy pools and have five lateral teeth. In *Thalarnita crenata,* ovarian maturity stage two was the most abundant throughout the sampling period while maturity stages zero, one and three occurred at low frequencies during the sampling period. All developmental phases one to ten of embryos were

observed in ovigerous females but later developmental phases predominated during the two spawning peaks in September and January. The size at first maturity ranged between 40.5-45.5 mm Carapace width. A positive relationship exists between fecundity and carapace width ($t = 9.908$; $d.f. = 205$; $P < 0.001$) and embryo-mass weight ($t = 9.55$: $d.f. = 205$; $P < 0.001$) respectively while no significant relationship was found "between fecundity and embryo-size ($t = 1.04$; $d.f. = 205$; $P > 0.05$). The test of homogeneity of the binomial distribution of the sex ratio showed homoscedasticity ($X^2 = 16.83$; $d.f. = 11$; $P > 0.1$) i.e., the sex ratios did not differ significantly between months but the overall sex ratio differed significantly from 1:1 ($X^2 = 19.577$; $d.f. = 1$; $P < 0.005$). The variance test of homogeneity of the binomial distribution of sex in relation to the size shows a very significant heterogeneity ($X^2 = 112.2$; $d.f. = 12$; $P < 0.001$). There was no significant difference when the overall mean sizes for males and females were compared using the t-test ($t = 3.163$; $d.f. • 24$; $P > 0.001$). This crab species breeds throughout the year. Female crabs with carapace width of 40.5 to 45.5 mm actively bred throughout the the sampling period. The females had active ovaries throughout the year, hence they are continuous breeders.

CHAPTER ONE

INTRODUCTION

Kenya's coastline is approximately 500 km long and the area of the continental shelf is approximately 6300 km^2 (Africa - East coast Sheet No. 3361 / 3362, 1967). The continental shelf is fairly narrow and fringed with coral reef which occur down to a depth of 20 m. There is little commercial fishing in deep waters along the Kenyan coast and the catch is relatively small. The bulk of marine fish is landed by the artisanal fishermen (Nzungi, 19S9). The majority of these artisanal fishermen concentrate on fin fish which are either demersal or pelagic. Some of these fishermen fish for crustacea and most of the fishery in Kenya is concentrated in the shallower regions of the continental shelf between the shore and the outer edge of the fringing reef. Crustacea are among the most delicious of all marine organisms therefore the landings of crustaceans is the most profitable. These crustaceans include prawns, lobsters and crabs. The presence of coral reefs and extensive mangrove areas along the coast encourages both crab and lobster fishery as these crustacea prefer such habitats. Of the crustacean production along the Kenyan coast, prawns form the bulk of the catch with crabs and lobsters roughly equal by weight and each constituting about 1/6 by weight of the prawn catch (Table 1). Crab food is only surpassed by lobster in

terms of taste and price in restaurants.

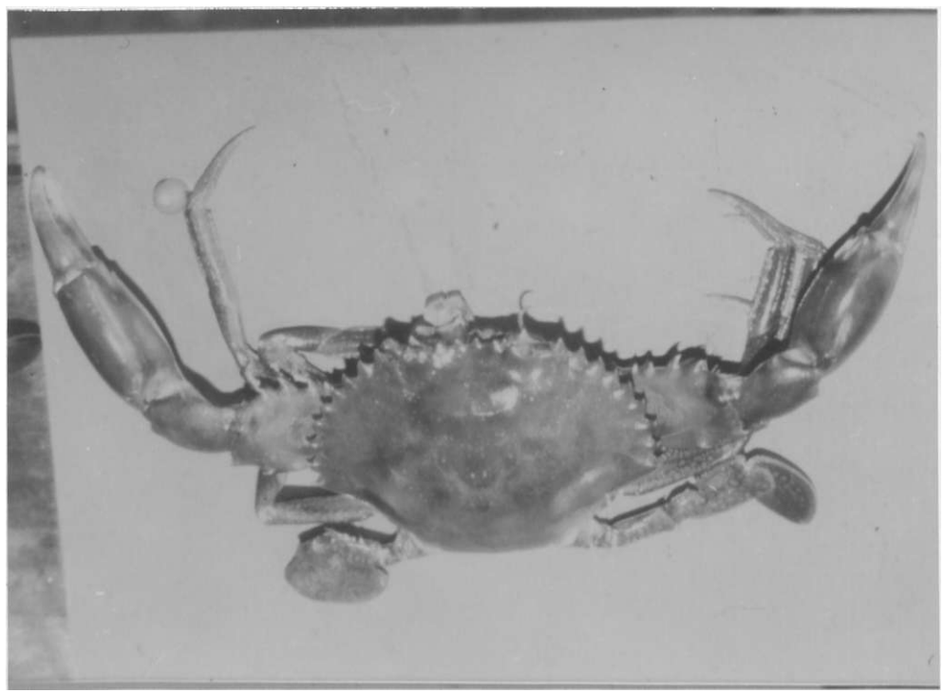
Because of their appearance and morphology, crabs have not been popular with most upcountry people living in the coastal towns (Bwathondi and Mwaya, 1984). Since the Kenyan coast has a flourishing tourist industry, the demand for crustacean food is increasing and has exceeded the supply provided by artisanal fishermen. In 1989, 80 metric tonnes of crab catch was landed along the Kenyan coast while in 1988, only 51 metric tonnes of crab catch was landed (Table 2).

The families of brachyuran crabs in Kenya include Xanthidae, Cancridae, Portunidae, Majidae, Ocypodidae, Grapsidae, Gecarcinidae, and Potamonidae. All these families are marine except the Potamonidae which live in freshwater. Of these families Portunidae, Xanthidae, and Cancridae are of commercial importance as luxury food (Provenzano, 1985). The edible Portunid (swimming) crabs found along the Kenyan coast include *Scylla serrata* (Forsska1), *Thalamita crenata* (H. M. Edwards), and *Portunus pelagicus* (Linnaeus).

Scylla serrata is a greenish-brown crab with a broad carapace whose antero-1atera1 margins are armed with eight or more teeth (Plate 1»A). Plate liB shows the ventral view of male and female *S. mmrrmts.* In Kenya it is locally known as Kaa mkubw* and because of it* size, it is the only crab fimhed

TABLE 2: Landings of crustaceans by groups and weight (metric tonnes) in 1988 and 1989 (Nzungi, 1989).

GROUPS	1988	1989
Lobster	**186**	74
Prawns	535	468
Crabs	51	**80**



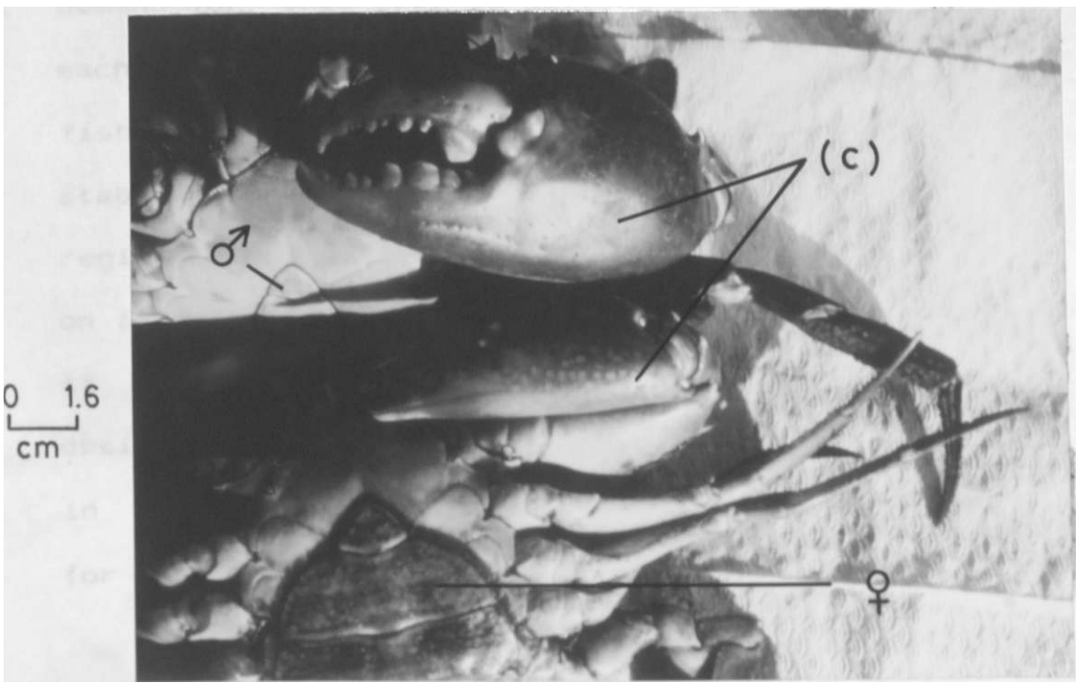


PLATE 1:A. Smaller adult *S.* serrata. Dorsal view of the crab. Note the antero-lateral margin with teeth.

B. Ventral view of a mating pair of S. •errata. The top crab is an adult male with a narrow abdomen and a bigger chelae (C) while the bottom crab i» an adult female with a broad abdomen and a much mmaller chelae (C).

for commercial purposes. The Kenyan coast falls under five main districts which are Lamu, Tana-River, Kilifi, Mombasa, and Kwale. Nyawira (1986) reported the occurrence of *Scylla serrata* landings at Shimoni, Majoreni, and Vanga areas which are all under Kwale district. Between 1980 and 1989, statistics show that Kwale district had the highest crab landings (166 metric tonnes), followed by Lamu (158 metric tonnes), Kilifi (115 metric tonnes), Mombasa (58 metric tonnes) and lastly, Tana-River (five metric tonnes) (Table 3). The demand for this crab is getting higher every year in each district. There is therefore, fear of over-fishing which will in turn interfere with the stability of the population. In the Indo-Pacific region, a lot of research work has been carried out on *Scylla serrata* with the general aim of culturing it (Marichamy et al_., 1986). This research is designed to help understand the reproductive habits in Kenya with a view to supplying scientific basis for potential mariculture of the species.

Thalamita crenata is a much smaller crab as compared to *Scylla serrata* (Plate 2A). It is also abundant in the mangrove areas but is usually sub-tidal. Plate 2B shows the ventral view of male and female *T. crenata.* It has five lateral teeth and occurs in three different coloursi greyish, greenish, and orange-yellow. Those which are

TABLE 3: Monthly landings of crabs in Kenya between 1980 and 1989 (Nzungi, 1989).

YEAR	LAMU	TANA RIVER	KILIFI	MOMBASA	KWALE	TOTAL
1989	28	0	27	16	9	80
1988	12	3	13	6	17	51
1986	15	0	17	8	15	55
1985	19	0	18	8	19	64
1984	19	0	17	7	22	65
1983	16	0	2	5	34	57
1982	20	1	4	3	23	51
1981	21	1	11	3	18	54
1980	18	0	16	3	19	56
TOTAL	168	5	125	59	176	533

0 < 500 Kg.

0 2.5cm

0 3 cm

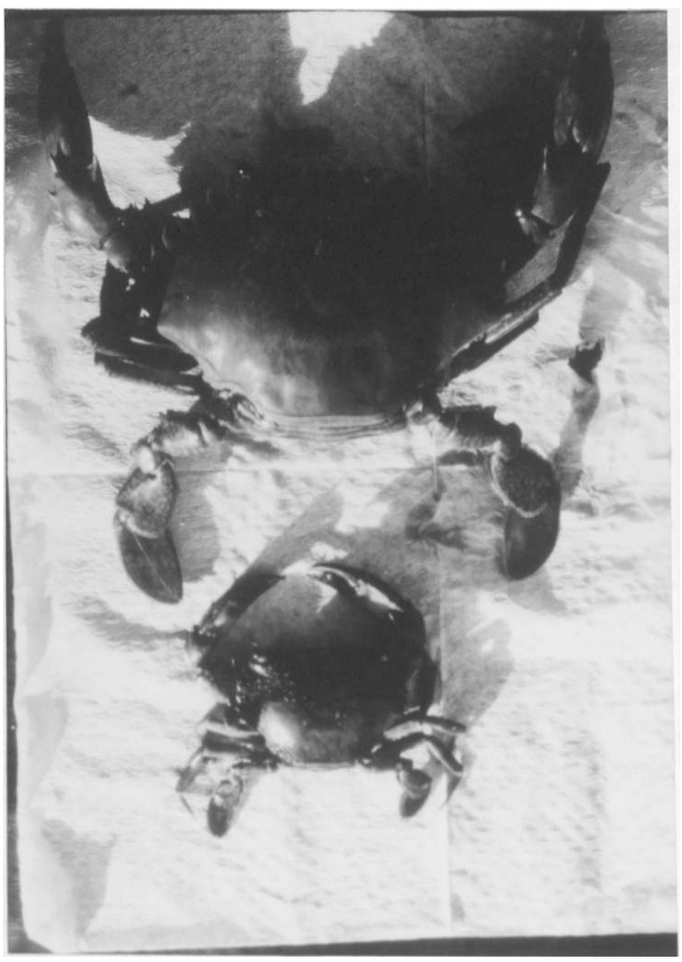


PLATE 2A: Top. Adult female *Scylla serrata.* Dorsal view.

Bottom. Adul female *Thalarnita crenata.* Dors 1 view.

PLATE 2B: Top. Adult female *T. crenata.* Ventral view, note the broad abdomen.

Bottom. Adult male *T. crmnata.* Ventral view, note the narrow abdomen.

greyish and greenish are abundant in the sandy pools and around the pneumatophores of mangrove trees at the edge of water where there is soft mud. The orange-yellow *T. crenata* are rare and are found in any of the two locations (i.e., sandy pools and at the edge of water). Because of their small size, they are usually fished mainly by children although if fishermen come across larger ones, they usually fish them for their own consumption. They are locally known as Chanje. Little research work has been done on this crab. The present research was therefore done to help in understanding the reproductive habits of this crab along the Kenyan coast where they are abundant.

Portunus pelagicus (Linnaeus) is also abundant at the Kenyan coast. They are locally known as Kisaqa unqa. They occur in large numbers in the sandy pools, from where they are fished by children for their own consumption. Its carapace is armed with nine antero-1atera1 teeth of which the last one is greatly elongated. They are much smaller than S. serrata and slightly bigger than *T. crenata.*

LITERATURE REVIEW

Research work on crabs has been carried out by researchers all over the world. All families of the infra-order Brachyura which includes Xanthidae, Cancndae, Potamonidae, Geearcinidae, Majidae,

Grapsidae, Qcypodidae, and Portunidae have been reported on in various scientific journals. Various aspects of life history of crabs have been studied including distribution and growth, feeding habits, methods of capture, nutritive values of crab meat, culture, reproduction and diseases.

Nearly all the large species of brachyuran crabs are edible, but the crabs of commercial importance are members of three families Portunidae, Xanthidae and Cancridae because they grow to large marketable sizes (Provenzano, 1985). In the Indo-Pacific region, a lot of research work has been carried out on portunid crabs especially the mangrove crab *Scylla serrata* which occurs in large numbers and also forms part of the crustacean fishery in this region (Franklin and Petterson, 1974). Nearly all ecological aspects have been studied on this crab while other edible crabs e.g., *Portunus pelagicus* and *Thalamita crenata* have received less attention because of their smaller sizes.

1.2.1 Distribution and growth.

Crabs are decapod crustaceans and are widely distributed all over the world. On the Northwest Shelf of Australia, Ward and Rainer (1988) reported a highly diverse fauna of epibenthic crustaceans. These epibenthic crustaceans recorded from only four sites are more than reported from any other

continental shelf. The dominant taxa were amphipods, portunid, xanthid, majid and hermit crabs, and different shrimp species. The abundance of many decapod crustacean species was related to depth, sediment type, bottom type, or sedentary fauna. This high diversity of crustaceans on the Northwest Shelf of Australia is attributed to the large area covered by the continental shelf, while in other continental shelves, the decapod crustaceans are partly zoned by depth. Of the decapod crustaceans on the Northwest Shelf of Australia, crabs alone comprised 24 ⁄. of the total number of crustacean spec ies.

Galil (198*?) reported that the Trapeziidae, one of three brachyuran families that are obligatorily symbiotic, are associated with corals. The species *Trapezia latreille* are obligate symbionts of pocilloporid corals, whereas *Ouadrella dana* and *Calorcarcinus caiman* typically occur on octocorallians. This family of small once obscure crustaceans is now acknowledged as one of the most successful and ubiquitous components of the coral reef. Five genera with 16 species are known to date from the Red Sea and East Africa.

Bennet (1954) observed that the males of Cancer *pagurus* (Linnaeus) showed progressive growth increments whereas female growth was reduced and regressive. Moult frequency in male crabs seem to be

more closely related to total live weight than to carapace width, while in females, moult frequency was more related to carapace width than to total live weight. This difference between the sexes is due the greater size of the chelae which results in male crabs being heavier than females of the same carapace width.

Scylla serrata are found in the coastal and estuarine waters of the Indo-Pacific region, specifically in India, Sri-lanka, Thailand, Vietnam, Malaysia, Indonesia, Philippines, Japan, Australia, Fiji, Hawaii and the eastern coast of Africa. Crab culture is variously developed in the different countries of the region e.g., in the Philippines where the juveniles are caught from the wild and constitute the main source for stocking ponds in polyculture with milk-fish *Chanos chanos* (Forsskal) or prawns *Penaeus monodon* (Fabricus) (Pagcatipunan, 1972).

Hill (1975) working on the abundance, breeding and growth of *S. serrata,* reported that population density in a South African estuary was estimated at one crab per 124 m^2 and production at 3.4 g per m^2 per annum. Growth was rapid in the first 12 to 15 months when crabs attained a carapace width of 80 to 160 mm, thereafter it slowed. Females mated at carapace width of 103 to 148 mm while males mated at carapace width of 141 to 166 mm. The females migrate

Vonk (I960), ma1acostracans with well developed gastric mills do not chew their food using their mouth parts. This is because their gastric mill grinds the food into a paste which is mixed with enzymes from the midgut and the resulting mixture is then passed back to the midgut and the digestive gland. Foregut clearance of soft tissue was rapid and almost complete after 12 hours while fish bone was retained for two to three days and shell for five to six days. *S. serrata* remained buried during the day, emerging at sunset to spend the night feeding.

Williams (1978) reported that *S. serrata* have large, very powerful dimorphic chelae. The larger *i* is modified for crushing and has a number of molariform teeth on the propodus while the smaller is a "biter" with only conical teeth. Therefore, it has the ability to crush the shells and pick the flesh of molluscs. The rapid beating of the second maxillipeds which have chitinous spines on the dactyls removed the tissue from the mollusc shell.

Again Hill (1979) reported that food location in *S. serrata* was by contact chemoreception using the dactyls of the walking legs. The major prey in a South African estuary were burrowing bivalves, attached bivalves and small crabs. He observed that *S.* •errata showed a preference for small crabs especially *CJeimtomoma algoenme* because the smaller crabs yielded one and half times as much energy as

bivalves. He also observed that *S. serrata* feeds on a wide size range of prey. This has been a major factor in its successfully occupying estuaries throughout much of the Indo-Pacific region.

Hill and Williams (1980) found that both feeding and activity of *S. serrata* decreased markedly at temperatures below 20°C.

Williams (1981) reported that the points method and the occurrence method are the only methods which can be applied readily to the analysis of gut contents in portunid crabs. He observed that food categories found in the gastric mills of portunid crabs *(Thalamita crenata* (H. M. Edwards), *Thalamita danae* (Stimpson), *Thalamita sima* (H. M. Edwards) and *Portunus pelagicus* (Linn.)) include polychaeta, crustacea, mollusca, foraminifera and various algae and sea grasses. But most food ingested by the crabs was finely fragmented, although the extent of mastication varied with the type of food and the way it is manipulated.

1.2.3 Methods of capture.

In the Camarines Norte (Philippines), the seed of *S. serrata* for stocking in ponds is caught using "bubo" (bamboo cages), "bintol" (lift net), and "sakag" (scissor net) or even by hand as Pagcatipunan (1972) observed. Heath (1971) used four different gear* in trapping *S. merrata* and *Portunus pelagicu**

along the Tanzanian coast. He reported that madema traps caught more *P. pelagicus* than the British creels and experimental steel traps but the American blue-crab pot was much more successful than the experimental steel traps though not as good as madema traps.

Williams and Hill (1982) reported that capture in pots relies upon a feeding response and any factor which reduces feeding such as low temperatures and moulting will result in decreased pot captures. They also observed that presence of a crab in a pot reduced the probability of further crabs entering that pot, and that catches of *S. serrata,* taken in pots are inadequate in representing the relative size and sex composition of a total population although they do provide a representative sample of the adult (>150 mm carapace width) population.

On movements within and between different habitats by the portunid crab *S. serrata*, Hyland et al. (1984) reported two categories of movements: i) free-ranging type and ii) off-shore migration by females. Crabs in a narrow creek with mangrove-covered banks displayed little movement while those in areas with large inter—tidal flats devoid of mangroves undertook greater movement. They also observed that in an area with direct access to the sea, males and females moved equal distances but in a long channel behind an island, mean female

movement was significantly greater than that of males. Tag recaptures showed an exchange between the populations of a mangrove creek and those in a neighbouring bay. No exchange was found between neighbouring areas separated by a region of habitat unsuitable for *S. serrata.* Mutagyera (1984) reported that the crustacea of Kenya are all caught in shallow water areas by artisanal fishermen who use simple methods like skin-diving for lobsters, beach seining and stake traps.

1.2.4 Nutritive values of crab meat.

Kannupandi and Paulpandian (1975) extracted proteins from the blood and chelate leg muscles of *Ocypode macrocera* (Milne Edwards), *Uca artnulipes* (Milne Edwards), *Uca triangularis* (Milne Edwards), *Thai amita crenata, Scylla serrata* and *Cardisoma carnifex* (Herbst). They reported that the number of blood proteins is greater in the more fully marine crabs *Thalamita crenata* and *Scylla serrata,* than in the more terrestrial crabs i.e., *Uca* spp. and the most terrestrially adapted crabs *O. piatytarsis* and *C. carnifex.* They reported that the number of myogens in the chelate leg muscle of *T. crenata* and *S. serrata* is smaller than in the blood of the same crab. In other crabs, the number of myogens is greater than that of blood protein*.

Srinivasagam (1979) studied the nutritive values of the meat of four commercially important portunid crabs i.e., *Scylla serrata, Portunus pelagicus, Portunus sanguinolentus* (Herbst) and *Charybdis cruciata* from Porto Novo waters (India, Longitude 79, Latitude 11). He reported that carbohydrate content varied from 0.14 ′/. dry weight (P. *pelagicus)* to 0.17 ′/. dry weight (C. *cruciata) .* The highest protein content was observed in P. *pelagicus* (15.65 ′/. dry weight) and the lowest in *C. cruciata* (12.25 7. dry weight). *P. pelagicus* appeared to be more fatty than the other three species while moisture content showed very narrow variations among the species.

Siddiquie et_ al_. (1988) analysed the biochemical composition and calorific values of the three edible species of portunid crabs *Portunus pelagicus, Portunus sanguinolentus* and *Scylla serrata.* They reported that dry tissue contains 85-95 ′/. organic matter of which 55-65 V. is protein. Crab tissue is highly nutritious, having CsN values between 3.34tl and 4.29:1 while percent lipid, carbohydrate and ash content are low.

1.2.5 Culture of crabs.

The brachyuran families that contain most species of current and probable future interest for food cultivation include Cancridae, Portunidae, Majidae and Xanthidae (Provenzano, 1983).

The Cancridae contain species of commercial interest but only *Cancer magister* (Dana) of the west coast of United States of America is a candidate for culture because the species attains a very large size, demand is always in excess of the apparently dwindling supply and the price per unit is high.

The Portunidae contain some of the most economically attractive crabs. The Japanese have attempted to culture *Portunus pelagicus* and *Portunus trituberculatus.* In the Indo-pacific, the mud crab *Scylla serrata* has been cultured in fish ponds and is an important fishery species. In the United States *Callinectes sapidus* (Rathbun) is a rapidly growing species of great value but its culture has never been attempted.

Among the Majidae, few species are both large and abundant enough to be of commercial interest. The largest crab in the world is the Japanese spider crab *Macrocheira kaempferi* (de Haan) which lives in deep water and is not very suitable for culture.

