STUDIES ON PORTUNID CRABS
(CRUSTACEA DECAPODA BRACHYURA)

THESIS SUBMITTED TO THE UNIVERSITY OF COCHIN
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE
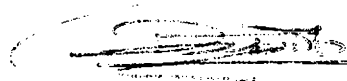DEGREE OF DOCTOR OF PHILOSOPHY

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CERTIFICATE

This is to certify that this thesis is an authentic record of research work carried out by Mrs. Mercy Thomas, M. Sc., under my supervision and guidance in the Department of Marine Sciences for the Ph. D degree of the University of Cochin and no part of it has previously formed the basis for the award of any other degree in any University

Cochin-682016

25th
January, 1984

DR. R. Damodaran
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DEDICATED

TO MY

HUSBAND

AND

PARENTS

ACKNOWLEDGEMENT

(ii)

C O N T E N T S

GENERAL INTRODUCTION

1.1   PREFACE

        True crabs are the most fascinating group of
organisms among the decapod crustaceans. Great importance
is attached at present to the increased exploitation of
these animals and therefore there is great scope for
further development of their fishery. They have a
broad and hard carapace, massive chelate legs, bent
abdomen and exhibit high degree of adaptation to the
environment. They show pelagic, benthic, intertidal,
burrowing and terrestrial modes of life. Their commensal
association with other invertebrates, their breeding
behaviour and life history are of great interest to
biologists. More than six hundred species of crabs are
known to occur in Indian waters and among them
about eight species form a regular fishery along the
entire stretch of peninsular India (Rao et al., 1973)
round the year. Crab fishery in India is fast developing
and there is vast scope for them as there are many more
potential species. Among the various crustacean diets,
crabs are celebrated for deliciousness and for nutritional
richness. In recent days, crab food items have become
more popular and gained global reception. These resources
can also be augmented further by culturing them in ponds
in the future. Information on biology and ecology of

constituent species go a long way not only in effective
exploitation and regulation of the respective fishery
resources but also helps in evolving a suitable gear
for their capture. Information collected on the
national level in various aspects as reproduction, growth
rate, larval development, parasites, diseases, nutritive
values etc. will be of help in evolving a national
policy for the effective utilisation and conservation
of this resource. They also provide the baseline infor-
mation for undertaking any purposeful and meaningful
culture activities. Information on the various aspects
mentioned above is very much restricted in true crabs
and hence the present study.

1.2   REVIEW OF LITERATURE

Investigations on members of the group brachyura
are available from all parts of the world from 18th Century
and most of the earlier works relate to taxonomic aspects.
The review of literature here is restricted only to
Indian works and even among these works, only pertinent
studies to the topic dealt within this thesis and fishery
are referred to.

The monumental and classical work of Alcock
(1895, '96, '98, '99, 1900) deals with the description
of species and is mainly taxonomical. The first work
on crab fisheries of India was that of Rai (1933) who

dealt with the shell fisheries of Bombay coast. Hora
(1935) outlined the bionomics of estuarine crabs and
crab fishing at lower Bengal. Chopra (1936,'39) listed
all the important crabs and described their food habits
and fishing methods. Chacko and Palani (1952) gave an
account of the crab fishery off Ennur near Madras.
The crab fishery of Chilka lake was discussed by Jones
and Sujansingani (1952). Menon (1952) studied the crab
fishery of Malabar coast. Another valuable study on
crab fishery was that of George and Nayak (1961) from
Mangalore coast. An annotated bibliography of the biology
and fishery of the edible crabs of India was compiled by
George and Rao (1967). It is of practical use to workers
in this field and the works included here mainly refer
to _Portunus pelagicus_, _P. sanguinolentus_, _Charybdis_ spp.,
Scylla serrata and _Paratelphusa_ spp. Thomas (1972) reported
about the crab fishery of Pulicat lake. Rao _et al._
(1973) while describing the crab fishery of Indian coast
discussed about the bionomics and marketing of commercially
important crabs. Srinivasagam and Natarajan (1976) added
one more species (_Podopthalmus vigil_) of crab in the list
of edible crabs of India. Dhawan _et al._ (1976) while
studying the ecology of the blue crab _Portunus pelagicus_
discussed about its potential fishery in Zuary estuary.