Among the Xanthidae, the stone crab *Menippe* mercenary* (Say) is of economic importance in the south-eastern United States of America. But this species feed on molluscs and other large invertebrates, therefore is expensive to raise.

Along the East African coast and most of the Indo-pacific region, only portunid crabs are abundant and therefore are of commercial interest.

In the Philippines, *Scylla serrata* is cultured as a subsidiary crop in the milk fish (*Chanos chanos)* ponds. Pagcatipunan (1972) reported that juveniles entered the milk fish ponds on their own accord and grew to marketable size but there were difficulties in total harvesting because of the boring, crawling and cannibalistic habits of the crab.

Varikul ejt aj_. (1972) reported that *S. serrata* can be reared successfully in ponds as they grow to marketable size and good guality within a period of 45 days. He stocked ponds with 4000 young low quality crabs of varying sizes and fed them on trash fish. They grew to marketable size and of good quality within a period of 45 days.

Escritor (1972) carried out a research on the possibility of breeding *S. serrata* in brackish water ponds, hatching the eggs in the laboratory and raising larvae to marketable size. He reported that mating took place in brackish water ponds but most female crabs died as they tried to escape into the open sea. He hatched the eggs of one berried female successfully in an aquarium in the laboratory but all the larvae died after 40 hours.

Pillay (1972) reported that experiments to rear larval stages to juveniles have been conducted in Malaysia, India, Sri Lanka and Philippines with

varying degrees of success but a suitable technique for application in the field requires to be evolved. The culture of young ones to marketable size is done on moderate scale in Taiwan and Singapore. In Taiwan emphasis is on the fattening of the female with young ovary to promote development of the ovary which has a high commercial value to its full size.

In experiments conducted in Tuticorin Research Centre India (Anonymous, 1983) on *Scylla serrata*, 1.5 million zoeae emerged from eggs after an incubation period of 8-10 days. There were five zoea stages and one megalopa stage lasting 28-30 days, therefore constituting the larval development of the crab. The larvae of the crab were fed on artemia and rotifers and the rearing media were treated with mild antibiotics to control ciliates. A total of 145 crabs from this experiment were stocked in ponds for culture and this break-through indicates the possibility of setting up a hatchery. Marichamy and Rajapactiam (1984) also incubated ovigerous *S. serrata* but at the end of the experiment concluded that rearing of larvae was unfortunately of little commercial value and labour intensive.

Marichamy al. (1986) cultured S. serrata in different types of cages in a shallow bay in Tuticorin (India), the young crabs (<100 mm carapace width) were reared first in basket type cages made of cane splits for two to three months while box type

cages made of soft wooden planks each comprising 8-10 compartments and metal framed synthetic twine mesh cages with compartments were preferred for culturing the grown up crabs (>100 mm carapace width). The crabs were fed on trash fish, clam meat and gut wastes of fish from the fish market. The crabs were observed to reach marketable size through four to five moults in a period of 9-10 months. Since crustacean eyestalks contain centres for distribution of gonad hormones, two female crabs were selected and each had one eye ablated. After an interval of 30 days, they died but on dissection, the ovary was found in a fully matured condition having a bright orange-red colour. They also confirmed that individuals of a species generally do not mature at the same age or size, when they were observing mating behaviour in S. *serrata* in which there was no egg carrying after copulation.

1.2.6 Reproduction.

Thorson (1950) reviewing reproduction and larval ecology of marine bottom invertebrates reported that marine species often produce millions of eggs per female, therefore there must be wastage of eggs and larvae during development. Bhupendra and Crisp (1961) reported that in many crustacea, the male regularly copulates with a female just after she has moulted and this includes brachyura. In portunid

crabs, sex recognition is tactile and possibly olfactory. In crustacea, the female does not usually mature until immediately after a particular moult, therefore the male takes possession of an immature female ensuring that he is present to effect copulation after that moult. The soft condition acquired by the female will render her a passive partner during copulation. The advantage of first finding a virgin female is important in species where a single copulation provides sperm for several broods as is common in brachyura. Bardach et al- (1972) reported that a single copulation provide sperms for two or more spawnings and usually the crabs have means of retaining the sperms. This applies to crabs which copulate in both soft and hard states. In brachyura, the eggs are attached to the pleopods by the perivitel1ine membrane of the egg itself as pointed out by Broekhyusen (in Bhupendra and Crisp 1961).

On reproductive strategies in marine benthic invertebrates, Vance (1973) reported that producing a pelagic pianktotrophic larvae entails only a small amount of energy since egg size is small, therefore large numbers of eggs are produced from a fixed amount of energy devoted to egg production. PIanktotrophic larvae are dependent on the ocean's particulate food supply and are subjected to planktonic predation and non-biological planktonic

mortality sources. Producing lecithotrophic larvae is subjected to planktonic predation but the larvae are not dependent on the ocean's particulate food supply because they survive on stored nutrient, therefore only small number of eggs is produced on a fixed energy budget. Non-pelagic development reduces planktonic mortality to zero, but it is more expensive because energy must be put into egg cases, brooding or internal incubation. Larval mortality sources in non-pelagic development can be due to starvation, predation or being carried to unsuitable settling sites.

Working on the reproductive cycle and biochemical changes in the gonads of the freshwater crab *Barytelphusa cunicularis* (Westwood), Diwan and Nagabhushnam (1974) reported that the crab bred during the rainy season and that the reproductive activity of the crab appeared to be dependent on rainfall. Biochemical studies showed that protein level in ovary and testis were highest when the gonads are in developing condition and lowest during the spawning period.

Hill (1974) reported that the first zoeae stages of *S. serrata* have low resistance to high temperatures and low salinities, and are therefore unsuited to life in estuaries. The migration of ovigerous females into the sea prevents the exposure of zoeae to the very high temperatures and low

salinities experienced in estuaries. The post-larval stages drift towards the coast in currents and have greater tolerance to reduced salinities and high temperatures. *Thaiamita crenata* is a permanent resident in the estuaries. Ovigerous females were obtained within the sandy lagoons suggesting that they do not migrate offshore to spawn (personal observation).

Nagabhushanam and Kulkarin (1977) reported that the sand crab *Emerita holthuisi* is a continuous breeder with two spawning peaks though the berried females were obtained throughout the year. Pillay and Ono (1978) observed that the lower inter-tidal crabs i.e., *Hemigrapsus penicillatus* (de Haan) produce smaller but greater number of eggs while supra-tidal crabs produce fewer but larger eggs. This may be because the lower inter-tidal crabs have long pelagic larval life and need to counteract the high mortality during the pelagic phase. The supra-tidal crab i.e., *Sesarma pictum* (de Haan) produces larger eggs which have a large accumulation of yolk which facilitates the liberation of larvae at a late stage of development, therefore the pelagic larval life may be short, hence fewer eggs are produced during the breeding season.

McLay (1982) observed that the female sponge crab *Cryptodromis hilgendorfi* (de Mann) had only one

breeding season and the larvae in each brood were released synchronously. Wild (1983) observed that crab ovaries of *Cancer magister* begin re-developing soon after spawning while the crabs are still brooding their eggs. Spawned, fertilised eggs develop more slowly in cold water, therefore if ovaries do not begin re-developing until after the eggs are hatched, significant differences in ovarian development rates would be expected.

Thurman II (1985) observed that the comparatively large ova, low fecundity and low per capita egg production are adaptations to a terrestrial habitat in *Uca subcylindrica* (Stimpson). Initially the sexes are in equal proportions but males are more common in the larger size classes. Survival in the crab stage is relatively low and there is an increased rate of mortality with size. Only 30 %. of the individuals grow to modal carapace size and even fewer appear to participate in reproduction.

Prasad and Neelakantan (1989) reported that *Scylla serrata* attained sexual maturity (with stage iv ovary) in 81=90 mm size range, but the crabs were sexually active in size range of 120-180 mm. There was a sharp transition at 80 mm carapace width indicating morphological changes accompanied with sexual maturity. They observed that S. %*errata* bred all through the year but exhibited two peaks of

breeding. Spawning of *S. serrata* was found to occur only inshore and offshore waters but not in backwaters.

Wenner (1972) investigating sex ratio as a function of size in marine crustacea, reported that differential mortality between sexes and other factors create a differential in the costs of producing offspring of each sex e.g., differential growth rates, or size differences between sexes during the period of parental care can produce skewed sex ratios. A deviation from a ill sex ratio is widespread in marine crustacea but chi-square calculation normally obscures this.

1.1.7 Diseases of crabs.

Chong and Chao (1986) reported that *Scylla serrata* display an orange colouration on the ventral carapace and pincers when heavily infected. On dissection of these acutely sick crabs, very high concentrations of gram-negative bacteria of *Vibrio* species were identified microscopically. Bacterial culture of haemolymph from diseased crabs yielded *Vibrio a1ginolyticus.* They then advised the farmer to treat the crabs with Oxytetracyc1ine or Sulphadimethoxine-trimethoprim. The farmer reported fewer losses in cages receiving treatment.

From the above review, it is clear that most research work on crabs has been done elsewhere in the

world. Most of the research work on portunid crabs has been carried out in the Indo-pacific region but no serious work has been done along the East African coast except for preliminary reports on the occurrence of these portunid crabs.

Since the Kenyan coast has a flourishing tourist industry, the demand for crabs is increasing and has reached a level at which the catches from artisanal fishermen cannot meet the demand. The only possible way to improve this supply is by mariculture. Unfortunately, mariculture of *S. serrata* although tried elsewhere cannot be started without the knowledge of its reproductive behaviour pattern here in Kenya. The culture of crabs is also complicated due to the fact that the zoeae spend parts of their life cycle in different parts of the ocean. This study will therefore be a step towards understanding *S. serrata* reproductive habits in Kenya before any mariculture can be attempted.

Besides the demand in tourist hotels, the surplus can be exported to earn the country foreign exchange. The world supply of *S. serrata* to the market is dwindling due to increase in the human population in the far east where it is abundant. The increase in population has resulted in higher local consumption and thereby a decrease in the surplus left for the world market. There is also decrease in abundance of *S. zerrata* in the far east because of

the destruction of the natural habitats of the crab due to increased pollution of the seas.

Besides *S. serrata,* research was carried out on *Thai amita crenata,* another edible portunid crab to establish its reproductive habits in Kenya, since it is also eaten on a small scale by local fishermen. This study on the reproductive behaviour of *T. crenata* was also important because crabs provide protein and since protein supply from terrestrial animal meat is not keeping up with demand and getting expensive due to increase in population, mariculture on both crabs might be attempted by future researchers to provide an alternative source of protein.

1.2 OBJECTIVES OF THE STUDY

The following were the objectives of the study :

i) To determine the maturity stages of the crab ovaries.

ii) To determine the developmental phases of the crab embryos.

iii) To find the Size at first maturity.

iv) To estimate fecundity of the crabs.

v) To find the sex ratio of the crabs.

vi) To determine the breeding cycle of the crabs.

All these were to be carried out on both *Scylla •errata* (forsskal) and *Thalamita crmnat** (H. Milne Edwards).

CHAPTER TWO

MATERIALS AND METHODS

2.1 STUDY SITES.

Sampling for both crabs was carried out in two different locations along the Kenyan South coast, with Kiwambale being approximately 65 Km from Mombasa and Gazi 45 Km from Mombasa (Fig. 1). *S. serrata* was sampled at Kiwambale on the Ramisi river near Shimoni (Fig. 2) while *T. crenata* was sampled at Gazi (Fig. 3).

2.2 GENERAL CRAB FISHING METHODS.

There are five main methods of fishing crabs along the Kenyan coast. These include:

1) Rods with metal hooks.
2) Trot line.
3) Traps.
4) Scoop nets.
5) Fishing nets.

2.2.1 Rods with metal hooks.

The fishermen cut long straight mangrove rods which measures between one to one and a half metres on which a strong metallic hook is fixed. In some cases, the fishermen cut off sub-branches of the main branch but remain with a short branch at the tip which functions as a hook. The fishermen then identify crab holes which usually extend between the roots of mangrove trees and prod the holes with the

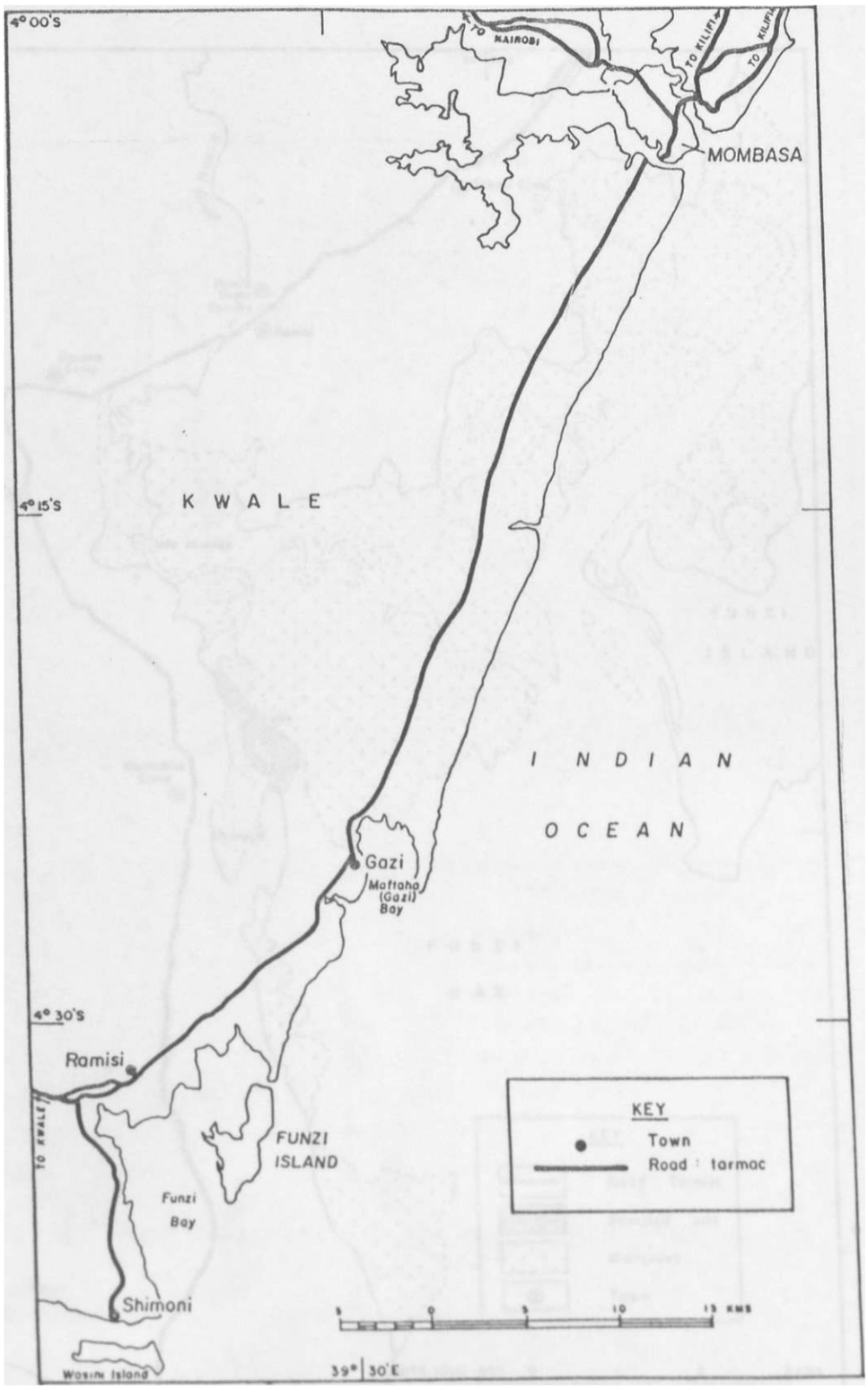


Fig.1: The Kenyan South Coast.

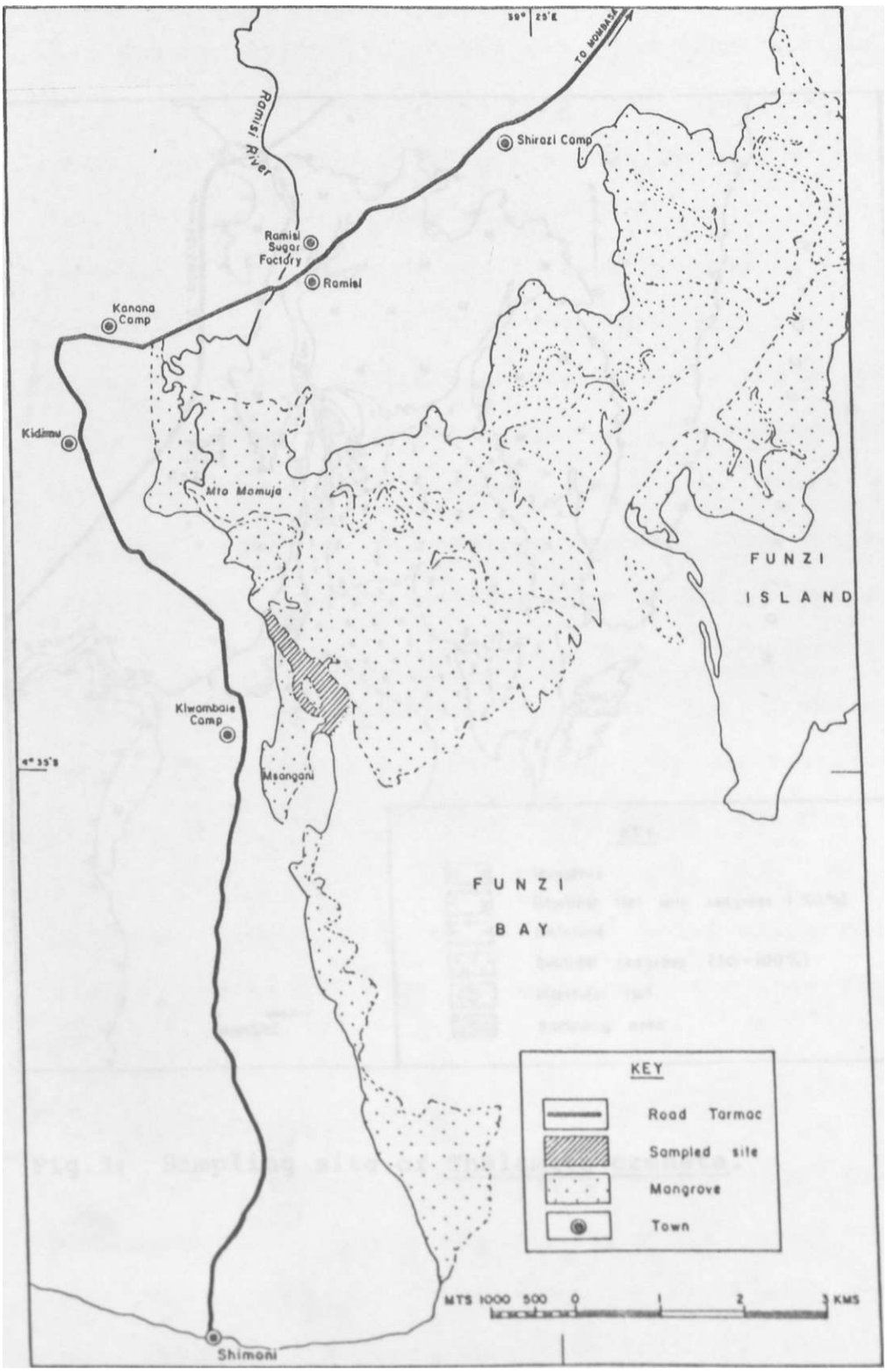


Fig.2j Sampling site of Scylla serrata.

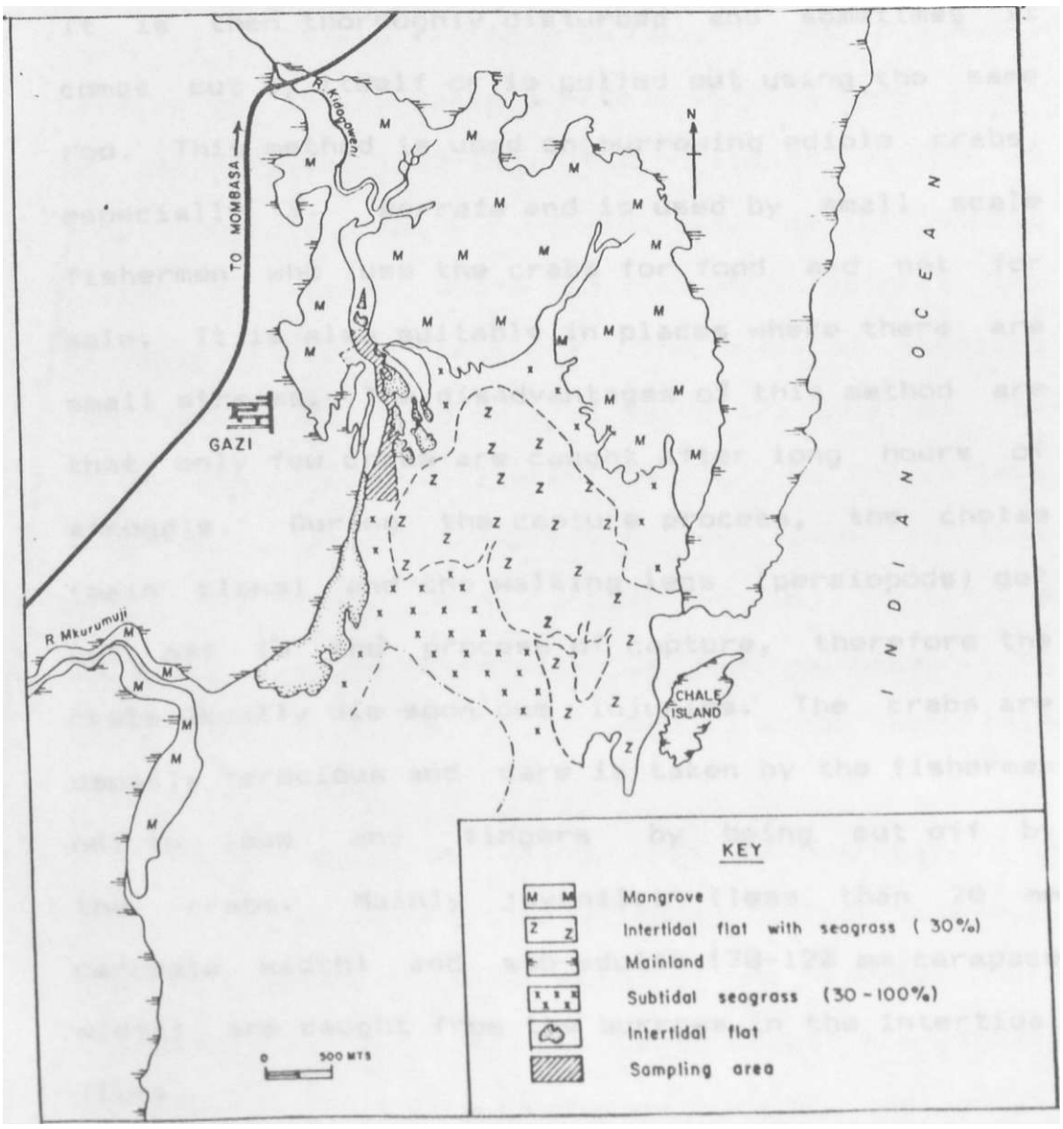


Fig.3: Sampling site of Thalamita crenata.

hooked rods. If there is a crab in the hole, it will snap the rod using its chelae and so produce a sound. It is then thoroughly disturbed and sometimes it comes out by itself or is pulled out using the same rod. This method is used on burrowing edible crabs, especially *S. serrata* and is used by small scale fishermen who use the crabs for food and not for sale. It is also suitable in places where there are small streams. The disadvantages of this method are that only few crabs are caught after long hours of struggle. During the capture process, the chelae (main claws) and the walking legs (pereiopods) get cut off in the process of capture, therefore the crabs usually die soon due injuries. The crabs are usually ferocious and care is taken by the fishermen not to lose any fingers by being cut off by the crabs. Mainly juveniles (less than 70 mm carapace width) and sub-adults (70-120 mm carapace width) are caught from the burrows in the intertidal flats.