Ameerhamsa (1978b) also commented on the fishery of the
above species from Palk Bay and Gulf of Mannar. Shanmugam
and Bensam (1980) reported the fishery of _Scylla serrata_
from Tuticorin for the period 1974-'75, and Aravindakshan
(1980) on the unusual catch of portunid crab _Charybdis_
(_Charybdis_) _lucifera_ from Bombay.

Breeding:

Rai (1933) found out the breeding season in
some crabs of Bombay Presidency. Panikkar and Aiyar
(1939) investigated breeding in some brackish water crabs
of Madras. Menon (1952) while discussing the bionomics
and fishery of the swimming crab _Neptunus sanguinolentus_
from the Malabar coast reported about the breeding season.
Prasad and Tampi (1953) found out the breeding season of
the crab _Neptunus pelagicus_ in Mandapam coast. Chhapgar
(1956) commented that most of the crabs in Bombay waters
breed after the monsoon (southwest monsoon). Rahaman
(1967) and Krishnaswamy (1967) carried out studies on
the reproductive and nutritional cycles of the swimming
crab _Portunus pelagicus_ from the east coast of India.
Chandran (1968) correlated breeding periodicities of
Charybdis variegata with reproductive and nutritional
cycles. Pillay and Nair (1971, '73b) studied the reproduc-
tive cycle in some crabs from the southwest coast of

India. Srikrishnadhas and Ramamoorthi (1976) observed the reproductive behaviour and spawning in the crab *Philyra scabriuscula*. Dhawan *et al.* (1976) during their brief study, reported that *Portunus pelagicus* in Zuary estuary breed during February, March. Simon and Sivadas (1978, '79) observed the morphological and histological changes in the development of the ovary in eyestalk ablated estuarine crab *Scylla serrata*. Radhakrishnan (1979) conducted some studies on the breeding biology of *Portunus pelagicus* and *P. sanguinolentus* from Porto Novo coast. Farooqui (1980) studied the reproductive physiology of the marine crab *Scylla serrata*. Nagabhushanam and Farooqui (1981, '82b) conducted experiments on the photo-periodic stimulation of ovary and testis maturation in the immature crab *Scylla serrata* and found that ovarian enlargement took place in a long day (more photoperiod). Sethuramalingam *et al.* (1982) probed the breeding aspects of two other portunid crabs (*Portunus spinipes* and *Thalamita chaptali*) from Porto Novo coast. Joel and Sanjeevaraj (1982) traced the breeding biology in three edible portunid crabs (*Portunus pelagicus*, *Scylla serrata* and *S. tranquebarica*) of Pulicat lake. However, a comprehensive study covering different aspects of reproduction (size frequency, size at first maturity, sex ratio, fecundity, reproductive cycle etc.) has been lacking.

Age and growth and length-weight relationship:

Age and growth of numerous fin fishes have been studied employing both direct (using scale, otolith, vertebrae etc.) and indirect methods (statistical methods). But among crabs very few studies were carried out. Menon (1952) while studying the bionomics and fishery of the swimming crab *Neptunus sanguinolentus* commented about growth. Prasad (1954b) studied the relative growth of the crab *Neptunus pelagicus* in relation to different parts of the body. Regarding length-weight relationship except the work of Dhawan et al. (1976) on *Portunus pelagicus*, no other information is available. The above observation was also a short term one.

Larval development and experimental studies:

Study of larval stages of crustacea and its significance was outlined by Prasad (1967). Comparatively more information is available regarding the larval stages of different crabs. In keeping with the international trend here in India also initially larval stages of crabs were separated from the planktonic samples and described. Menon (1933, '37, '40) constructed the life history of crabs from materials separated from the plankton sample. Prasad (1954a) observed the distribution and fluctuations of crab larvae in plankton of Mandapam coast. George (1958) reported the occurrence of zoea larvae of crabs in

plankton of Cochin backwaters and their season of
occurrence. Patel and Mahyavanshi (1974) isolated the
larva of Callianassa tyrrhena from plankton collections and
it was a new record for the Gulf of Kutch. Vijayalakshmi
and Paulinose (1982) collected and described some crab
larvae from the nearshore waters of Karwar. Such materials
were disputed and the authenticity of those findings
questioned as there were chances of one species of larvae
being mistaken for the other (Costlow, 1963). So
scientists working on this line, collected berried
crabs and hatched the first stage larvae in the laboratory
and constructed the larval life history by separating
further stages from the plankton sample. Rajabai
(1950,'54,'55,'59,'60a,b,'62,'72,'74) studied the
early development in many species and post larval
development of few species of crabs. Prasad and Tampi
(1953,'57) hatched the first zoea of Neptunus pelagicus
and Thalamita crenata in the laboratory. Chhapgar (1956)
also reported the early larval stages of some crabs of
Bombay by hatching them in the laboratory. Sankolli
(1961) described the early larval stages of the leucosid
crabs Philyra corallicola and Arcania septemspinosa.
Noble (1974) observed the early larval stages of two
pinnotherid crabs. Krishnakumari and Rao (1974)

collected berried females of the pea crab Pinnotheres
vicaiii which infested the clam Paphia malabarica
and hatched the first zoea in the laboratory. With the
help of this laboratory hatched material, they isolated
further zoeal stages and megalopa from the plankton
sample. Srinivasagam and Natarajan (1976) described the
first zoea of Podopthalmus vigil by hatching it in the
laboratory. Prasad and Tampi (1953) tried to construct
the larval life history of Neptunus pelagicus by
hatching the first zoea in the laboratory from berried
females and separating further stages from plankton
sample. Here also there was every chance for mistaken
identity. So techniques for rearing the larvae from
hatching to post larvae in the laboratory were developed
(Costlow,1963; Provenzano, 1967; Williamson, 1967;
Sastry, 1973). This resulted in the publication of
numerous papers on the larval development from hatching to
post larval stages in different species of crabs
(Chhapgar, 1958; Sankolli and Shenoy, 1967,'75a,b;
Kakati, 1977; Kakati and Sankolli, 1975a,b,c; Kakati
and Nayak, 1977; Kannupandi et al., 1980). However in
India, studies pertaining to portunid crab larval life
histories (whole) are wanting.

Standardization of rearing techniques in the
laboratory, provided large number of larvae of known

identity, stage and age for a variety of experimental
purposes and many experimental studies as effect of
environmental parameters such as salinity, temperature
(in different combinations), diet, pollutants etc. were
conducted elsewhere (Bookhout and Costlow, 1974). But
in India no work in this direction has so far been done on
crabs and it is a virgin field.

Proximate composition:

Not much information is available regarding
this aspect in Indian waters. The works of Chinnamma
et al. (1970), Chinnamma and James (1971), Chinnamma
(1973a,b)   on the edible crab Scylla serrata deal with
the keeping quality of the crab meat, their storage
conditions, nutritive values and its seasonal variations.
Rahaman (1967) studied the nutritional cycle of the crab
Portunus pelagicus from Madras coast. Chandran (1968)
reported the nutritional cycles of the crab Charybdis
variegata from Madras coast. Pillay and Nair (1973a)
observed the biochemical changes in the gonads and other
organs in Uca annulipes and Portunus pelagicus during
the reproductive cycles. Ameerhamsa (1978a) commented
on the meat content of Portunus pelagicus with some
observation on lunar periodicity in relation to abundance,

weight and moulting. Radhakrishnan (1979) carried out experiments on the nutritive value of *Portunus pelagicus*, *P. sanguinolentus* and *Scylla serrata*. He also studied the biochemical constituents of the muscle, hepatopancreas and ovary during maturation in *Portunus pelagicus* and *P. sanguinolentus*.Radhakrishnan and Natarajan (1979) investigated the nutritive value of the crab *Podophthalmus vigil* from Porto Novo coast. Nagabhushanam and Farooqui (1982a) traced the mobilisation of protein, glycogen and lipid during ovarian maturation in *Scylla serrata*.