2.2.2 Trotline.

The fishermen will at first catch fish using hook and line. These are usually small fishes less than 500 g in weight. They then cut the fishes half-way through the body, ensuring that it does not break into two pieces. The fish is then tied with a strong string round the cut surface and this string

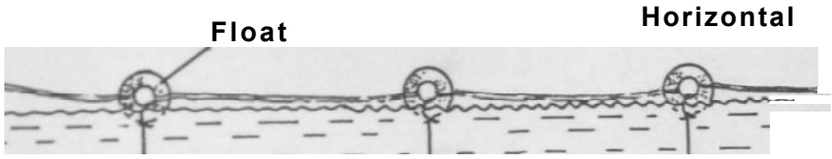
is then tied to one horizontal long string. A float is fastened at the point of attachment of this string with fish. There are then several fishes suspended vertically at appropriate distances from each other on the horizontal string. The horizontal string is then tied onto poles placed vertically at appropriate places in water, where the fishermen suspect the crabs can be found (Fig. 4). The crabs on locating the fish will hold onto it using its chelae. The weight of the crab will make the float at the surface sink in water. The fisherman then moves to that particular float using a boat and will pull the vertical string carefully to the surface. The scoop net (Plate 3) is then used to scoop out this crab holding onto fish.

Crabs obtained using this method have no injuries and therefore live longer. The fishermen use this method in muddy parts of the stream where the stream bed is not flat. Crabs caught are usually sub-adults (70-120 mm carapace width) and adults (> 120 mm carapace width).

2.2.3 Traps.

These are locally known as <u>madema</u>. There are three main sizes i a) Small ones are 3 ft high. b) Medium ones are 5 ft high (Plate 4). c) Large ones are 7 ft high. They are constructed using reeds and the entire trap is then held firmly by supporting

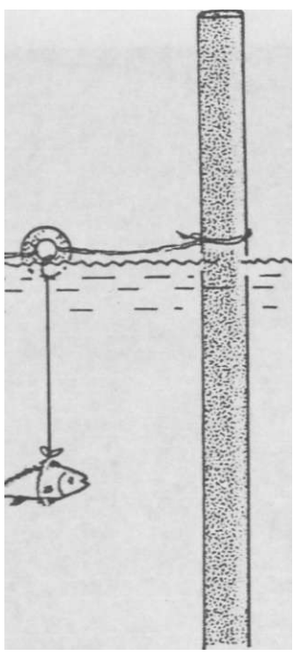
-Pole



-Vertical
string

Small fish"

iline.



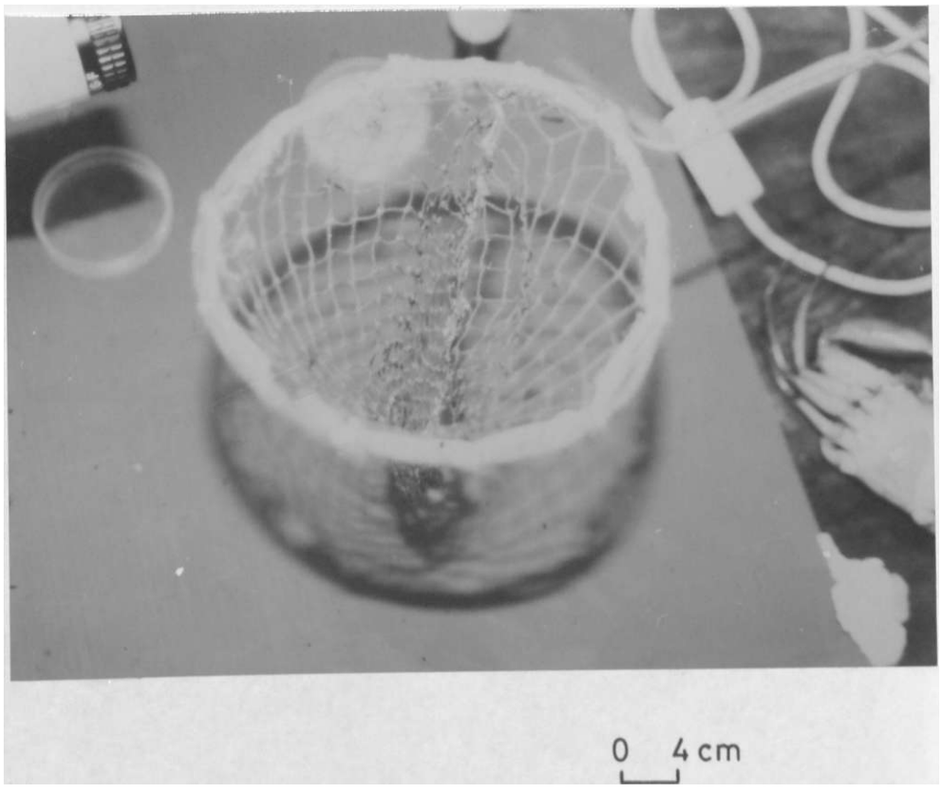
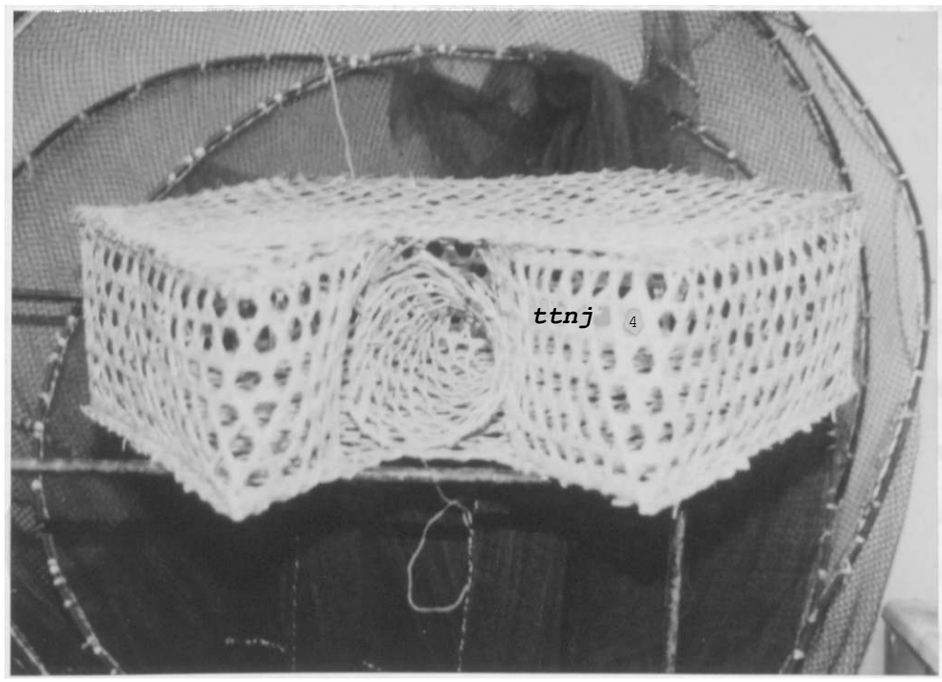


PLATE 3: Scoop net.



0 14 cm
1 i

PLATE 4s Madema trap. Note the funnel shaped entrance.

mangrove rods. Each trap has only one entrance which is funnel shaped with the wider end being the entrance facing the outwards. The bottom of the trap is usually flat and the reed face is untied at one corner to create a passage during the removal of the contents of the trap. This trap can also trap fin fishes when in operation. The fishermen usually use the medium size trap because it is more convenient.

When fishing for crabs, the fishermen usually pick a gastropod, *Terebralia palustris* from the mangrove area and crush their hard shells. They then stuff them into the traps and submerge the traps in the estuary during low tides. The fishermen usually ensure that the traps are placed on a flat ground during submergence. The traps are then retrieved during the next low tide. Crabs caught by this method have no injuries and so live longer. The main disadvantage of using this method is that fishing is restricted to periods of low tides. During the rainy season, more fresh water is emptied into the estuary and this lowers the salinity and temperature during low tide. Trapped crabs therefore die because of low temperates and low salinities. All the three crab sizes are caught by the traps i.e., juveniles, young adults and adults.

2.2.4 Scoop nets.

These are regularly used by fishermen and are suitable especially for the capture of crabs in sandy pools. The net has meshes of three centimetres and the opening ring has a diameter measuring 30 cm. The bottom part of the net is tied to seal it completely (Plate 3).

2.2.5 Fishing nets.

When the fishermen set up their nets to catch fish, some crabs get entangled in these nets and are therefore a by catch. These nets usually trap ovigerous *Scylla serrata* which are moving out into the sea to spawn. *Thai amita crenata* and *Portunus pelagicus* are also caught in this way. crabs are also caught by beach seines, especially *S. serrata* during their breeding season.

2.3 COLLECTION OF SAMPLES.

The samples were collected for a period of 12 months. *Scylla serrata* was collected from January 1990 to December 1990 while *Thalamita crenata* was collected from April 1990 to March 1991.

2.3.1 Materials.

a) Madema traps.

b) Sack.

c) Scoop net.

d) Pail.

2.3.2 Methods.

A preliminary sampling method for *S. serrata* was tried at Gazi located at Maftaha bay. The equipment used was the rods with metal hooks. A distance of approximately two kilometres was covered during the sampling process. Only ten crabs were obtained after eight hours. The small catch could be attributed to fishermen who had fished for the crabs a few days before along the same stream or because some crab holes were deeper extending beyond one and a half metres which was the length of the mangrove rods used. Therefore the crabs were out of reach. This fishing exercise was carried out along river Kidogoweni at Gazi in December 1990. Due to the low catch obtained, the sampling site was then changed to Kiwambale on river Ramisi estuary.

The river Ramisi enters the ocean through an estuary at Kidimu where the main stream is called Mto mamuja. The main stream extends to Mchangani at Kiwambale and into Funzi bay. This estuary is wide and deep enough enabling commercial crab fisheries to be carried out. Fishermen use madema traps for commercial fishing because they are easy to handle and to maintain. The method is also convenient and less laborious. Traps were set up randomly within the estuary in places where the ground surface was flat and preferably under the trees where the crabs move to in search of food. The traps were completely

submerged and at the same time anchored properly so that they were not swept away by oncoming or outgoing tides. The traps were set up during low tide and were retrieved after 12 hours during the next low tide. Since crabs do not die immediately when out of water, the few collected each time were kept in a wooden box with few branches of mangrove tree *Ceriops tagal* and moistened with sea water every day for one week each month. The crabs were then packed in a sack and transported to the laboratory for further analysis.

Thalamita crenata was sampled at Gazi at Maftaha bay. Gazi is a mangrove creek with a permanent small river called river Kidogoweni. This creek has a small lagoon which keeps water even at spring low tides. The area is undisturbed because it has no industrial establishments and there is no sewage effluents discharged into the creek or the river. Disturbance of the eco-system due to human settlements is not alarming because the area supports small scattered villages. The inhabitants are cutting the mangrove trees for building and for fuel on a small scale. The creek supports a small artisanal fishery which includes fin fishes and prawn catches during the long rainy seasons.

Thalamita crenata occurred in large numbers sub-tidally in the main channels of water at the edge of mud in Maftaha bay. Using a scoop net, any crab

sighted in the sandy pools or at the edge of mud was caught irrespective of its size and sex and then placed inside the plastic pail. Sampling was done during low tides everyday for one week each month. The distance covered during the sampling process was approximately two kilometres. All crabs obtained were transported to the laboratory for further analysis.

2.4 PRESERVATION AND TREATMENT.

All the samples of *Scylla serrata* and *Thalamita crenata* obtained were taken to the laboratory and kept in a deep freezer which killed them by lowering their temperatures.

For each crab, the following was recorded s

i) Carapace width (mm) at the level of eighth to ninth post-orbital teeth *S. serrata* and the fourth post-orbital tooth in *T. crenata* (to the nearest 0.1mm).

ii) Body weight using an electric balance (to the nearest 0.1 g).

iii) Sex.

The number of ovigerous (with extruded ovaries) female crabs was recorded and for the non-ovigerous female crabs, their carapace was opened up for observation of the maturity stages of the ovaries. The following was recorded for ovigerous female crabsi

i) Weight of embryo-mass together with pleopods.

ii) Developmental phases of crab embryos,

iii) Embryo-size using an ocular micrometer,

iv) Maturity stages of ovary.

The whole embryo-mass together with pleopods was preserved in Gilson's fluid (Bagenal and Erich, 1978) made up as follows s

100 ml 60 ". methyl alcohol.

880 ml distilled water.

15 ml 80 ". glacial acetic acid.

20 g mercuric chloride.

This fluid preserved and hardened the embryos but failed to break up the ovarian tissue. Therefore the embryos could not be counted using a volumetric sub-sampling method and so a gravimetric sub-sampling method was used instead. In this method, the wet method was used whereby a section of the ovaries was weighed after removing excess water by filter paper. The number of eggs was then counted, and this was done for three sub-samples which were counted three times. Three averages were obtained and an overall average calculated. This average was then used to estimate the overall number of embryo* in the entire embryo-mass.

2.5 Analysis of samples.

2.3.1 Ovarian maturity stages.

The maturity stages of crab ovaries were grouped into four main classes following the procedure

adopted by Pillay and Ono (1978). Observations of the ovary were made under a standard binocular microscope (Laborlux). The following are descriptions given for ovary development arbitrarily distinguished by the size and colour of the ovary:

stage <3 Virgin / Resting. Ovary is very thin (< 2mm) and transparent (colourless). No initiation of gametogenesis (No activation and the ovary is apparently resting).

stage 1 Developing. Ovary (approx. 2 mm thick) is active (showing signs of development) but still thin and creamy white in colour.

stage 2 Well developed. Ovary is thick (approx. 5 mm thick), broad, yellow and contains medium sized oocytes.

stage 3 Ripe. Ovary is dark brown and practically fills the body cavity, pressing against the hepatopancreas and the stomach. The ovary is highly lobulated and has large oocytes. After this stage the eggs are extruded onto the pleopods.

2.5.2 Developmental phases of crab embryos.

The developmental phases of crab embryos were determined following the procedure adopted by Boolootian et al» (1959). Observations of the embryo developmental phases were made under a standard dissecting microscope (Wild M3C Heerbrugg). The following are the descriptions given for embryonic development :

Stage 1 - No segmentation observable entire egg is yellow.

Stage 2 - Cleavage has taken place, i.e., the egg has several small sections visible.

Stage 3 - The developing egg has two regions: a very small yolk free (transparent) region and a larger yolky region.

Stage 4 - Distinction into two almost almost equal yolk-free and yolk-containing parts is visible.

Stage 5 - Eye pigment of the embryo visible.

Stage 6 - Light pigment bands of embryo visible.

Stage 7 - Larva strongly pigmented but still has much yolk.

Stage 8 - Yolk reduced to two small separate patches.

Stage 9 - Zoeae larvae recognizable.

Stage 10 - Swimming larvae emerge.

2.5.3 Size at first maturity..

This was ascertained by collecting 1030 *Thaiamita crenata* **and 742** *Scylla serrata* **and noting the carapace width at which 50 7. crabs are carrying embryos on their pleopods. The samples for the whole year was pooled.**

2.5.4 Fecundity.

For each ovigerous female crab, the following was recorded:

i) Carapace width (millimeters).

ii) Embryo-mass weight was obtained by first weighing the embryo-mass together with pleopods, then removing the pleopods manually, getting their weight and subtracting from the weight of the embryo-mass together with pleopods.

iii) Embryo-size was obtained by measuring the diameter of 10 embryos in each of the three sub-samples using an ocular micrometer. An average size was then calculated from the three average sizes. This average size was then converted to millimetres with the help of a stage micrometer.

Three sub-samples were taken from each preserved embryo-mass manually, and weighed. Water was added to the Bogorov counting chamber and the embryos were spread out manually using a fine dissecting needle.

Counting was done under the dissecting microscope (Wild M3C Heerbrugg). Each sub-sample was counted three times. From these, the average weights and average numbers were obtained. The total number of embryos was then estimated for the whole embryo-mass.

The relationship between fecundity and: i) carapace width, ii) embryo-mass weight and iii) embryo-size was determined using the formula of Bagenal and Erich (1978) as follows:

$$F = ax'^{3}$$

This curve is transformed to a straight line by Logarithmic transformation:

$$\text{Log } F = \text{Log } a + b \text{ Log } x$$

Where F = fecundity.

a = a constant,

b = an exponent.

x = any of the above parameters i.e., carapace width, embryo-mass weight, and embryo-size.

The linear relationship formed by logarithms allows standard statistical technigues to be used and also stabilizes the variance.

Regression analysis was used to estimate the linear relationship between fecundity, carapace width, embryo-mass weight and embryo-size.

2.5.5 Sex ratio.

The ratios of males to females of both *Thalamita crenata* and *Scylla serrata* were determined in monthly catches. A variance test of homogeneity of the binomial distribution was performed on the monthly samples to verify whether there was significant difference in sex variation using the formular

$$x^2 = \frac{\text{f}p_i.a_i - pA}{p\,q}$$

$D_i = a_{-1} / n_{\bullet 1}$. a_r = males or females,

$n_.$ = monthly totals. A = total of (a_i).

p = totals of males (A)/overall total (N).

q = totals of females (A)/overall total (N).

The overall sex ratio was calculated using the Chi-square formular

$$x2 = (f\_F)^2 / F$$

F = expected f • observed

(Snedecor and Cochran 1967).

2.5.6 Sex ratio in relation to size (carapace width) of the crabs..

The size-frequency distribution of males and females was also determined in both crab species S. serrata and *T. crmnata.* A variance test of homogeneity of the binomial distribution was performed on the samples using the formular in 2.5.5. The overall »iz#m of «nd females,

respectively, were compared using the t-test (Snedecor and Cochran, 1967).

2.5.7 Breeding cycle of the crabs.

This was obtained from the percentage of ovigerous females in each month. The mean size (carapace width) of ovigerous females in each month was determined. The abundance of ovigerous females in the population and the ovarian activity was also estimated for the whole year.

CHAPTER THREE

RESULTS

3-1 OVARIAN MATURITY STAGES.

In this study, it is evident that crab ovaries increase in size and undergo colour changes since all the four stages were observed in both crabs *S. serrata* and *T. crenata.*

3.1.1 Maturity stages of *S. serrata* ovaries.

Maturity stage zero was obtained only once during the sampling period in July (Fig. 5). The number of crabs with their ovaries in stage one of development was also low, and these were found in eight months during the sampling period (January, February, March, July, August, September, November and December).

Maturity stage two occurred in large numbers in the samples throughout the sampling period. Plate 5A shows maturity stage two without any accumulation of the fatty body. There were four different sizes and colour of fatty body associated with this stage as shown in Table 4A. Plate 5B. shows two crabs with maturity stage two ovary with large quantity of the fatty body (crab I) and crab II with medium quantity of the fatty body.

Maturity »tage three was obtained only in four months (March, May, June and September) during the sampling period and in low numbers (n-8). It was

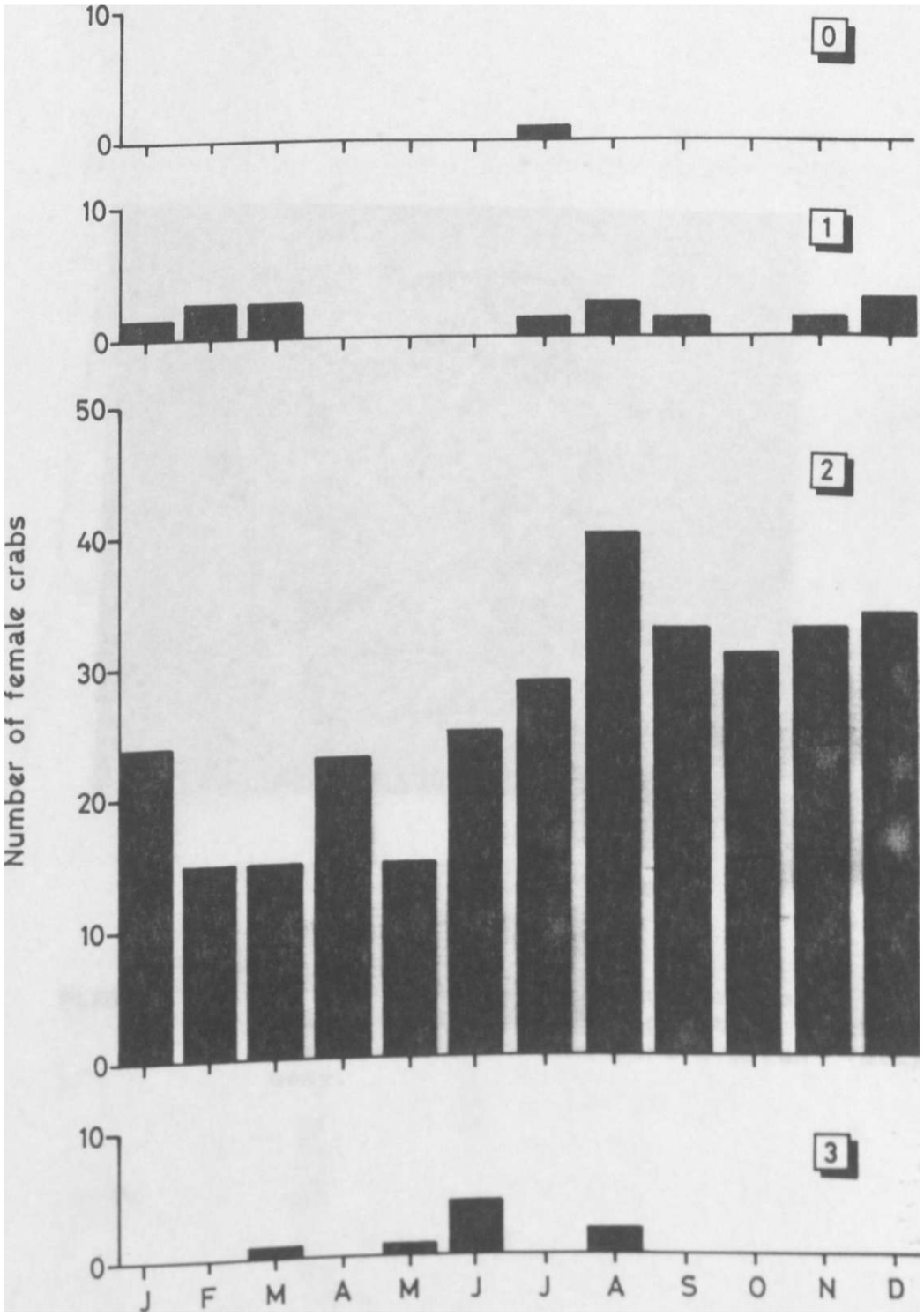


Fig.5: s. serra", M «turity 8taReS o„3 of

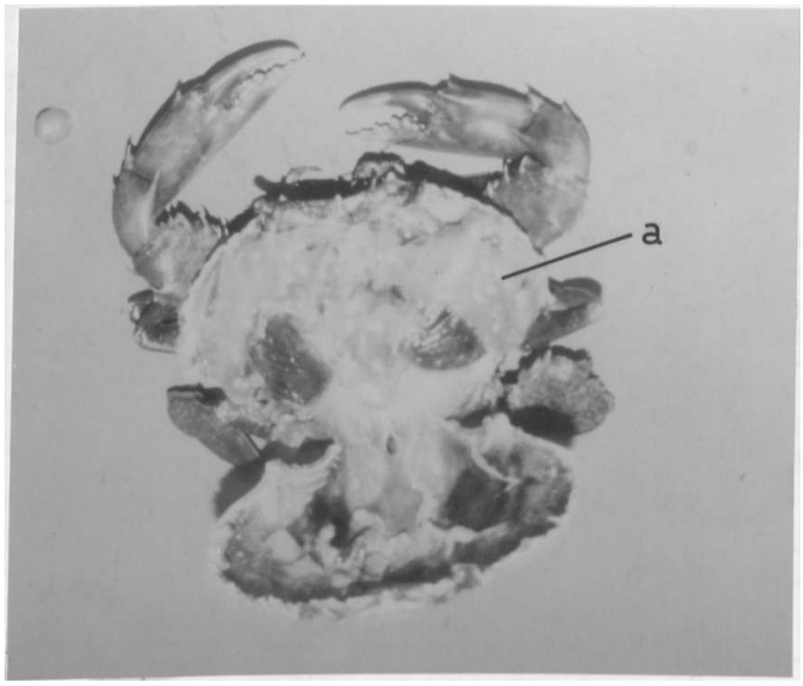


PLATE 5A: ***S. serrata.*** **Maturity stage two (a) of the ovary development without accumulation of the peri-ovarian fatty body.**

TABLE 4A: *S. serrata.* **Sizes and colour of peri-ovarian fatty body.**

Size of fatty body	Colour of the fatty body and colour of ovary.
1. Very thin (< 2mm) transparent layer	Creamy-white over the bright yellow stage two ovary.
2. Thin opaque layer (Approx. 2 mm)	Cream-orange over the bright yellow stage two ovary.
3. Medium quantity (Approx. 5 mm) (PLATE 5B. II)	Bright-orange fat, larger in volume than the bright-yellow stage two ovary.
4. Large quantity (over 5 mm thick) (PLATE 5B. I).	Orange-red fat, larger in volume than the bright yellow stage two ovary.

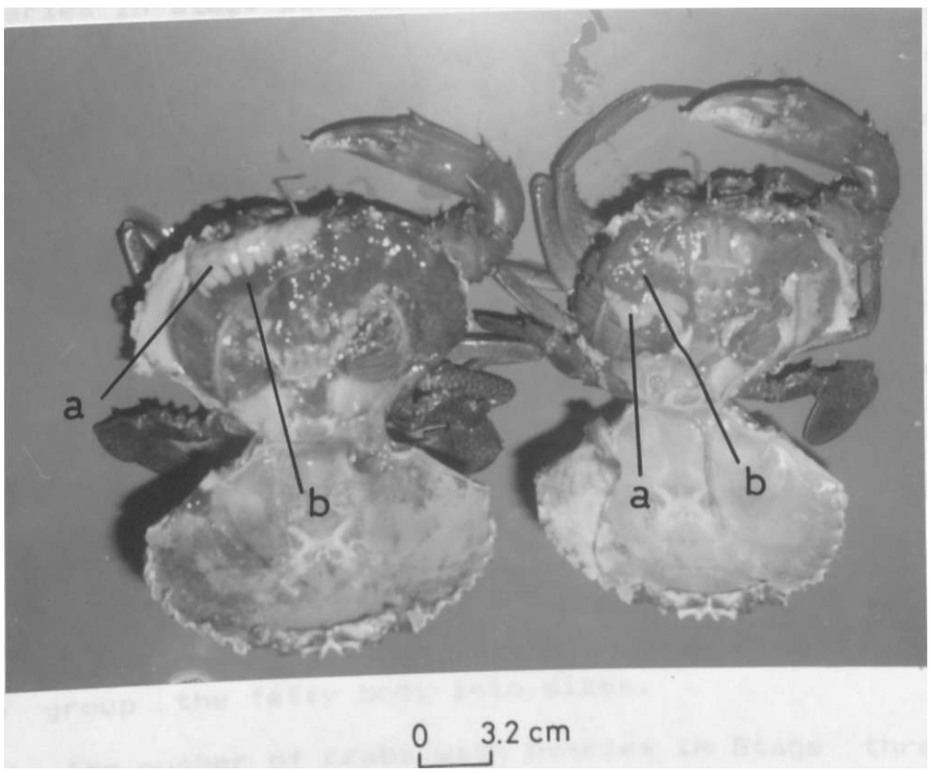


PLATE 5B» I * ***S. serrata.*** **Maturity stage two ($_a$) of the ovary with accumulation of the fatty body (b) size three and four (Table 4A).**

during these months that the proportions of *S serrata* with fatty body were high (Table 4B).

3.1.2 Maturity stages of *T. crenata* ovaries.

During the sampling period, the crabs with ovaries in stage *zero* of development were few. Fig.6 shows that the months of April, June, November and December, had no Stage zero of development. The number of crabs with ovaries in stage one was higher than the total number of crabs with ovaries in stage zero and only June had no female crab in that stage of development. Crabs with ovaries in stage two of development were abundant in each month throughout the sampling period. There was a grey mass which was thought to be a fatty body bright yellow ovary stage two. Because of the crab's size, it was difficult to group the fatty body into sizes.

The number of crabs with ovaries in Stage three tended to be low though occurring in each month throughout the sampling period. Crabs in this maturity stage had the grey mass over the ovary.

3.2 DEVELOPMENTAL PHASES OF CRAB EMBRYOS.

As the embryos of crabs develop, they undergo marked colour changes from yellow when l«i$_{d}$ to almost black when the zoeae are being emerge. These embryos are attached to the pleopods and are brooded externally•

TABLE 4B: Percentage of female *S. serrata* with peri-ovarian fatty body.

MONTH	TOTAL NO. OF FEMALES.	FEMALES WITH FATTY BODY.	% OF FEMALES WITH FATTY BODY.
JAN (1990)	25	9	36
FEB	17	7	41
MAR	18	8	44
APR	24	7	29
MAY	1^	12	75
JUN	29	17	59
JUL	31	11	36
AUG	42	17	41
SEP	37	10	27
OCT	31	8	26
NOV	34	4	12
DEC	37	5	14
TOTAL	341	115	33.7

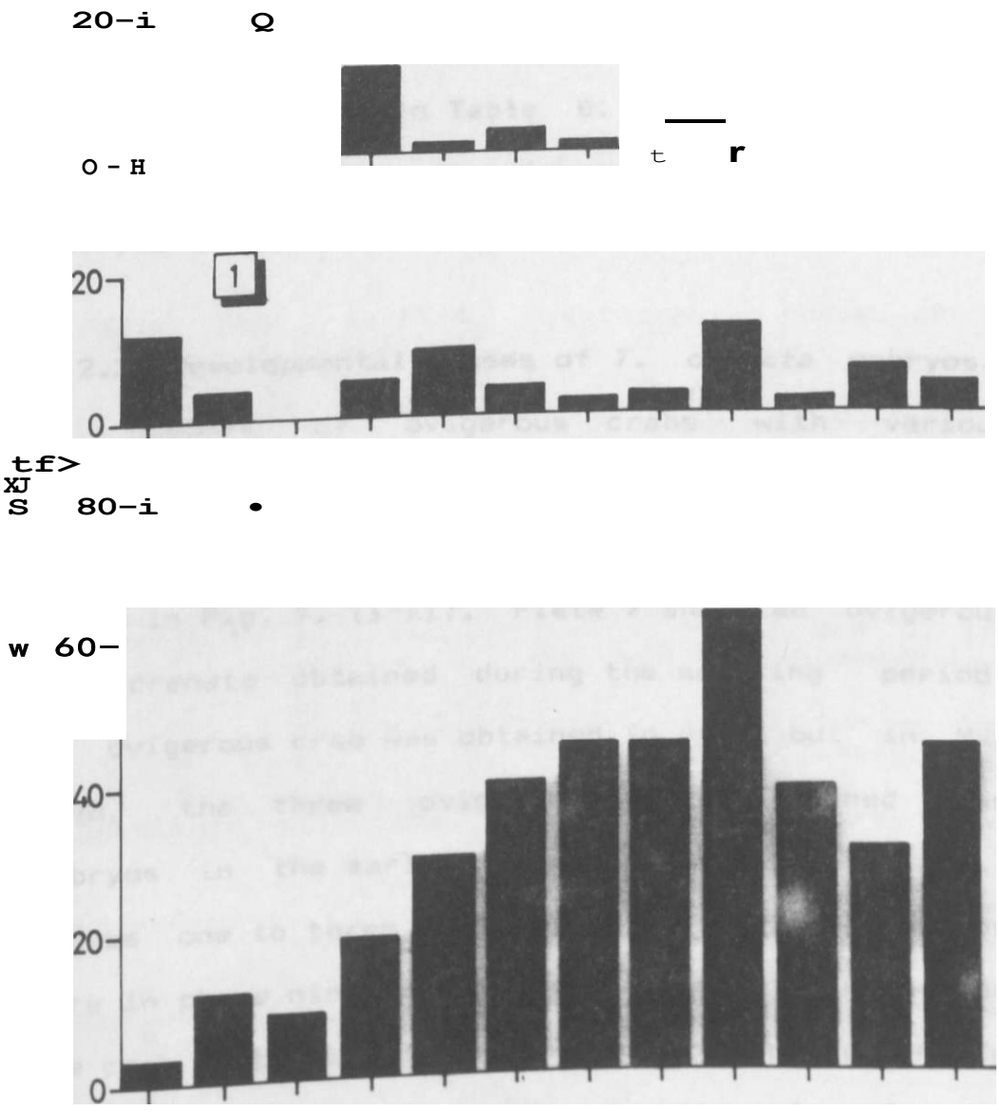


Fig. 6. L. crenata- Maturity stages 0-3 of Ovaries.

3.2-1 Developmental phases of *S. serrata* embryos.

Five ovigerous crabs were obtained during the sampling period. These had their embryos in various phases as is shown in Table 5.

Plate 6 shows an ovigerous female crab with embryos in phase three of development.

3.2.2 Developmental phases of *T. crenata* embryos.

Numbers of ovigerous crabs with various developmental phases of embryos observed in the samples obtained throughout the sampling period are shown in Fig. 7. (i-xi). Plate 7 shows an ovigerous *T. crenata* obtained during the sampling period. No ovigerous crab was obtained in April but in May 1990, the three ovigerous crabs obtained had embryos in the early phases of development, i.e., phases one to three. In July, most of the embryos were in phase nine, indicating imminent spawning and one crab in the sample had embryos in phase ten in which the swimming zoeae emerge. In August, majority of the ovigerous crabs had embryos in phase nine of development. In September, the majority of ovigerous crabs in the sample were in phases five to nine of development, thus, July to September is - .Pining season (Fig. 13>. In October, the ovigerous crabs obtained had their embryo. in P*—* to fiv*' whil* November, the few ovig*rou» crab* obt*in*d h«d <"«jority in

TABLE 5: *S. serrata.* **Developmental phases of embryos.**

Month	Number of crabs	7. in embryo-mass	Deve1opmen ta1 phases
August	two	over 70	one in the embryo-mass.
		over 70	two in the embryo-mass.
September	one	over 70	three in the embryo-mass.
November	one	over 70	three in the embryo-mass.
December	one	over 70	two in the embryo-mass.

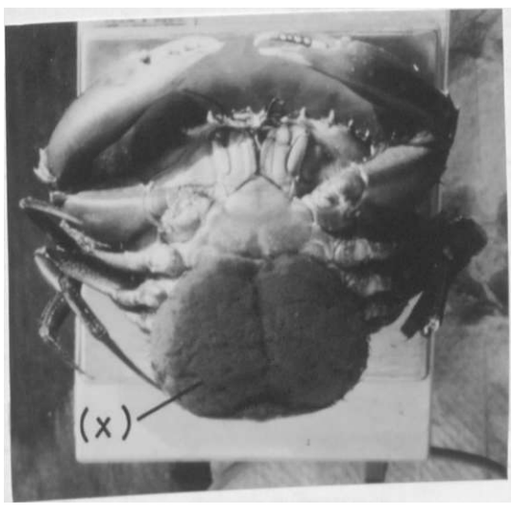
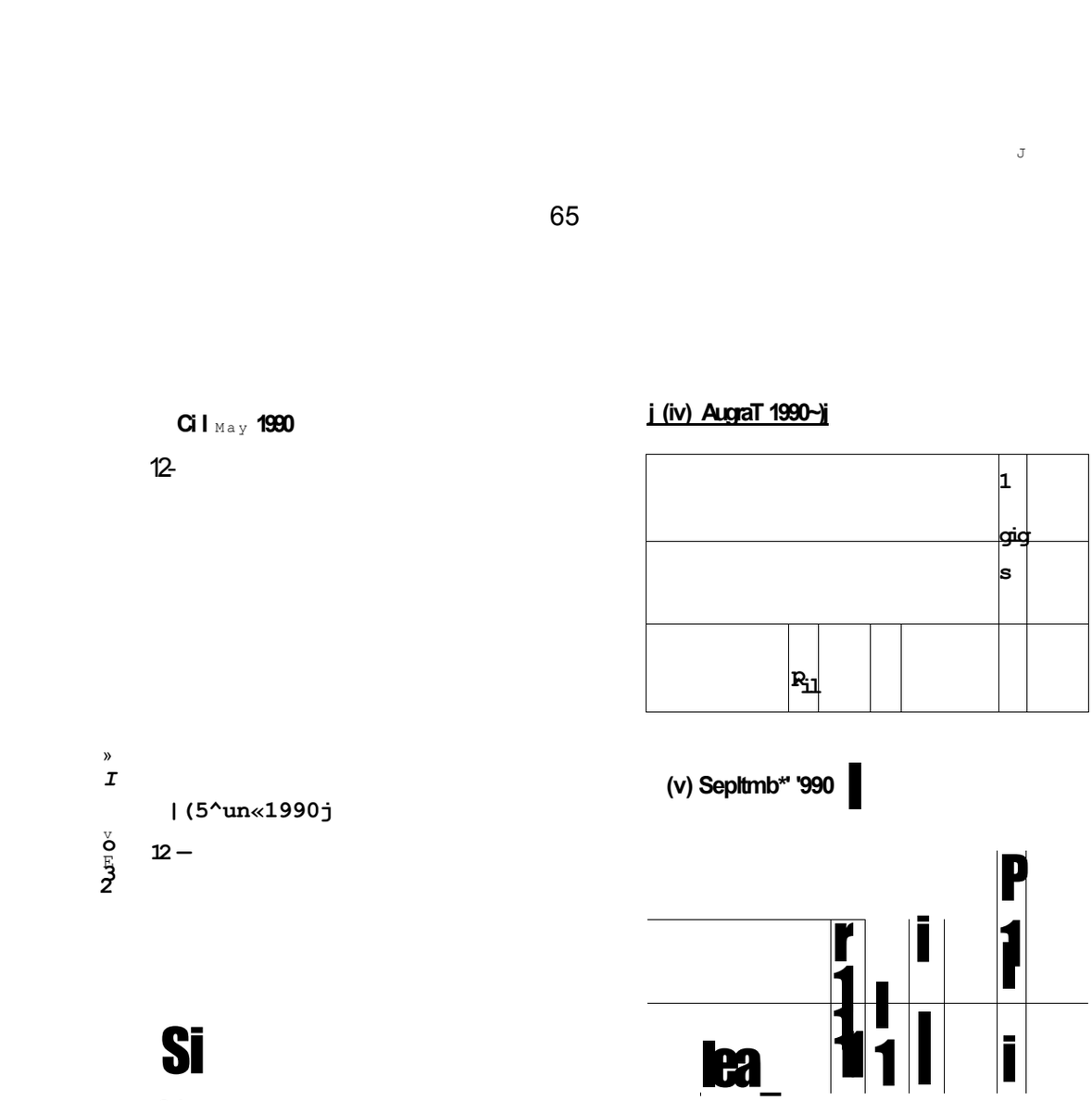


PLATE 6: oviaerous *Scylla serrata*. Note the Oviger^ embryo_mass (X) under the abdomei«• The embryos are in phase three of development.



Developmental phases of embryos.

Fic. 7: T. crenata

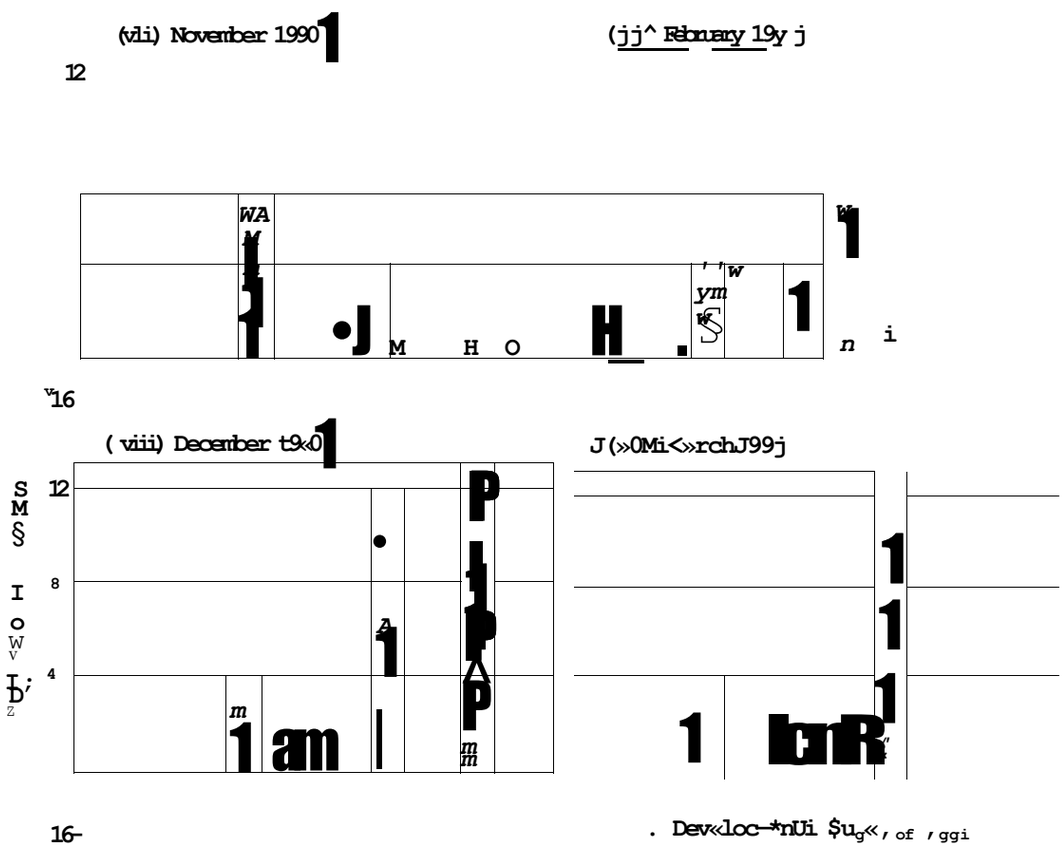
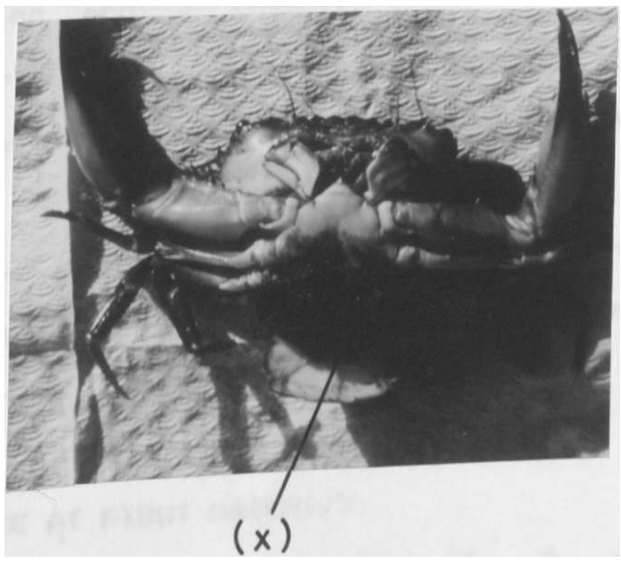


Fig. 7 (Cont.): T. crenata. Developnental phases of emoryos.



1.6 cm

PLATE 7: Ovigerous female of *Macrobrachium crenata*. Note the embryo-mass (X) under the abdomen. The embryo-mass of 15 development.

phase four of development and only one crab in phase nine and ten respectively. December and January had a considerable proportion of phase nine embryos indicating another spawning season. l_n February the ovigerous crabs obtained had embryos in nearly all phases except stages two, eight and ten. i_n March, majority of ovigerous crabs had embryos i_n stage seven of development. The second peak of spawning in the breeding cycle occurs between December and January.

3.3 SIZE AT FIRST MATURITY.

3.3.1 Size at first maturity of *S.* serrata.

The smallest ovigerous crab obtained during the study period had a carapace width of 139.75 mm (Table 6). But this could not have been the size at first maturity because from studies on maturity stages of crab ovaries, a crab of carapace width 77.1 mm was in stage one of development. This shows that these crabs start maturing at a smaller carapace width. The size at first maturity could not be ascertained because the number of ovigerous crabs obtained was so low (n-5).

3.3.2 Size at first maturity of *T. crmnat*.*

In this study the smallest ovigerous crab had « carapace width of 28.9 mm. But the ascertained .i_{It} at first maturity ranged between 40.5-45.44 mm

carapace width, when 50 7. of the females collected were carrying embryos on their pleopods. Studies on the maturity stages of ovaries indicate that a crab with carapace width of 16.75 mm was in stage one of development. This shows that these crabs also start maturing at a much smaller carapace width

3.4 FECUNDITY

3.4.1 Fecundity of *Scylla serrata.*

Table 6 shows fecundity, carapace width, embryo-mass weight, embryo-size, and live weight of *S. serrata* obtained during the sampling period.

3.4.1.1 The relationship between fecundity and carapace width.

A total of five ovigerous crabs were examined for fecundity studies as these were the only ones obtained.

The fecundity of this crab species ranged from 2,186,000 embryos in a specimen of 139.75 mm carapace width to 21,565,000 embryos in a specimen of 162.6 mm. The mean carapace width was 151.8 mm with average fecundity of 8,263,400. There i* * wide variation between maximum and minimum fecundities with the largest crab (886.8 g live weight) carrying the largest number of embryos compared to the smallest crab (429.8 g live weight). The mean fecundity th,o "cundit v of *hr.. crab. (Table 6).

Table 6: S. serrata. Fecundity, carapace width, live weight, embr and embryo-size.

Month	Fecundity	Carapace width (mm)	Live weight (g)	Embryo-mass weight (g)
Aug.	2,800,000	140.7	433.8	51.9
	9,932,000	158.2	713.1	179.7
Sept.	21,565,000	162.6	886.8	205.7
Nov.	4,834,000	157.8	715.1	164.2
Dec.	2,186,000	139.75	429.8	52.4
Mean	8,263,400	151.8	635.7	130.8

The regression line (Fig. 8a) fitted for fecundity on carapace width was

$\text{Log}_{10} F = -19.2 + 11.9 \text{Log}_{10} X$

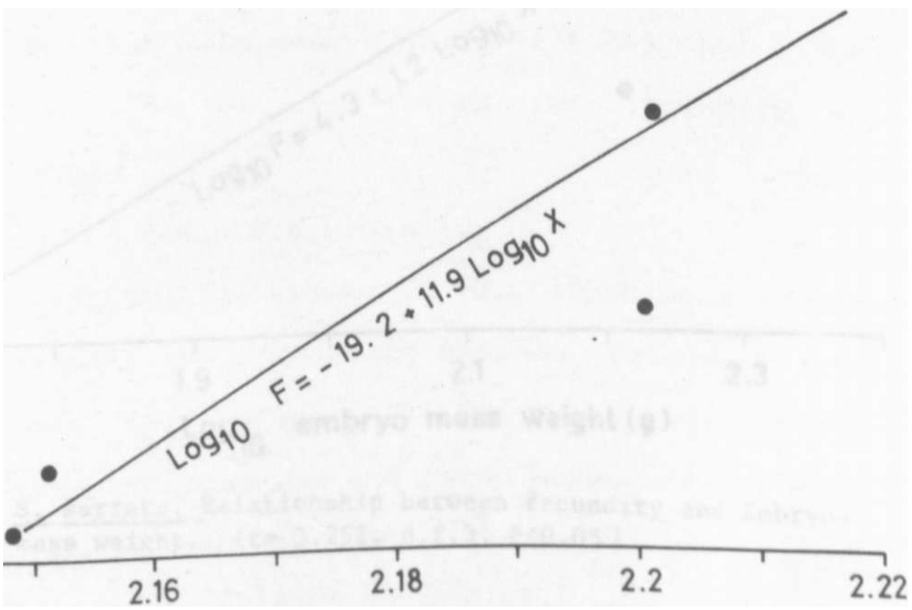
The exponential value was high 11.9 showing that the fecundity increases with increase in carapace width of the crabs. The regression coefficient value between carapace width of crabs and the total number of embryos carried in the abdomen was found to be statistically significant ($t = 3.546$; d.f. = 3. $P < 0.05$).