1.3   DESCRIPTION OF THE STUDY AREA

1.3.1   Cochin backwaters (Fig. 1):

Physiography

As the name implies, Cochin backwaters (lat.9° 58'N; long. 76°15'E) and inshore area include a system of interconnected lagoons, bays and swamps penetrating the main lands with many islands in between and its total area amounts to approximately 500 square kilometers. The Vembanad lake, the largest among the lakes of this region constitutes the bulk of Cochin backwaters. It runs almost parallel to the coast extending from Alleppey in the south to Munambam in the north. It has a maximum length of about 112 km and its breadth varies from

a few meters to 14.4 kilometers (Cherian, 1967). The
backwater is connected with the Arabian sea by two openings
one in the south near Ernakulam which is 400 metres wide
and another near Azhikode. The mouth regions are
relatively deeper areas with depth ranging from 5-15 metres
and are marked with flushing of the estuary with flood
and ebb tides whose maximum range is about 1 metre. The
upper reaches of the estuary are shallower (2-5 metres
deep) with little or no tidal influence and have a markedly
low salinity. The permanent sources of fresh water are
the two rivers, namely the Periyar in the north and Pampa
in the south in addition to several riverlets like
Achankovil, Manimala, Meenachil, Moovattupuzha with
several irrigation channels and innumerable drains.
During 1975, a 1447 metre long bund was constructed across
the lake at Thannirmukkam for preventing penetration of
salt water into the upper Kuttanad areas so as to ensure
paddy cultivation. The water flow through the bund is kept
open during June-December and will be closed during the
rest of the periods.

The physiography of backwaters does not agree
with Forsels (1892) definition of lake as a body of
standing water occupying a basin and lacking continuity
with the sea. The lake was part of the Arabian sea until

the uplift of part of the Alleppey and Ernakulam districts in 1841 (Menon, 1913). The conversion of original marine environment into brackish water is shown by the change of molluscan fauna (Rasalam and Sebastian, 1976). The fresh water discharge from rivers makes the lake a typical estuary as per the classification of Pritchard (1967). The run off plus precipitation exceed evaporation and it is a positive type of estuary (Balakrishnan, 1957) which is synonymous with the description of Pritchards estuary.

Hydrography

A cursory survey of literature on the hydrography of Cochin backwaters reveals that the changes are mainly due to tidal flow and fresh water discharge. These aspects were discussed in detail by Qasim et al. (1969), Josanto (1971) and others. Sankaranarayanan and Qasim (1969) reported that the hydrographical condition of this region is very much influenced by the fresh water discharge during the monsoon season. During summer, marine conditions dominate in the backwater due to the influx of sea water. A seasonal pattern could be seen in the variation of different hydrographical parameters.

From the analysis of salinity and temperature data Nair (1965) defined three seasons comprising of

monsoon (June-August), postmonsoon (September-December)
and summer (January-May) which was later adopted by
various workers (Pillai et al., 1975; Pillai, 1978).
The most outstanding feature of the monsoon period is
the flushing out of sea water from the harbour region by
the flow of fresh water brought by the monsoon rains.

Temperature

The surface temperature was found to be high
during October-January (29-32°C) and a steep and steady
increase was recorded from February to April, with the maximum
in March/April (33.5°C). From June onwards the tempera-
ture began to decline due to the onset of southwest monsoon,
the lowest being noted during August (25.8°C). The bottom
temperature varied between 28 and 31°C (Kurup, 1982).

The variation in temperature could be correlated
to the climatic conditions. Sankaranarayanan and Qasim
(1969) stated that the influx of freshwater into the
estuarine system is not the sole factor in bringing
down the temperature but the intrusion of a tongue of
cold water from the Arabian sea may also be a significant
factor. According to Ramamritham and Jayaraman (1963),
the incursion of cold upwelled water from the Arabian
sea may also result in the decrease in temperature of
the estuary during the monsoon.

Salinity

The most fluctuating parameter in the lake is salinity. Surface salinity was found to be quite high and stable during the period January-May, with the maximum (33.4‰) during March/April; with the onset of southwest monsoon in June, there was abrupt changes in salinity, which touched the lowest value (0.1‰) in some part of the lake in July-August. During September- December, there was improvement in salinity and the values were found to be higher than that of the monsoon period (June-August) but lower than that of premonsoon period (January-May). The distribution of salinity during this period is largely influenced by the intensity of northeast monsoon. Josanto (1971) who studied the pattern of bottom salinity distribution in Vembanad lake, found the salinity to vary from 25.23 to 32.7‰ during the dry season and from 0.16 to 31.04‰ during the monsoon season. During southwest monsoon period, there was stratification and the horizontal distribution in salinity was influenced mainly by the fresh water discharge.

Dissolved oxygen

Qasim et al. (1969), Haridas et al. (1973), Pillai et al. (1975) and Kurup (1982) reported high values of Oxygen during the monsoon periods in the estuary.