3.4.1.2 The relationship between fecundity and embryo-mass weight.

The total number of crabs for this study was five. The fecundity ranged from 2,800,000 embryos in a specimen with embryo-mass weight of 51.9 g to 21,565,000 embryos in a specimen with an embryo-mass weight of 205.7 g. The mean embryo-mass weight was 130.8 g with a mean fecundity of 8,263,400 embryos. There is a great difference between maximum and minimum embryo-mass weight. The regression line (Fig. 8b) fitted for fecundity on egg-mass weight was

$\text{Log}_{10} F = 4.3 + 1.2 \text{Log}_{10} X$

The exponential value of 1.2 showed that fecundity increases with increase in embryo-mass weight. The regression coefficient value between embryo-mass weight of crabs and the total number of



Fi&- 8a- **s** serrata Relationship **between fecundity** and carapace **width, (t ^ 3.546**, d.**f.3**, **P<0.05).** _

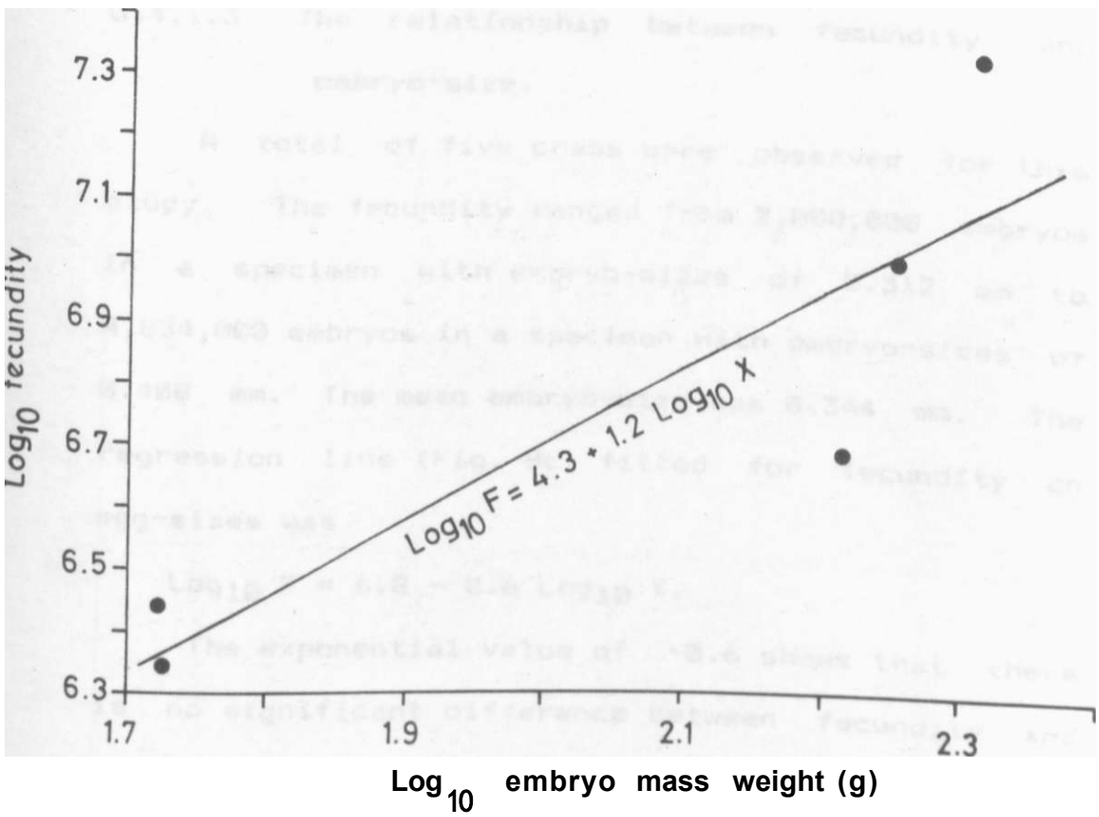


Fig. 8b: S^ serrata. Relationship between fecunditv i r u mass weight. (t- 3.251, d.f.3, P<0.05) ^{En}>br$_{yo}$-

embryos carried in the abdomen was found to be statistically significant (t = 3.251; d.f. = 3. p < 0.05).

3.4.1.3 The relationship between fecundity and embryo-size.

A total of five crabs were observed for this study. The fecundity ranged from 2,800,000 embryos in a specimen with embryo-sizes of 0.312 mm to 4,834,000 embryos in a specimen with embryo-sizes of 0.408 mm. The mean embryo-size was 0.344 mm. The regression line (Fig. 8c) fitted for fecundity on egg-sizes was

$$Log_{10} F = 6.8 - 0.6 Log_{10} X.$$

The exponential value of -0.6 shows that there is no significant difference between fecundity and embryo-size. The regression coefficient value between embryo-size of crabs and the total number of embryos carried under the abdomen was found to be nut statistically significant (t = 0.029; d.f. = 3j p > **0.1).**

3.4.2 Fecundity of *Thalamita* creoata.

A total of 207 crabs were observed for fecundity studies. The carapace width ranged from 23.44-70.44 mm, the embryo-mass weight ranged from 0.n g to & ^ g, the embryo-size ranged from 0.3 mm to 0.405 mm in diameter, while fecundity ranged from 1,321 to 209,450 embryos.

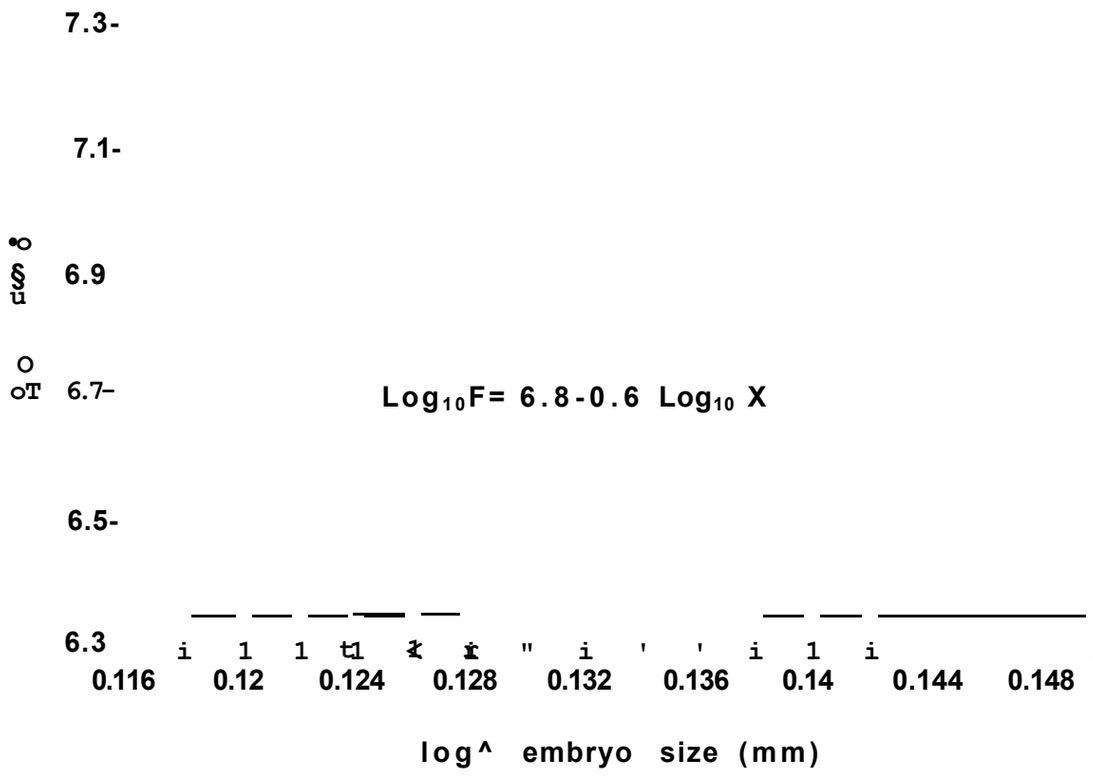


Fig 8c. S. serrata. Relationship between fecundity and embryo-sTze. (t- **0.029, d.f. 3, P>0.1)**

3.4.2.1 The relationship between fecundity and carapace width.

A total of 207 crabs were observed for this study. The highest fecundity recorded for this crab species is 207,710 in a specimen of 60.4 mm carapace width while a specimen with carapace width of 50.9 mm had 13,650 embryos. The mean carapace width was 47 mm with a mean fecundity of 74,320. The regression line (Fig. 9a) fitted for fecundity on carapace was

$$\text{Log}_{10} F = -0.5 + 2.4 \text{ Log}_{10} X$$

The exponential value of 2.4 shows that fecundity increases with increase in carapace width of the crabs. The regression coefficient value between the carapace width of the crabs and the total number of embryos carried on the abdomen was found to be highly significant ($t = 9.908$; $d.f. = 205$; $p < 0.001$).

3.4.2.2 The relationship between fecundity and embryo-mass weight.

The highest embryo-mass weight recorded in the sample was 5.6 g with a total of 170,000 embryos while the lowest embryo-mass weight recorded was 0.1 g with a total of 6,760 embryos. The total number of crabs observed was 207. The mean embryo-mass weight was 1.8 g with a mean fecundity of 74,320. The regression line (Fig. 9b) fitted for fecundity on embryo-mass weight was

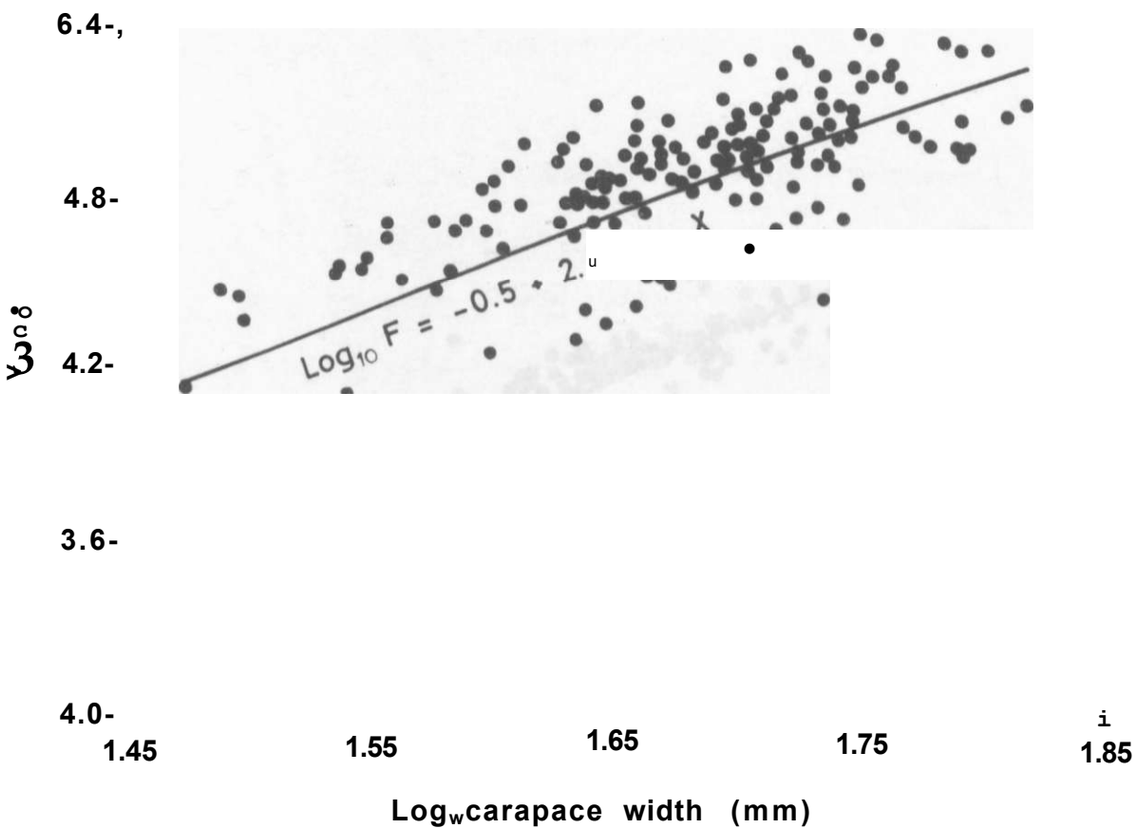
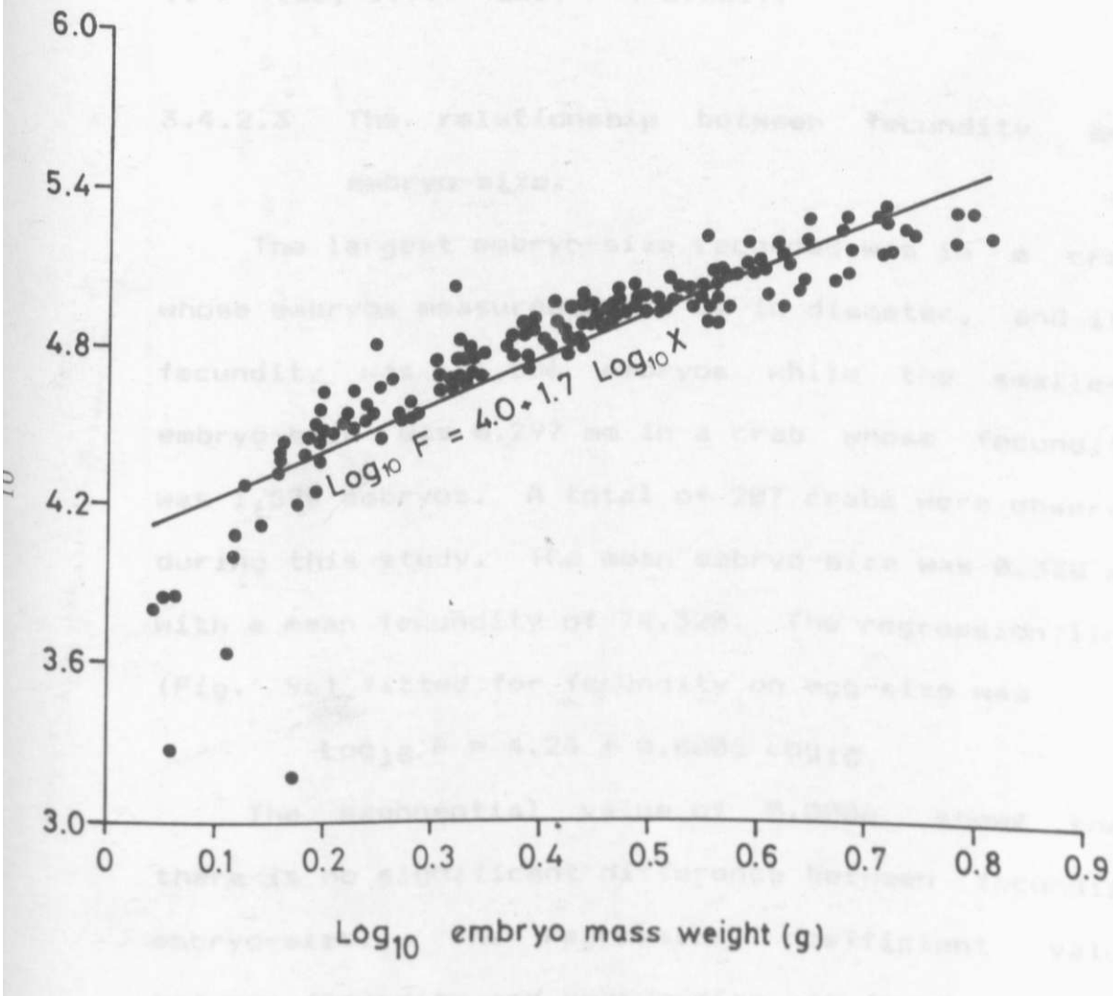


Fig. 9a: T. crenata. Relationship between fecundity and carapace width. (r = 0.908, d.f. = 205, P < 0.001)



Fi 9b- T crenata. Relationship between fecundity and embryo-
^88, weight. (t - 9.55, d.f. - 205,. P < 0.001)

$$\text{Log}_{10}\ F = 4.0 + 1.7\ \text{Log}_{10}\ X$$

The exponential value of 1.7 shows that fecundity increases with increase in embryo-mass weight The regression coefficient value between fecundity and embryo-mass weight was found to be highly significant ($t \ll 9.55$; d.f. = 205; $P < 0.001$).

3.4.2.3 The relationship between fecundity and embryo-size.

The largest embryo-size recorded was in a crab whose embryos measured 0.405 mm in diameter, and its fecundity was 51,506 embryos while the smallest embryo-size was 0.297 mm in a crab whose fecundity was 1,520 embryos. A total of 207 crabs were observe! during this study. The mean embryo-size was 0.33 mm with a mean fecundity of 74,320. The regression line (Fig. 9c) fitted for fecundity on egg-size was

$$\text{Logia}\ F = 4.24 + 0.0006\ \text{Log}_{10}$$

The exponential value of 0.000^ shows that there is no significant difference between fecundity and embryo-size. The regression coefficient value between fecundity and embryo-size was found to be not statistically significant ($t \cdot 1.04$; d.f. = 205| $P > 0.05$).

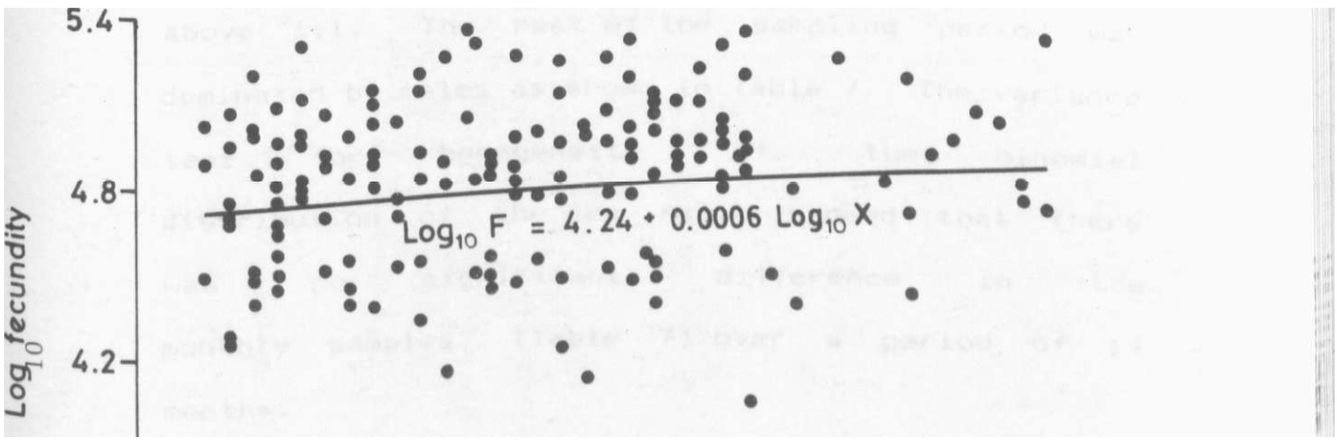


Fig 9c. T> crenata. Relationship between fecundity and embryo-size. Zt « 1.04, d.f. - 205, P > 0.05)

3.5 SEX RATIO OF THE CRABS

3.5.1 Sex ratio of *Scylla* serrata.

The highest male to female ratios was recorded in April. June, July and August also show a ratio above 1:1. The rest of the sampling period was dominated by males as shown in Table 7. The variance test for homogeneity of the binomial distribution of the sex ratio showed that there was no significant difference in the monthly samples (Table 7) over a period of 14 months.

$X^2 = 14.615$; d.f. = 13; $P > 0.05$

The overall sex ratio was not significantly different from 1:1 as shown by the chi-square test.

$X^2 = 0.776$; d.f. - 1; $P > 0.25$.

3.5.2 Sex ratio in relation to size (carapace width) in S. *serrata.*

Table 8 shows that the males were more numerous in the catch in small size ranging from 80.5-110.44 mm carapace width with a mode of 101 in size 100.5-110.44 mm, while the females dominated the catch in larger sizes ranging from carapace width 130.5-170.44 mm with a mode of 75 in size 110.5-120.44. The modal size is the class range 110.5-120.44. This table also shows that size frequency distribution is unimodal in this population as shown by the total numbers in each size class.

TABLE 7s *S. serrata.* Sex ratio during the sampling period. (pooled sex ratio 111) X^2 = 14.615; d.f. =13; P > 0.05)

MONTH	MALES	FEMALES	TOTAL	M:F
JAN (1990)	26	25	51	1:0.96
FEB	21	17	38	1:0.82
MAR	26	18	44	1:0.7
APR	14	24	38	1:1.7
MAY	16	16	32	111
JUN	22	29	51	111.33
JUL	26	31	57	111.17
AUG	31	42	73	1:1.33
SEP	38	37	75	1:0.96
OCT	35	31	66	1:0.89
NOV	46	34	80	1:0.74
DEC	51	37	88	1:0.72
JAN (1991)	11	07	18	1:0.64
FEB	20	11	31	110.55
TOTAL	383	359	742	1:0.94

8: *S. serrata.* Sex ratio in relation to size (width) of carapace (t = 4.26; d.f. = 18; P < 0.001)

Carapace width (mm)	MALES	FEMALES	TOTAL	M:F	V. of total
< 80.5	3	5	8	1:1.67	1 -[0]
80.5 ~ 90.4	22	20	42	1:0.91	5.7
90.5 - 100.4	69	31	100	1:0.47	13.5
100.5 - 110.4	101	74	175	1:0.77	23.6
110.5 - 120.4	72	75	147	1:1.07	19.8
120.5 - 130.4	54	46	100	1:0.92	13.5
130.5 - 140.4	27	52	79	1:1.92	10.7
140.5 - 150.4	23	40	63	1:1.77	8.5
150.5— 160.4	11	13	24	1:1.18	3.2
160.5 - 170.4	1	3	4	1:3.00	0.5
TOTAL	383	359	742	1:0.94	100

The variance test for homogeneity of the binomial distribution in relation to size frequency distribution showed that there is a very significa t heterogeneity when the size frequency distribution is

(Considered (Y^2 a = 32.83; d.f. = 9. p << 0 05)

Similarly, when the overall mean sizes for males and females were compared using the t - test it was shown that a very significant difference occurred between the sexes .< t = 4.26; d.f. = ie; p < 0.001)

3.5.3 Sex ratio of T. crenata.

It can be seen from Table 9, that the highest female to male ratio was recorded in June. The other months with high female ratios are May, October January, February and March. The female? dominated the catch in most months during the sampling period i.e., May, June, July, August September, October, December, January, Februar and March as shown in Table 9. The variance te?t for homogeneity of the binomial distribution of the sex ratio showed that there was no siamf difference in the monthly binomial distribution during the sampling period.

X^2 - 16.83» d.f. - 11, P ^ 0>05

Therefore there is no evidence of »*gnificant heterogeneity.

The overall sex ratio was »»gnificantly different from 111 as shown by the chi-mqu«r^ t(t

X^2 - 19.577| d.f. - 1, p < 0.001

T. crenata. **Sex ratio during the sampling period. (Pooled ratio 1:1.32) (x^2 = 16.83; d.f. 11; P > 0.05).**

MONTH	MALES	FEMALES	TOTAL	M:F
APR (1990)	32	21	53	1:0.66
MAY	16	24	40	1:1.50
JUN	12	24	36	1:2.00
JUL	30	40	70	1:1.33
AUG	40	55	95	1:1.38
SEP	51	64	115	1:1.25
0CT	36	58	94	1:1.60
NOV	62	54	116	1:0.87
DEC	67	87	154	1:1.27
JAN (1991)	31	53	84	1:1.70
FEB	30	45	75	1:1.50
MAR	37	61	98	1:1.64
TOTAL	444	586	1030	111.32

3.5.4 Sex ratio in relation to size (carapace width) in *T. crenata.*

From Table 10 it can be observed that the females were more numerous in the catch than males in the smaller size classes with carapace width ranging from 15.5-55.44 mm with a mode of 115 in class size 45.5-50.44 mm. The males dominated the catch in larger size classes 55.5-80.44 mm with a mode of 60 in size class 35.5-40.44. The table also shows a unimodal distribution of this population in relation to the different size classes when looking at the percentages of the totals. The variance test of homogeneity of the binomial distribution of $_{5e}x$ i_n relation to size, shows a very significant evidence of heterogeneity (X^2 - 112.20; d.f. = 12; $p < 0.0_{01}$) Similarly, when the overall sizes for males and females were compared using the t-test, it was shown that a very significant difference occurred between the sexes in the different size classes (t « 3.163; d.f. - 24; P > 0.00D.

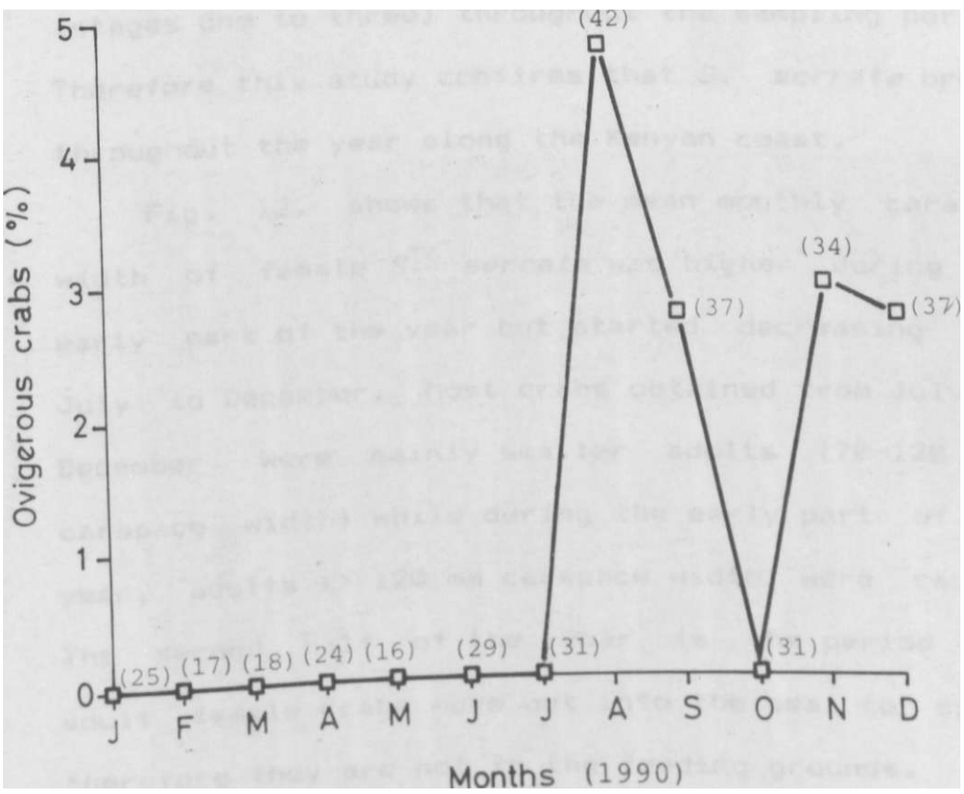
3.6 BREEDING CYCLES OF THE CRABS

3.6.1 Breeding cycle of *S. serrata.*

The percentage of ovigerous females in *merrsts* i« plotted on Fig. 10, however, the to number of ovigerous *S.* serrata caught throughout year was »o small five, that no mignific statement can be made on the spawning cycles on

TABLE 10= *T' crenata.* Sex ratio in relation to size (width) of carapace (t = 3.163; d.f. = 24; P > 0.001).

Carapace width (mm)	^ LES	FEMALES	TOTAL	M:F	V. of total
15.5 - 20.4	3	3	6	111	0.6
20.5 - 25.4	16	19	35	Is 1.19	3.4
25.5 - 30.4	42	41	93	1:0.98	8.1
30.5 - 35.4	50	76	126	1:1.52	12.2
35.5 - 40.4	60	8^	149	1:1.48	14.5
40.5 - 45.4	50	107	157	1:2.14	15.2
45.5 - 50.4	49	115	164	1:2.35	15.9
50.5 - 55.4	41	83	124	1:2.02	12.0
55.5 - 60.4	47	38	85	1:0.81	8.3
60.5 - 65.4	39	I4	53	1:0.36	5.2
65.5 - 70.4	28	1	29	1j 0.036	2.8
70.5 - 75.4	16	0	16	16:0	1.6
75.5 - 80.4	3	0	3	3:0	0.3
TOTAL	444	586	1030	1:1.32	100



r- c serrata. Percentage ot ovigerous female
Fig. 10: -^^-^btained during the sampling period.
'{Total number of females crabs in each month
in brackets). (Ovigerous crabs obtained were five).

basis of the presence of such females.

Fig. 11. shows the percentage frequency of maturity stages of ovaries in non-ovigerous crabs, it is evident that the females had active ovaries (stages one to three) throughout the sampling period. Therefore this study confirms that S. serrata breeds throughout the year along the Kenyan coast.

Fig. 12. shows that the mean monthly carapace width of female *S. serrata* was higher during the early part of the year but started decreasing from July to December. Most crabs obtained from July to December were mainly smaller adults (70-it mm carapace width) while during the early part of the year, adults (> 120 mm carapace width) were caught. The second half of the year is the Period when adult female crabs move out into the sea to spawn, therefore they are not in the feeding grounds.

3.6.2 Breeding cycle of *T. crenata.*

The percentage of ovigarous females crenata sampling is plotted on Fig. t. The species breeds throughout the year because ovigerous crabs were obtained from May to March 199i. This. Figure also shows two breeding peaks. one in September and the other in January 1991 though this crab breeds throughout the year.

The relative abundance of ovigerous shown more clearly in Fig. 14, t from which it

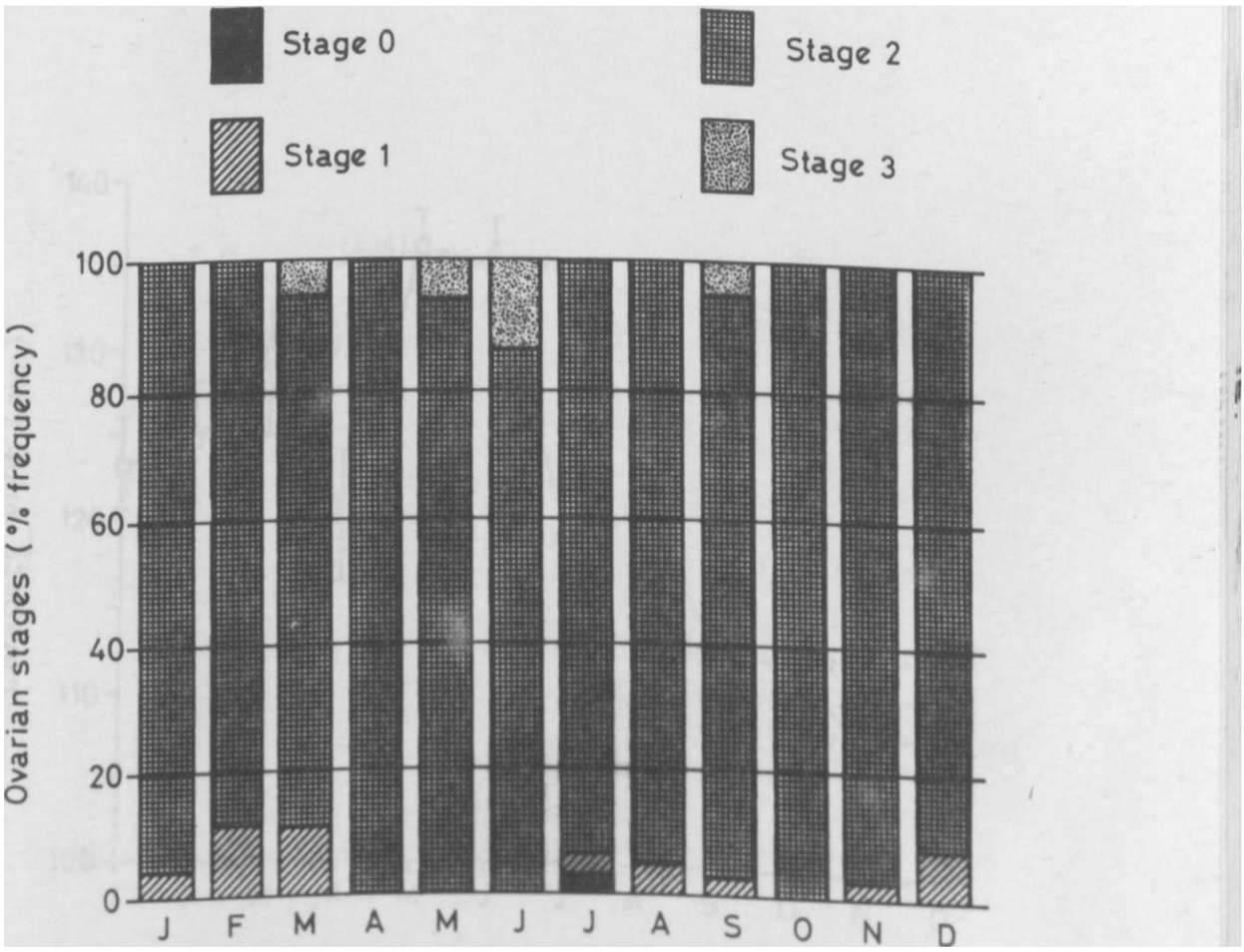
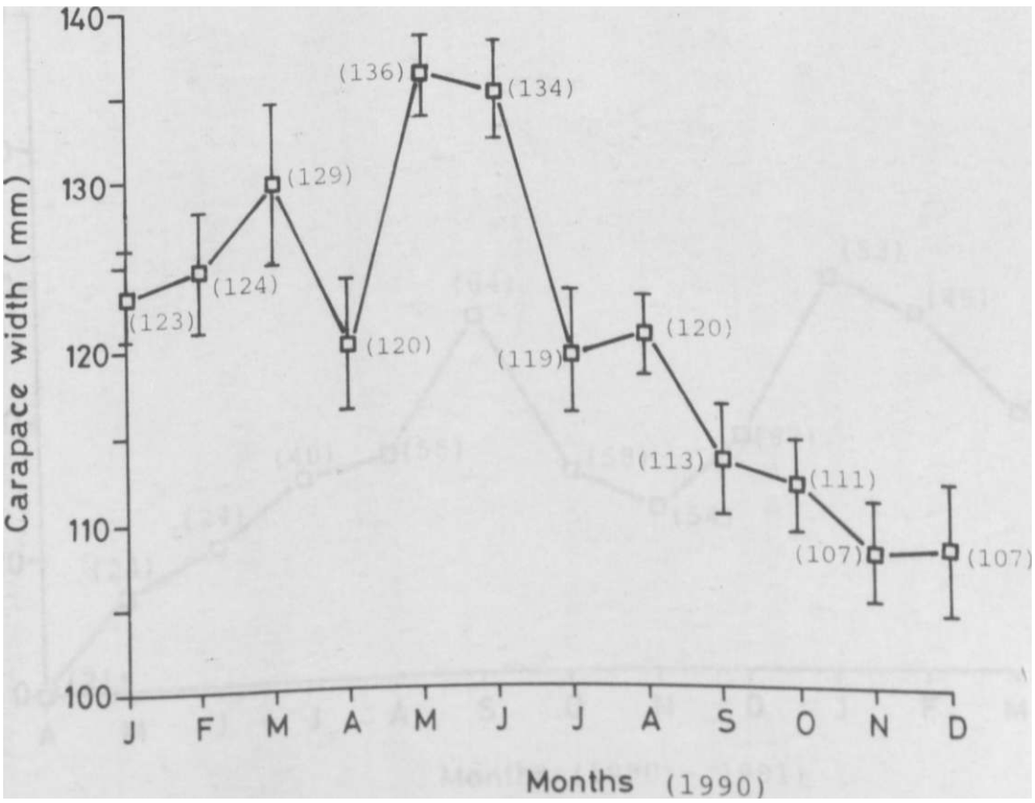


Fig 11. S. serrata. Percentage frequency of ovarian maturity stage of all non-ovigerous female crabs obtained during the sampling period.



1? S serrata. Variation xn the mean monthly carapace ' width"of female crabs. Numbers in pooled monthly sample means are given. (Bars indicate standard errors of the means).

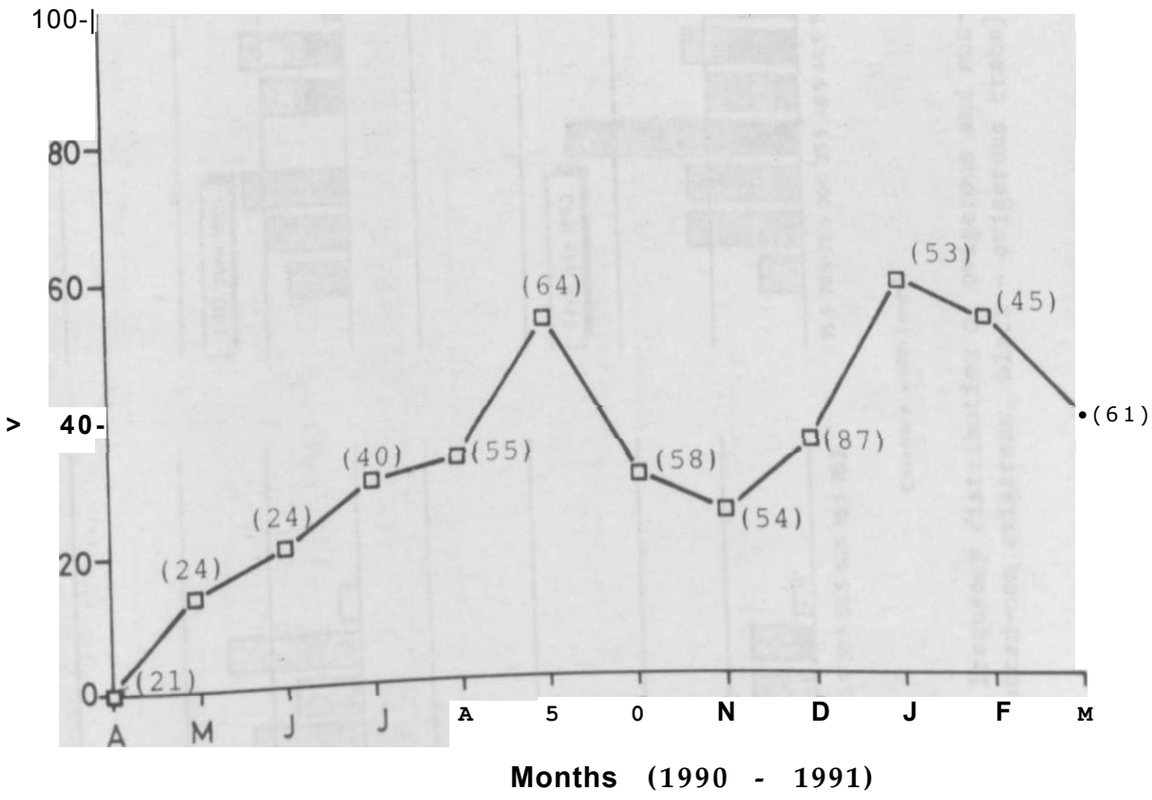


Fig. 13. T. cr^na • Percentage ol ovigerous females obtained period. (Total number of female crabs in each month in brackets).

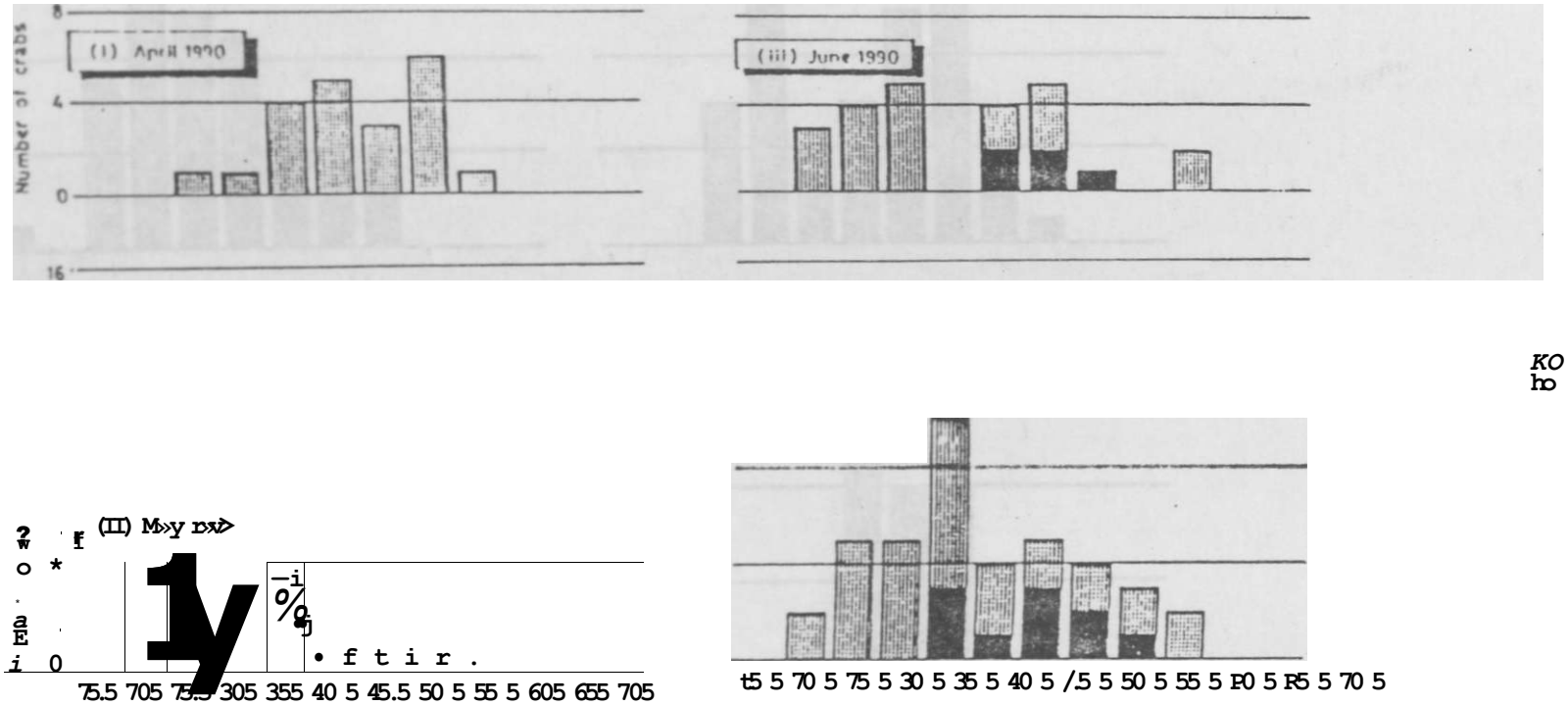
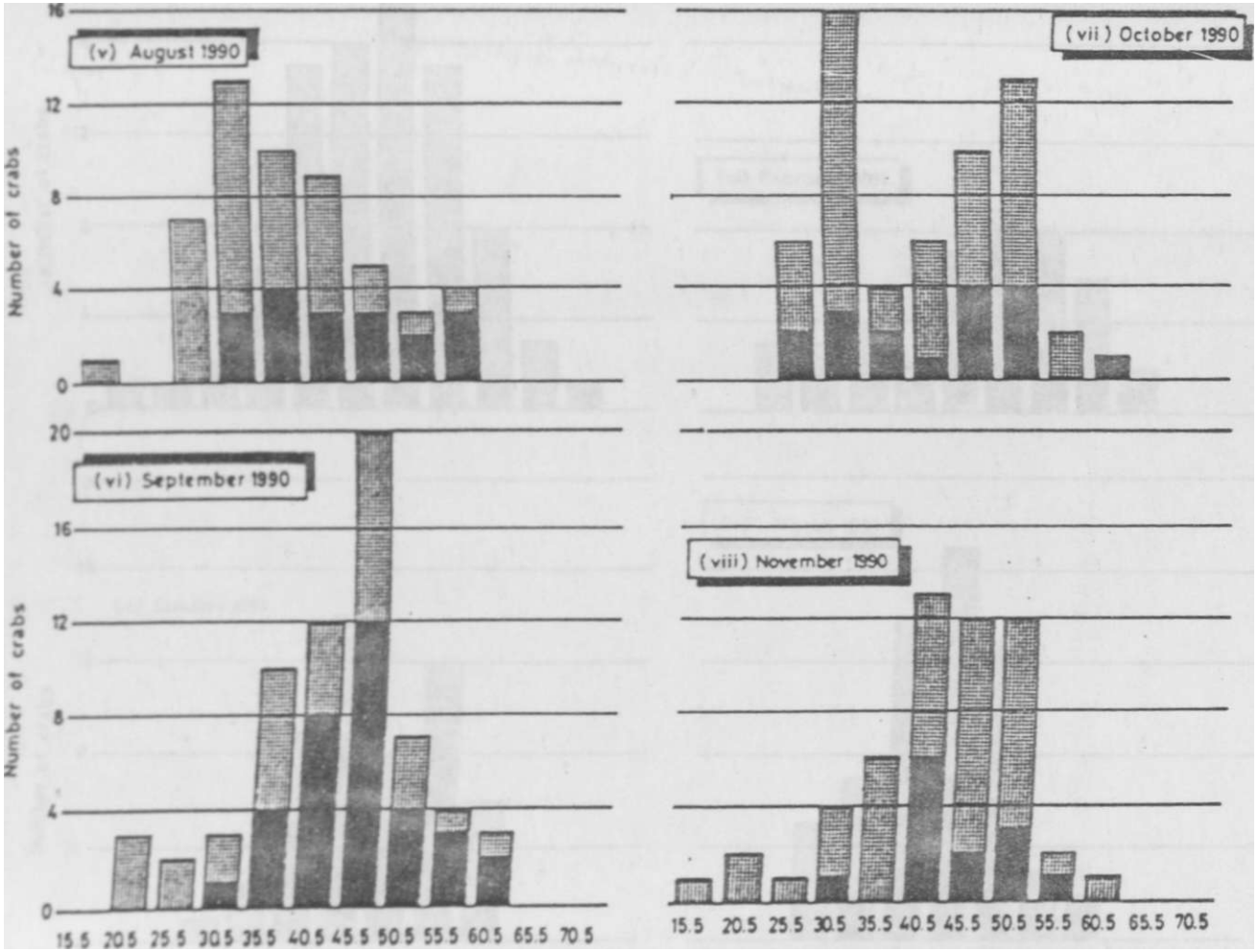


Fig 14. T. crenata. Size frequency distribution of ovigerous and non-ovlgerous female crabs. (Dotted-non ovigerous, black - ovigerous crabs).



Ct'tptct width ***(mm)***

Fig. 14. T. crenata. Size frequency distribution of ovigerous and non-ovigerous female crabs. (Dotted-non ovigerous, black - ovigerous crabs).

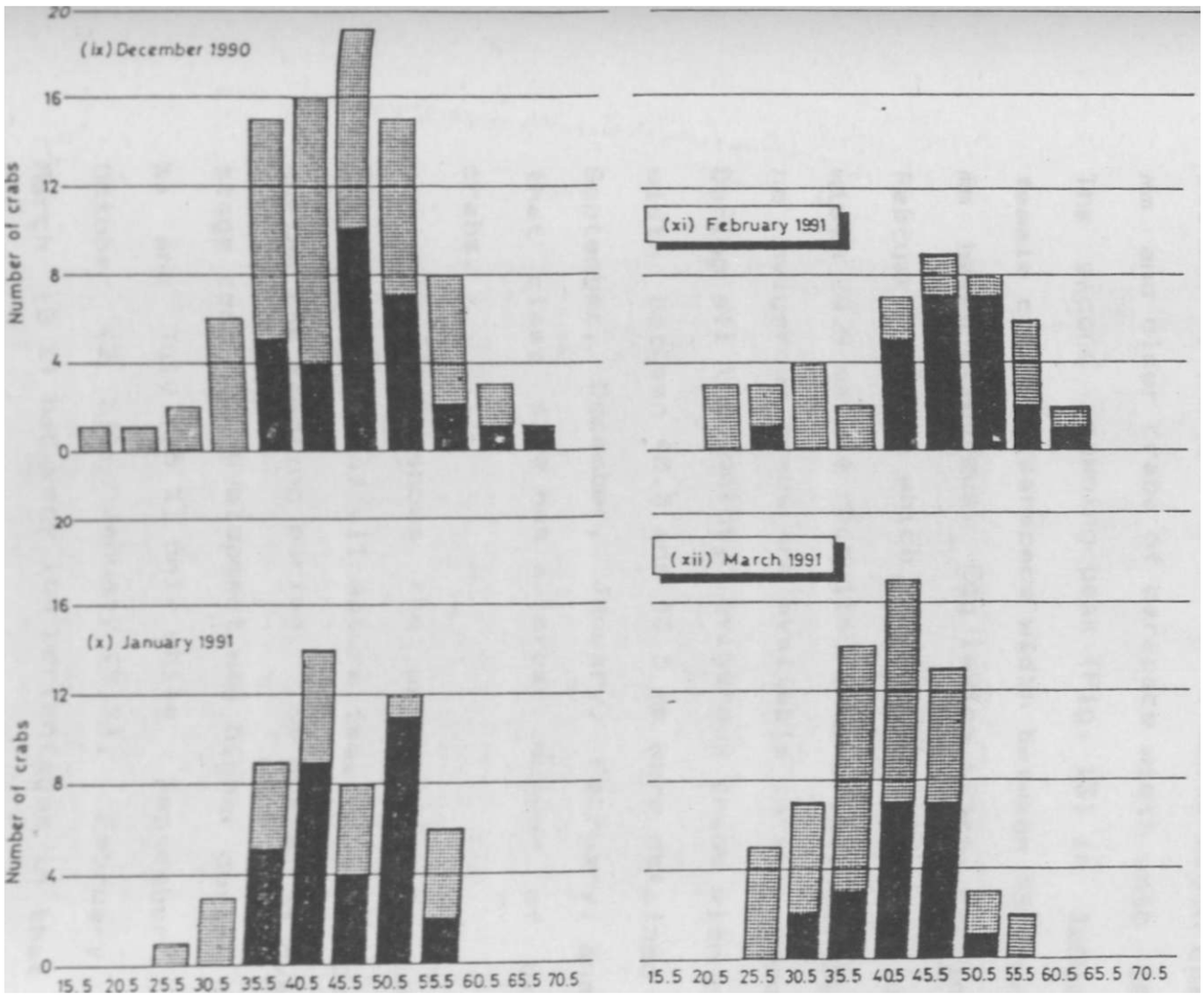
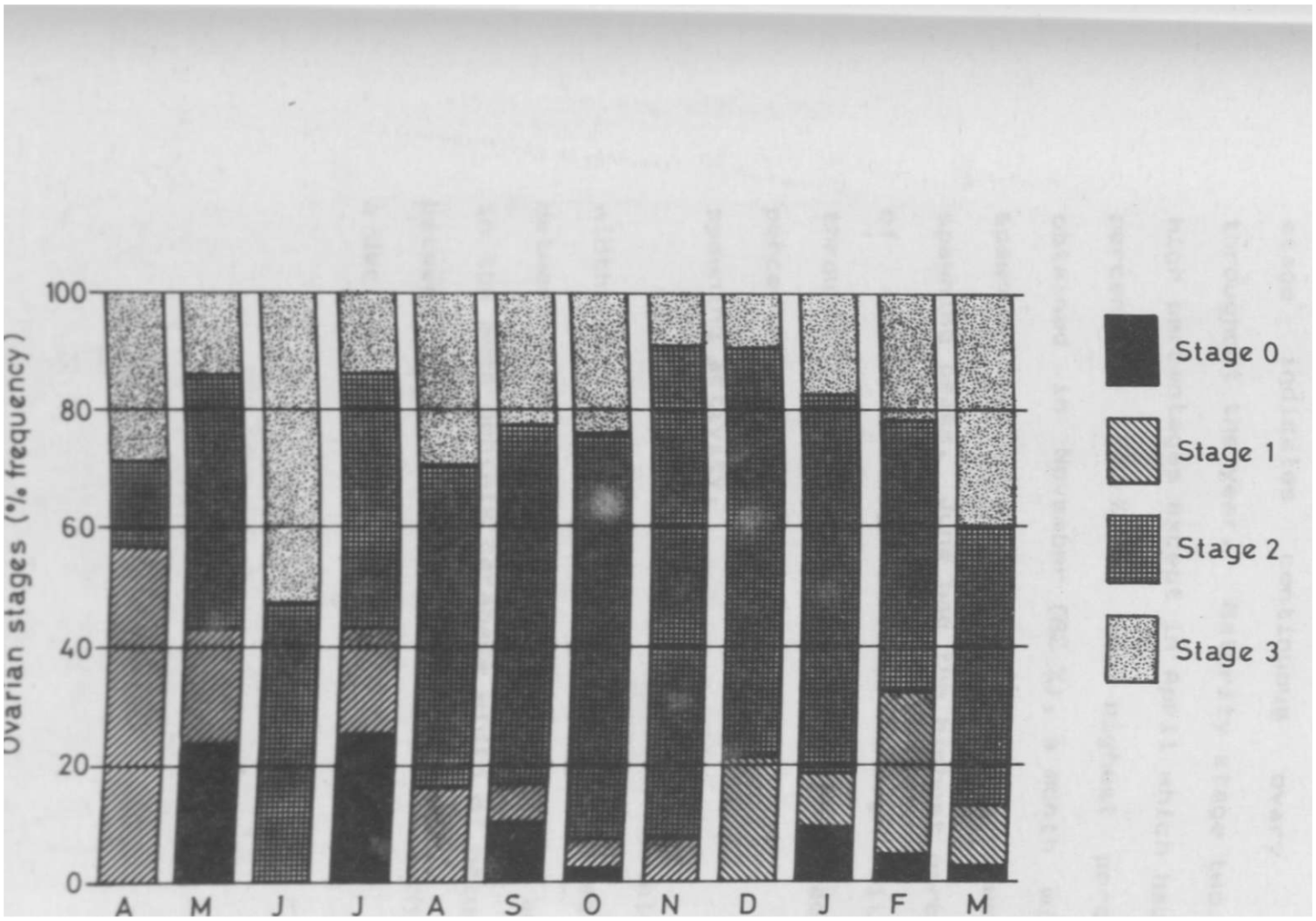


Fig. 14. T. crenata. Size frequency distribution of ovigerous and non-ovigerous female crabs. (Dotted-non ovigerous, black - ovigerous crabs).

evident that female crabs of carapace width 40.5 mm initiate the egg laying cycle in May. During the first spawning peak (Fig. 13) in September, they are joined by younger crabs of carapace width upto 30.5 mm and older crabs of carapace width upto 60.5 mm. The second spawning peak (Fig. 13) in January has female crabs of carapace width between 35.5 and 55.5 mm being ovigerous. Egg laying starts declining in February during which a few young crabs of carapace width 28.9 mm are recruited into breeding. By April, no ovigerous crabs are available in the population. During all the months, ovigerous crabs with carapace width between 40.5 and 45.5 mm were obtained and in September, December, January, February, and March that class size has a larger number of ovigerous crabs.

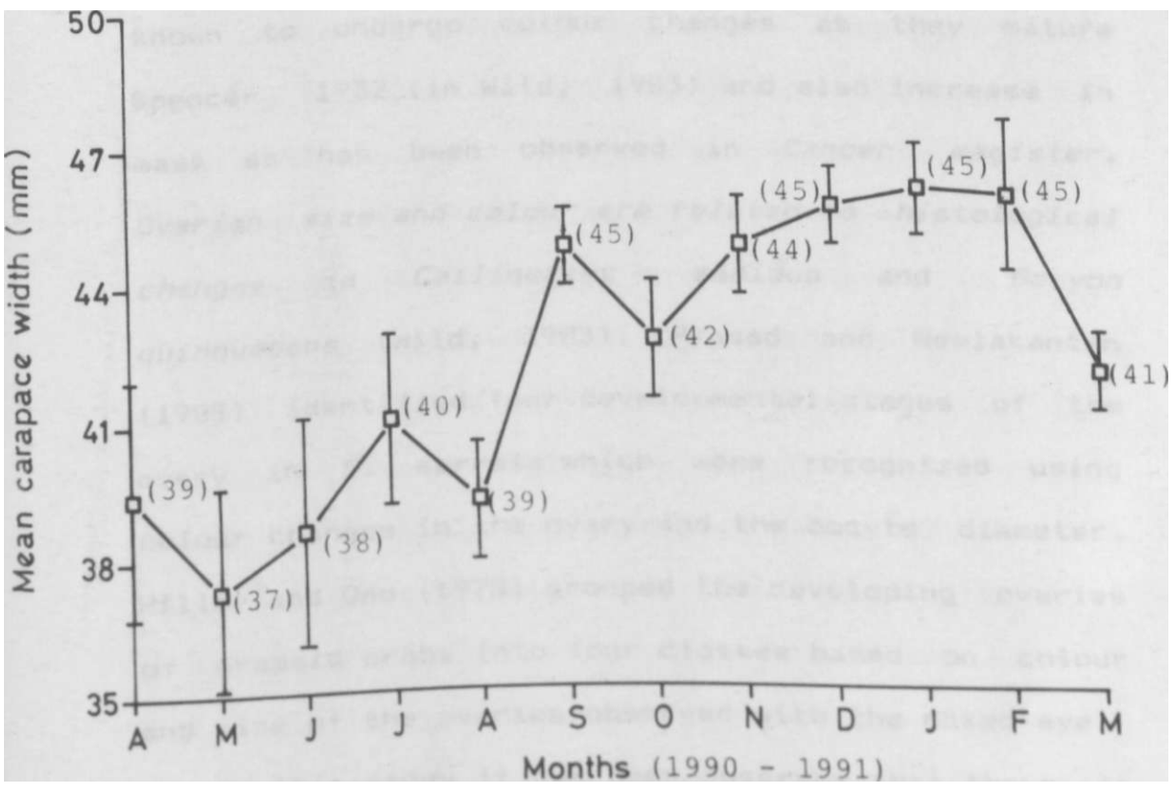
Fig. 15. shows the percentage frequency of maturity stages of all mature female crabs collected during the sampling period. The number of ovaries in stage zero of development was higher during May (24 •/.) and July <25 X) only while September (10 X), October (2 X), January (9 X), February (3 X), March (2 X) had very low percentages in that stage. Maturity stage one and above occurred throughout the year indicating that some mature females were actively breeding throughout the year. April had the highest maturity etage one percentage (57 X), a month with the no spawning activity. February had 27



ig. 15. T. crenata Percentage frequency of ovarian matui ity stages of all fenale crabs obtained during the sampling period.

, and December had 21 "/.. Thi<= stage had the lowest percentage in October (4 *,. The occurrence of this stage indicates continuous ovarv development throughout the year. Maturity stage two occurred in high percentages except in April which had the lowest percentage (14 X). The highest percentage was obtained in November (82 '/.), a month wxtn reduced spawning activity because it occurs between the two spawning peaks. June had the highest percentage (52) of maturity stage three, though it occurred throughout the study period. November had the least percentage (9.8 7.) and it is a period of reduced spawning activity.

Fig. 16. shows that the mean monthly carapace width of all mature female crabs obtainnn was iow between April and August but therp u.^ an increase in the mean monthly carapace width of mature females between September and February, twr which there was a decline.



Fia 16 T*i* crenata. **Variation** in the mean **monthly** carapace width of mature female crabs. Numbers in pooled **monthly sample** means **are given. (Bars indicate Standard** errors of the means).

CHAPTER FOUR

DISCUSSION

4.1 OVARIAN MATURITY STAGES.

The crab ovary is a bilobed structure with two antero-lateral lobes which fuse posteriorly. Paired reproductive oviducts connect the ovary to a pair of external genital openings on the crab's sixth thoracic sternite (Wild, 1983). Crab ovaries are known to undergo colour changes as they mature Spencer 1932 (in Wild, 1983) and also increase in mass as has been observed in *Cancer magister. Ovarian size and colour are related to histological changes in Callinectes sapidus* and *Geryon quinquedens* (Wild, 1983). Prasad and Neelakantan (1989) identified four developmental stages of the ovary in S. serrata which were recognized using colour changes in the ovary and the oocyte diameter. Pi 1 lay and Ono (1978) grouped the developing ovaries of grapsid crabs into four classes based on colour and size of the ovaries observed with the naked eye.

In this study it has been observed that there is an increase in mass and colour changes in the ovaries of the two crab species S. .errata and *T. crmnsts,* similar to that observed by Pi Hay and Ono, 1970. All the ovarian maturity .tag.. ob..rv.d in both crabs.

4.1.1 Maturity stages of *Scylla serrata* ovaries.

In mature female *S. serrata* the developing ovary increases in mass and undergoes colour changes from creamy white to yellow to dark brown before the crab spawns, at which time the ovaries occupy a major portion of the crab's interior as was observed by Pi 11 ay and Ono (1978).

In the present study, Fig. 5. maturity stage zero was rare, being obtained only once during the sampling period in a female crab whose carapace width was 90.85 mm. This could have been due to the fact that some crabs mature at larger sizes since a crab of carapace width of 77.1 mm had its ovary in stage one of development and this was a smaller adult crab (70-120 mm carapace width). Juvenile crabs in this study had carapace width less than 70 mm while adult crabs had carapace width greater than 120 mm. An alternative reason could have been that smaller adult and adult crabs obtained could have had stored sperms for fertilization which promoted ovary development immediately after spawning therefore making maturity stage zero very rare. Maturity stage one had a low freguency throughout the sampling period and was absent in the samples obtained in April, May, junc(and October. Maturity stage two was the most abundant in each month throughout the s.mpl1ng period (Fig. ID- Augu.t and November which indicate the

,_____ __Lm had 97 X. «nrt V _

October, when no ovigerous crab was obtained represents a period of reduced spawning activity (Fig. 10) had all the female crab in "«turlty stage two of development (100 X). This which confirms the abilitv of *S. serrata* to reproduce throughout the year because must be longer and is the period of active feeding accumulation of the fatty bodv TH,^ ^ Tatty body is similar to nutrient reserves reported by Nanah ' ^agabushnam and Farooqui, 1980 (in Prasad and Neelakantan 1989). The fatty body was associated with this s and stage three only throughout the sampling Maturity stage three was also rare in the sample obtained, occurring in March. May, June, and September in low numbers, and whenever this stage occurred the crabs had a large accumulation of the orange-red fatty substance over the brownie "rownish coloured ovary. Rarity of stage three could ^ due to two reasons or a combination of both « -) short duration, b) because more crabs in this and have Migrated to spawning areas. Therefore very ^ stage were obtained. Table 4r shows the estimates of female *S. serrata* with P^iovarian fatty body found over the ovary in different months. There were four different sizes and colour fatty body, easily recognized in <; ' during the study period because of the the er

active feeding prior to spawning. Since crabs with accumulation of the fatty body occur throughout the year and is associated with maturity stage two, therefore, *S. serrata* breeds throughout the year and it can also be seen that the crabs with this fatty body decreased to very low percentages towards the end of the year. This, therefore, confirms the peak of spawning in the second half of the year because the breeding crabs had moved out of the feeding areas. The highest percentages coincide with months with stage three ovaries (Fig. H). Table 4A. shows four different sizes of the fatty body which seems to be related to the ovary maturation (Plate 5B). The ovaries in stages three of development had a large guantity of bright orange-red fatty body. The crabs could not go into spawning before accumulating large guantity of f_{at} which provide energy during the spawning period when the ovigerous females migrate out of the feeding area into the sea. Studies on maturity stages of crab ovaries show that crab ovaries begin re-developing soon after spawning while crabs are .till brooding their embryos. This is important because these crabs produce planktotrophic larvae with greater mortality (Wild, 1983). As far as I know, there i% no Qth#r work which relates maturity stages of crab ovaries to the breeding cycle.

4.1.2 Maturity stages of *T. crenata* ovaries.

Sethuramalingam et al. (1982) identified three stages of ovary development in *Portunus sinipes* (Miers). These were: a) non-maturing ovary was microscopic, threadlike and whitish in colour, b) Maturing ovary was pale yellow and c) Matured ovary was red-orange. These were observed with the naked eye. They also identified three stages in T. *chaptali*, which were: a) Non-maturing ovary was microscopic and white in colour, b) Maturing ovary was yellow but half size of hepatopancreas and c) Matured was ovary red-orange and equal to hepatopancreas. During the present study, the maturity stages of the ovary were based on colour changes which ranged from creamy white to yellow to brown as was seen in *S. serrata.* It was also observed that the ovary increased in size. The dark grey mass over the ovary in stage two and three of development was identified as the fatty body accumulation. Because of this crabs small size, it was difficult to group the fatty body into sizes and colours. From Fig. 6 maturity stage zero was absent in April, June, November, and December. in th. other months this stage occurred in low numbers less than 20. This could have been due to the fact that they »tore sperms for *fmr*tilii.tion which promoted ovary development immediately after

A Crhirtratl and

Prasad and Neelakantan, 1989). Maturity stage one also occurred in low numbers less than 20, but was only absent in June only. Maturity stage two was the most abundant in each month being highest in December. Maturity stage three occurred throughout the sampling period but in low numbers also less than 20. The presence of maturity stage two and three confirms that this crab is a continuous breeder in the estuary where it is found in abundance. There were some ovigerous crabs with stage zero ovary development which had carapace width above 35 mm. This could have been because they had no sperms in store to stimulate ovary development immediately after spawning. This observation concurred with observations of Prasad and Neelakantan (1989) that even larger crabs had to be impregnated more than once for development of the ovary. in thiB crafa species juveniles have carapace width less than 20 mm, Smaller-adults between 20-35 mm and adults above 35 mm. As far as I know there is no other work which relates maturity stages of crab ovaries to the breeding cycle.

4.2 DEVELOPMENTAL PHASES OF CRAB EMBRYOS.

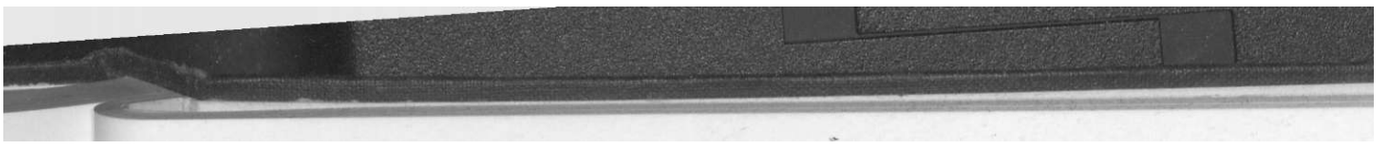
Early development in benthic marine invertebrates may vary along . spectru* from planktotrophy to 1ecithotrophy. Whatever the n.f».m_ it i» thought to reores^n*__

energetically efficient strategy in producing the largest number of individuals surviving to produce eggs (Vance 1973). Abiotic factors e.g. low availability of food, temperatures are closely correlated to 1ecithotrophy. Low temperatures are closely correlated to 1ecithotrophy in benthic, polar and abyssal communities. Thorson (1950) pointed out that at lower latitudes where predictable but short periods of rainfall occur, 1ecithotrophic development may occur in organisms with reproductive periods restricted to these seasons. Boolootian et a! (1959) reported that eggs of crabs undergo marked colour changes during the course of development and since all eggs of a given individual have been fertilized at approximately the same time and are in synchronous division, a few eggs were observed from which the ten stages were found to be distinguishable. In the Dungeness crab *Cancer magister,* the newly spawned egg-mass is usually orange in colour (Wild 1983). In S. serrata the newly spawned eggs are completely yellow and compact but as development proceeds with the formation of chromatophores and the eyes, the embryo-mass changes to the colour to greyish-yellow, brown, brownish black and finally completely dark (Marichamy and

embryo-mass changed colour similar to that of *S. serrata* observed by Marichamy and Rajapackiam (1984). The present study also confirms that the eggs of both crab species are p1anktotrophic because they lack large quantities of yolk characteristic of lecithotrophic eggs therefore, are very small in size (0.344 + 0.0168 mm SE of means and 0.338 + 0.0187 mm SE of means) in *S. serrata* and *T. crenata* respectively.

4.2.1. Developmental phases of *Scylla serrata* **embryos.**

All ovigerous crabs obtained during the **sampling period had their eggs in early phases** of **development. It is therefore possible** that **they** were **caught on feeding grounds in the estuary** at low tide. **In Hawaii, the ovigerous females appeared** to migrate **from brackish water to marine conditions** at or prior **to spawning (Brick, 1974). This migration would result in the larvae being released in the sea.** Hill **(1974) reported that the first zoeal stages** of **S.** *serrata* **is unsuited to estuarine conditions, being killed by salinities below 20 parts per** thousand. **The few ovigerous crabs obtained confirm this** seaward **migration because the sampling site at Ramisi River is an estuary. Manch*my and Rajap*ckiam (1984) observed that the development of spawned S.** »»rr***ta** **eggs take 28-30 days to attain the (1r«t cr*b instar.**



4.2.2 Developmental phases of *Thalamita crenata* embryos.

This species is a permanent resident in an estuarine habitat. During the present study, all the ten developmental phases of embryos were observed, therefore, the population studied does not carry out any migrations out of its habitat. Since there is no literature on the culture of the larvae of this crab species, it is not known how long the incubation period takes to attain the first crab instar. Boolootian et al. (1959) observed that some lower intertidal crabs re-berry themselves a few days after the escape of the larvae, it is also not known how long *T. crenata* takes to re-berry after spawning. The spawning peaks observed show the time when majority of the female crabs sampled were ovigerous.

4.3 SIZE AT FIRST MATURITY.

Female crabs become maturity only after they have reached a given size. By collecting large numbers of measuring their carapace width, this could be ascertained. The size at which crabs reach its sexual maturity is important for conservation of a minimum legal size that may be needed to secure a spawning part of the population (El-zarka

breeding female is expected to vary from speci species.

4.3.1 Size at first maturity in *S. serrai*fra.

Hill (1975) reported that the size at which Kleinomond crabs extruded their eggs ranged from 137 mm to 161 mm with a mean of 148 mm. These are larger than values reported from other areas. Escritor (1972) reported 85 mm, 88 mm and 111 mm in Philippines while Varikul et aK (1972) measured 12 ovigerous females ranging from 94 mm to 127 mm with a mean of 106 mm in Thailand.

From the present study, the smallest ovigerous female obtained had a carapace width of 139.75 mm (Table 6) which is as large as the results obtained by Hill (1975). Therefore these results coincide with the findings of Hill who observed that S *serrata* in Southern African waters mature at an older size than elsewhere. Prasad and Neelakantan (1989) reported that *S. serrata* attains sexual maturity (with stage iv ovary) in 89-90 mm size range but the crabs were found to be sexually active only in size range of 120-180 mm. They also reported that small percentage of immature ovaries even in the crabs belonging to 120mm and above indicate that even larger crabs had to be impregnated more than one. fo-

4.3.2 Size at first maturity in *Thalamita crenata*

Sethuramalingam et aj_- (1982) reported that in *Thalamita chaptali,* the size at first maturity was at the size group of 8-8.4 mm but the 50 7. level in maturity was found to be 8.7 mm. During the present study, the smallest ovigerous crab had a carapace width of 28.9 mm. The size at first maturity of *T. crenata* at the Kenya coast was in the size range 40.5-45.5 mm carapace width when 50 ⁄. of the crabs sampled were ovigerous. Studies on the maturity stages of ovaries indicate that a crab with carapace width of 16.75 mm was in stage one of development. This also shows that these crabs start maturing at a much smaller carapace width than *Thalamita chaptali* found at Porto Novo (India).

4.4 FECUNDITY.

Fecundity studies are important for estimating the reproductive capacity of a species. Besides that, the early stages of organisms contribute a major proportion to the annual production. Bagenal and Erich (1978) reported that fecundity studies give data relating to population stability and year to year class fluctuations which may be a major factor determining variations in production from $_{yv}«_{r}$ $_{t}$o year. Hines (1982) observed that, female body size is the principal determinant in reproductive output in brachyuran crabs. Therefore the volume of the

body cavity limit the brood size in brachyuran crabs.

4.4.1 Fecundity of *S. serrata.*

Escritor (1972) observed that *S. serrata* like other brachyuran crabs have a high reproductive capacity. He obtained three ovigerous female crabs with carapace width ranging from 85-111 mm and the approximate number of eggs carried ranged from 457, 790 to 987,723. Varikul et aj_. (1972) reported that 12 ovigerous *S. serrata* of 93.7-127 mm carapace lengths and weights of 180-390 g, carried between 1,077,211 to 2,713,858 eggs, with an average of 106.3 mm carrying 1,838,774 eggs. A research carried out in Tuticorin Research Centre, India (Anonymous, 1983), realized 1.5 million zoeae from one ovigerous female of *S. serrata.* Marichamy and Rajapackiam (1984) hatched two million zoeae from one ovigerous female crab with a carapace of 140 mm at the same research station.

During this study period, the five ovigerous female crabs obtained had carapace width ranging from 139.79 mm to 162.6 mm with fecundities between 2,186,000-21,565,920 eggs and an average carapace width of 151.8 mm and average fecundity of 8,263,400 eggs. The live weight of these crabs ranged from 429.8 g to 886.8 g, therefore it seems that crabs along the Kenyan coast are much bigger than in other places in the Indian ocean and Indo-Pacific region.

This research confirms observation by Hines (1982), that the volume of the body cavity limits the brood size in brachyuran crabs.

In the present study regression lines were fitted for fecundity on carapace width, embryo-mass weight and embryo-size. The results for *S. serrata* shows significant relationships between fecundity and both carapace width and embryo-mass weight, while there was no statistically significant relationship shown between fecundity and embryo-size. As far as I know, there is no other work which relates fecundity to carapace width, embryo-mass weight and embryo-size in crabs.

Thorson (1950) working on reproduction and larval ecology of marine bottom invertebrates reported that many marine species produce millions of eggs per female, therefore there is wastage of eggs and larvae during development. Since *S.* serrata produces pelagic p1anktotrophic larvae, the larvae are subjected to planktonic predation and other planktonic mortality pressure sources. The size of the eggs of S. *serrata* are small hence allowing the high fecundities observed during the study period. Pillay and Ono (1978) reported that intertidal crabs like *Hemigrapuum penicullatum* have long pelagic larval life, therefore to counteract the high mortality, they have to produce maximum number of eggs. 5. serrata spawns out of the estuary,

therefore there is high mortality rate because of the long distance between the spawning area and the mangrove area where it is a resident. This work has therefore confirmed that high fecundities are associated with smaller egg sizes observed in S. *serrata.*

4.4.2 Fecundity of Thalamita crenata.

Sethuramalingam et aj_. (1982) worked on fecundities of *Thalamita chaptali* and reported that fecundities ranged from 16,422 eggs in a specimen of 8 mm carapace length to 22,694 eggs in a specimen of 28 mm carapace length. They observed that a specimen of the same carapace length showed considerable variation in the total number of eggs produced. In *T. crenata*, fecundity ranged from 13,650 eggs in a specimen of 28.9 mm carapace width to 207,710 eggs in a specimen of 60.4 mm carapace width. Variation in the total number of eggs produced by crabs of the same carapace width was also observed in this study. The highest egg-mass weight recorded was 5.6 g with a total of 170,000 eggs while the lowest weight was 0.11 g with 6,760 eggs.

Regression lines fitted for fecundity on carapace width and embryo-mass weight were highly significant while there was no statistically significant relationship between fecundity and

embryo-size. These crabs are intertidal and as Thorson (1950) pointed out, they have high fecundities because there is wastage of eggs and larvae during development because their larvae are subjected to planktonic and non-planktonic mortality sources e.g., unsuitable salinities, variation in water temperatures and unsuitable habitats.

As far as I know, there is no other work which relates fecundity to carapace width, embryo-mass weight and embryo-size in crabs which I can refer to.

4.5 SEX RATIO.

Wenner (1972) explained that differences in size frequency ratios between sexes can be the result of the following factors:

i) Differential migration in such a way that either males or females of a particular size leave or move into the sampling area at a particular time.

ii) Differential mortality, e.g., where one of the sexes at a particular size are heavily preyed upon while individuals of the other sex escape.

iii) Differential growth rate in such a way that males at a particular age grow more rapidly than the females of the same age, with the result that thee may be fewer males of a particular *%izm.*

The size frequency distribution of a population i. a dynamic characteristic that change, throughout the year as a result of reproduction and rapid

recruitment "from larvae. In several species of *Uca*, unimodal population size structures have been observed (Thurman II, 1985). He also reported that unimodal distributions are observed in populations which reproduce continuously while bimodal distributions are observed where a species reproduces in particular seasons.

4.5.1 Sex ratio in *Scylla serrata*.

Jameson et al_- (1982) reported that the overall sex ratio of males to females in Tuticorin bay (India), was 1.5:1, with males dominating the catch for five months during the sampling period. Prasad and Neelakantan (1989) reported that from the back waters and inshore waters of Kawar, there was a near equal proportion of males and females in both biotopes although the sex ratio varied considerably with season and size of the female population. From the present work (Table 7), it is observed that the overall ratio of this crab species was close to 1:1 as shown by the chi-sguare results (X^2 - 0.776$ $_d$ ^ • 1, P > 0•25). Thus there is no evidence of significant departure from an egual sex ratio. A preliminary test of homogeneity of variance of binomial distribution had shown that there was no significan,t heterogeneity in the proportions of males to females throughout the year (X' » 14.613, d.f. - 13, P >

4.5.2 Sex ratio in relation size (carapace width) in *S.* serrata.

The males dominated the catch in smaller sizes i.e., between carapace width 80.5-110.44 mm with a mode of 101 in class size 100.5-110.44 mm. The females dominated the catch in the larger sizes ranging from carapace width 130.5-170.44 mm with a mode of 75 in class size 110.5-120.44 mm(Table S). The variance test for homogeneity of the binomial distribution in relation to size show that there is a very significant difference in the proportions of males to females ($\chi^2 = 32.83$; d.f. = 9; $P << 0.05$). Similarly, there was a very significant difference between the sexes when the overall mean sizes for males and females were compared using the t-test ($t = 4.26$; d.f. = 18; $P > 0.001$). a possible explanation for these observations is that the females dominate the larger sizes because they carry out differential migration to spawning grounds out of the feeding area with a possible resulting greater male fishing mortality in larger size classes. Observations on the percentage of the total column show that it has unimodal size frequency distribution (Table 8). This is typical of continuous breeders. In Kawar, analysis of the sex ratio of crabs from backwaters and inshore waters showed that there was an near equal proportions of males and females, the sex ratio varied with season and size of the female

population (Prasad, 1987). i$_n$ this study, the difference in sex ratio in relation to size frequency distribution was observed.

4.5.3 Sex ratio in *Thalarnita crenata.*

Sethuramalingam et aj_ (1982) reported that in *Thalarnita chaptali* the monthly sex ratio showed that males and females alternately dominated the population during the sampling period. In the data pooled for the whole year, the males were found to be slightly more than the females and the chi-square value deviated significantly from the expected 1:1 ratio in the first year of sampling although data pooled for both years conformed exactly to the expected 1:1 ratio.

In the present research, a preliminary test for the homogeneity of variance of the binomial distribution showed that there was no significant variation in the monthly binomial distribution as shown by the chi-square test ($_x^2$ - 16.83} d.f. - ii; P > 0.05). The overall sex ratio for *T. crenata* deviated very significantly from the expected 1:1 ratio (Table 10) being 1:1.32 males to females (X^2 - 19.577» d.f. « 1| P < 0.001).

4.5.4 Sex ratio in relation to si*, (carapace width) in *T. crenata.*

The size frequency distribution of both males

typical of continuous breeders (Thurman II, 1985). The size frequency ratios of males and females show that females dominated the catch from carapace width 15.5-60.44 mm but their numbers decreased in the larger carapace width which were dominated by the males (Table 10). The variance test for the homogeneity of the binomial distribution showed that there was a very significant variation in the classes as shown by the chi-square test (X^2 = 112.2; d.f. = 12; P < 0.001). But when the overall mean sizes for males and females were compared using t-test, there was a very significant difference between the sexes (t = 3.163; d.f. = 24; P > 0.001). This significant evidence of heterogeneity shown by the chi-square could have been due to differential mortality whereby the females in larger size classes are heavily preyed upon while males escape.

4.6 BREEDING CYCLES.

Giese (1959) stated that the life cycle of an animal is so timed by some environmental factors that the young are produced at a period favourable for their survival. Boolootian et aj_. (1959) reported that the ultimate aim of researches on reproductive cycles is to correlate these cycles with the causative environmental factors such as temperature, light, tidal variation and food availability. While working on five west coast crabs (California,

U.S.A.), they observed that there are both continuous and synchronized seasonal breeders. They concluded that synchronised breeding in semi-terrestrial crabs and continuous breeding in lower intertida1 and swimming crabs may be related to seasonal changes in temperature, day length and availability of food resources which are more sharply defined on land than in the aquatic environment.

4.6.1 Breeding cycle of *Scylla serrata*.

Jameson et aU (1982) reported that along Tuticorin coast (India), crabs of different sizes ranging from 0.6-13.1 cm were present throughout the year indicating that S. serrata is a continuous breeder. In the present study, crabs of different sizes ranging from 90.1-142.B mm were present throughout the the year indicating that *S. serrata* is a continuous breeder at the Kenya coast.

In the present study, ovigerous female crabs were obtained in the second half of the year (Fiy 10). *S. serrata* being a continuous breeder, this is an indication of the spawning peak. Ovigerous crabs were obtained in low numbers in the months of August, September, November and December when they were caught, but these were the months with large samples. The low number of ovigerous female crabs could have been a result of spatial distribution e.g., ovigerous crabs could have been in deeper

water while sampling was carried out at the top edge of their distribution. Therefore the absence of ovigerous females in most months could have been a result of sampling error.

Prasad and Neelakantan (1989) reported that S. *serrata* possesses all maturity stages throughout the year but with a considerable seasonal variation in intensity in the monthly observations of the gonadal development. They observed that the mean gonadosomatic index values exhibited two peaks, one between December and March and the other between September and November. Hence these were taken to be the actual breeding seasons. Observations on percentage frequency of ovarian maturity stages of mature non-ovigerous female crabs (Fig. H) indicates that *S. serrata* is a continuous breeder with over 50 7. of the sampled crabs having ovaries in stage two of development. This concurs with Boolootian et aj,. (1959) finding that swimming crabs are continuous breeders. The annual temperature range of the south coast of Kenya was 26.1 ± 2.2 °C with the highest temperatures in February and March and the lowest temperatures in July. This temperature range is small and need not affect the breeding cycle of these crabs seeing that the temperatures are high throughout the year. The sampling site (Shimonl) Fig. 17 has two rainy seasons, the long rains between April and July and

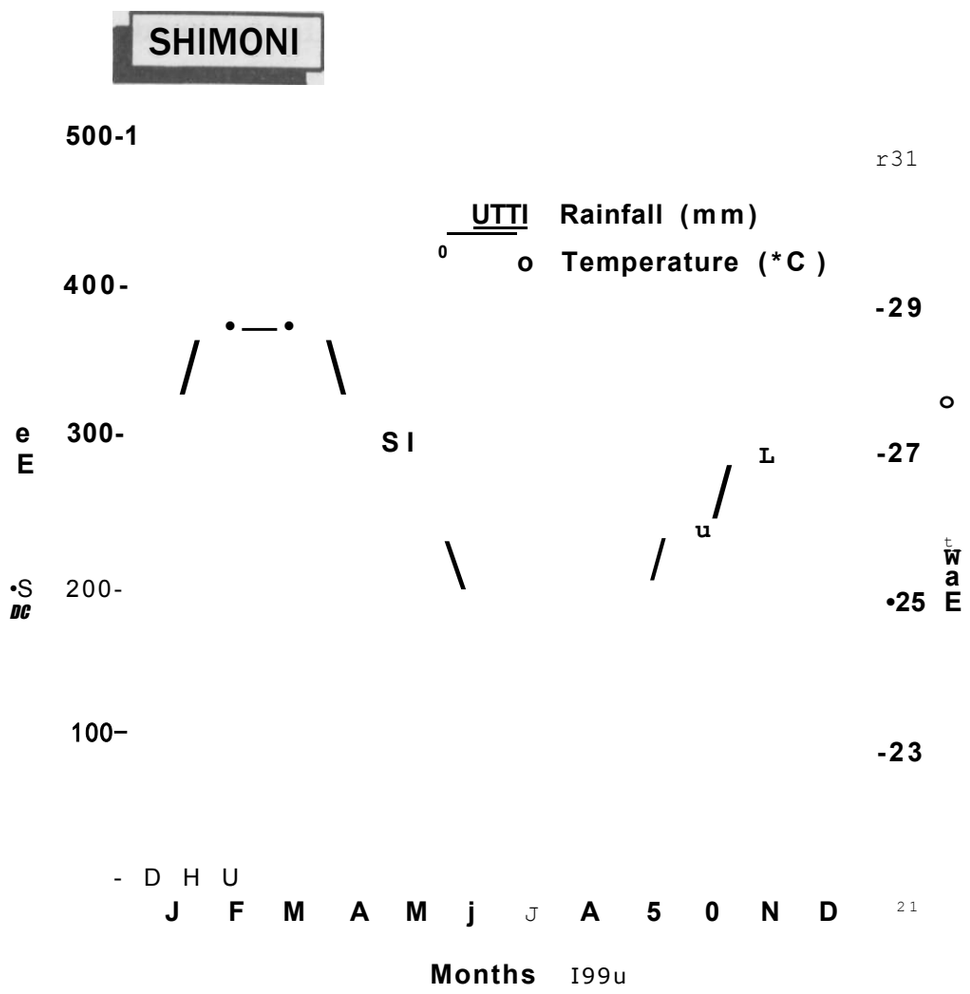


Fig.17. Annual variation in Rainfall and **Temoerar** ure distribution. (Kenya MeteoroJogill? Department, **1991).**

the short rains between October and December. The rainfall pattern does not affect the breeding cycle because in the tropics, there is availability of food resources which supports the zoeae throughout the year. This allows the continuous breeding pattern observed in this crab. The few ovigerous crabs obtained had their ovaries in stage two of development already undergoing maturation for the next spawning immediately after the release of the zoeae.

From the mean monthly carapace width of *S. serrata* (Fig. 12) it is observed that larger adult female crabs were caught in large numbers between January and July after which the smaller adult females were abundant in the catch. This shows that the breeding population is mainly composed of larger adult female crabs (> 120 mm carapace width) between January and July after which the breeding population becomes composed of smaller female adults (70-120 mm carapace width). The larger adult crabs either die or migrate subtidally hence their low catch in the last half of the year.

The few ovigerous crabs obtained is (n-S) an indication of migration out of the estuary and into the open sea where they are out of reach to spawn because their zoeae cannot survive the unfavourable conditions of fluctuating salinities and

with ovaries in maturity stage three because it must be very short duration after which spawning occurs, therefore the crabs undertake migratory movement to the sea.

4.6.2 Breeding cycle of *Thalamita crenata.*

Sethurama1ingam et aK (1982) reported that *T. chaptali* breeds from February to September when the ovigerous female crabs were obtained. The present study shows that *T. crenata* is a continuous breeder (Fig. 13) because ovigerous crabs were obtained throughout the year except in April. However September and January were peak months for spawning. These peaks are not apparently related to temperature (Fig. 18) because the sampling site had high temperatures throughout the year with an annual range of 26.1 ± 2.2°C . However these peaks fall outside the long or short rains. This may be significant in that fluctuation in salinity are minimized during the dry periods (Hill, 1974). The observations made by Boolootian et al_. (1959) that the lower inter-tidal crabs re-berry immediately after the escape of larvae, is confirmed in the present study for 7". *crrnats* because observations made on ovaries of some ovigerous crabs show that the crabs had their ovaries in maturity stage three ready f_{or} spawning after the escape of zoeae.

Fro* Fig. 14, it can be observed that

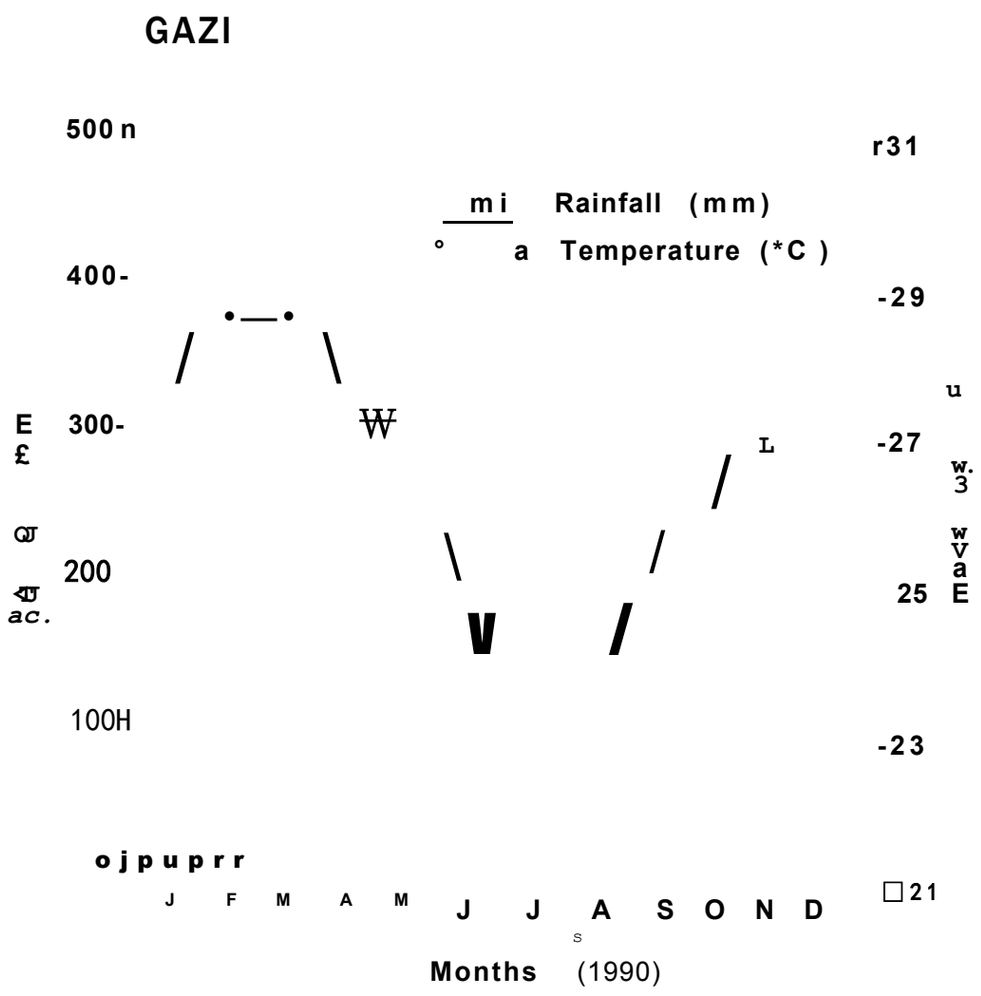


Fig. 18 Annual Variation in Rainfall » . t distribution. (Kenya Meui Jo;^ Department, 1991).

female crabs with a carapace width of 40.5 to 45.5 mm form the bulk of the breeding population. This therefore is the most reproductively active size. This is the size range of size at first maturity.

Fig. 15, shows that activated ovaries (stage one to three) were obtained throughout the sampling period, indicating that they are continuous breeders. This result concurs with the findings of Boolootian et al. (1959) that intertidal crabs are continuous breeders. The percentages on Table 10 shows a unimodal size frequency distribution which is characteristic of continuous breeders.

From the data on mean monthly carapace width of *T. crenata* (Fig. 16), it can be observed that the breeding population was composed of younger female crabs and were later joined by older female crabs. The older crabs start breeding between September and February after which they either migrate out of the intertidal area or die, therefore a decline from March during the breeding season.

5.0 SUMMARY

5.1 Ovarian maturity stages.

The ovaries of these brachyuran crabs were found to undergo observable colour changes and also increase in mass during development.

5.1.1 *S. serrata.*

a) In *S. serrata,* maturity stage zero was rare during the sampling period either because juvenile crabs stay in burrows and are out of reach during sampling (< 70 mm carapace width) or because smaller adult and large adult crabs (70-120 mm, > 120 mm carapace width) store sperms which promote ovary development immediately after spawning. Therefore it was never observed in older crabs.

b) In *S. serrata,* maturity stage two was associated with four different sizes and colours of a fatty body in some crabs. This was the most abundant maturity stage in the samples and could also have been a longer period when active feeding takes place.

c) Maturity stage three was also rare in S. *serrata* because it must have been a very short duration after which spawning takes place or crabs in this stage migrate to spawning areas or both.

5.1.2 T. *crenata.*

a) In *T. crmnata* maturity stage zero was observed in most months because there were many immature crabs and those which had not copulated after spawning. This ia because the crabs are permanent residents within the estuary.

b) In some *T. crenata* maturity stage two and three had an accumulation of a grey substance which might have been the fatty body, but could not be identified because the crab was too small in size.

c) The presence of maturity stage two and three throughout the sampling period confirms that both crab species are continuous breeders.

5.2 Developmental phases of crab embryos.

The embryos of these brachyuran crabs undergo marked colour changes during the course of development.

a) The embryos of *S. serrata* and *T. crenata* are 0.344 + 0.0168 mm SE of means and 0.338 + 0.00187 mm SE of means in diameter respectively, being an indication that both crab species produce planktotrophic larvae.

b) *T. crenata* does not undertake spawning migrations but remains in the intertidal region of the estuary where it spawns. This is confirmed by the presence of all developmental phases in the samples obtained.

c) S. *serrata* undertakes spawning migrations out of the sampling area, This is indicated by the very few ovigerous crabs which were obtained during the whole sampling period.

5.3 Size at first maturity.

a) The size at first maturity in *S. serrata* was an ovigerous female crab with carapace width 139.75 mm obtained during the study period. This could not have been the size at first maturity.

b) From studies on crab ovaries, the smallest female *S. serrata* with an ovary in stage one of development had a carapace width of 77.1 mm.

c) In *T. crenata*, the smallest ovigerous crab had a carapace width of 28.9 mm. The size at first sexual maturity was in the range of 40.5-45.5 mm carapace width.

5.4 Fecundity of the crabs.

Both swimming brachyuran crabs studied have high fecundities.

a) Both brachyuran crabs produce pianktotrophic 1arvae.

b) In both brachyuran crabs, there was a highly significant relationship between fecundity and carapace width and also between fecundity and embryo-mass weight.

b) In both brachyuran crabs, there was no significant relationship between fecundity and embryo-size (t • 0.029; d.f. • 3| p > 0.1) . 1.04| d.f. - 205, P > 0.03) in S. serrate «nd *T. crwnata* respectively.

5.5 The sex ratio of the crabs.

a) The variance test of homogeneity of the binomial distribution of the sex ratio showed that there was no significant difference in the monthly samples (X^2 = 14.615; d.f. = 13; P > 0.05) < X^2 = 16.83; d.f. = 11; P > 0.05) in *S. serrata* and *T. crenata* respectively.

b) The overall sex ratio was not far from 1:1 (X^2 = 0.776; d.f. = 1; P > 0.25) in *S. serrata* but was very significantly different in *T. crenata* (X^2 = 19.577; d.f. = 1; P > 0.05).

c) The variance test of homogeneity of the binomial distribution showed a very significant difference in the sex ratios of the different size classes (X^2 = 32.83; d.f. - 9; P < 0.05) (X^2 - 112.2; d.f. = 9; P < 0.05) in *S. serrata* and *T. crenata* respectively.

d) There was a significant difference between the sexes when the overall mean sizes for males and females were compared using the t-test (t • 4.26; d.f. = 18; P > 0.001) (t = 3.163; d.f. « 24; P > 0.001) in *S. serrata* and *T. crenata* respectively.

e) Both males and females of both crab species show a unimoda1 size frequency distribution.

5.6 Breeding cycle in the crabs.

a) Both brachyuran crab species are continuous breeders as shown by their ovaries being active (stages one to three) throughout the samplina period.

b) In ***T. crenata*** the occurrence of ovigerous crabs in the monthly samples indicate that it is a continuous breeder.

c) In ***S. serrata*** the occurrence of ovigerous crabs in the monthly samples was low (n=5) presumably because the crabs undertook spawning migrations out of the sampling site.

d) The breeding of these brachyuran crabs was not influenced by temperature patterns of the sampling stations but ***T. crenata*** shows breeding peaks in the dry seasons when salinity fluctuations are minimal.

e) The most actively reproductive size in *T. crenata* ranges from 40.5-45.5 mm carapace width.

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