Kurup (1982) reported highest values to be 5.79 ± 0.1 ml/l in June and August; the lowest being 1.83 ± 0.3 ml/l in different parts of the backwater. In general lower Oxygen values were noted in the premonsoon periods and higher values in the monsoon season and the fluctuations in Oxygen values during the postmonsoon season were rather significant.

1.3.2 Vellar-Coleroon estuarine system (Fig.2):

Physiography

The Vellar-Coleroon estuarine system in South India is characterised by the presence of neritic, estuarine, backwater and mangrove biotopes. The Vellar estuary (lat.11°29'N; long.79°46'E) is fertile and relatively unpolluted. The river Vellar originates in Servarayan hills of Salem (Tamil Nadu, South India), about 240 km west and flows east for about 480 km before joining Bay of Bengal at Porto Novo. The position of the river mouth changes frequently due to sand bar formation. The disappearance of the bar depends upon the amount of freshwater flow from upstream during monsoon months (normally Porto Novo region experiences an annual rainfall of nearly 1200 to 1300 mm). The estuary is an open type and is influenced by semidiurnal tides

throughout the year. The tidal amplitude is one metre and its influence extends upto a distance of 16 km upstream. The width of the river near its junction with the sea is about 600 metres. It is a true estuary, subjected to longterm changes in physiochemical parameters, due to the influence of monsoonal rains and a tidal rhythm. During the period of heavy rainfall (northeast monsoon : October-December) the estuary is flooded due to heavy freshwater flow which determines the duration of flood and ebb tide periods. The estuary also receives discharges from a few irrigation channels namely (1) the Long channel, (2) the Dog channel (3) the Buchingham channel and (4) the Railway bridge channel.

Following Rochford's (1951) classification, Ramamoorthi (1954) divided the Vellar estuary into the following four zones, viz., marine zone, tidal zone, gradient zone and freshwater zone. The above classification is only tentative, since in an estuary where most labile conditions are observed, the field zonation concept is difficult to fit (Rajendran, 1974).

Vellar estuary is connected to another estuary further south, the Coleroon estuary which is a distributory of the Cauvery river, by a watery labyrinth called as Killai backwaters and Pichavaram mangroves extending

over a length of 18 km. The backwater channels near the Coleroon estuary are dominated by mangrove plants, whereas the channels near the Vellar estuary are marked by extensive mudflats. This system lies alongside the sheltered coromandal coast running parallel to the sea shore and lies in close proximity to the coastline of the adjoining Bay of Bengal. The backwater proper has a total length of about 6 km. The backwater mangrove area is meandered with waterways. The net work of rivulets, creeks, gullies and canals interlace the mangrove forest and the backwater realm. The irrigation canals have further inland extensions irrigating mostly paddy fields. The Killai backwater has varying width ranging from 35 to 450 m. The depth of the backwaters varies from 1 to 1.5 m (at high tide). It has a direct connection to the sea at a place called Chinnavaikkal. The backwater system exposes areas of very fertile mudflats ranging in length from about 5 to 90 m at various places and the mud flats are productive-teeming with annelids, crustaceans, molluscs and fishes. The presence of an extensive, rich and fertile oyster bed comprising Crossostrea madrasensis in the backwaters is also worth mentioning. The discharge of fresh water in the back-water is largely from rivulets and irrigation channels adjoining the Vellar estuary.

The main waterways are rather shallow with a depth of 1.5 m. The mangroves serve as a nursery for many commercially important marine fishes and harbour a variety of animals such as crabs, prawns, molluscs and fishes. Though some of the fresh water organisms do invade into this habitat, majority of marine organisms migrate here for spawning.

Hydrography

Temperature:

The surface temperature varies with season between 31 and 26°C. The temperature is more in summer months and less during northeast monsoon months (October-December) which also coincides with winter season.

Salinity:

Less salinity coincides with the inflow of freshwater during the northeast monsoon. The range in salinity is 0-35‰. The postmonsoon season (January-March) is the recovery period for salinity. Summer is the drought period (April-June) when maxima in salinity is noticed due to mixing of high salinity neritic water of Bay of Bengal. During premonsoon period salinity is high but gets reduced on few occasions due to south-west monsoon showers.

Oxygen:

Oxygen content of Vellar estuary can

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generally be directly correlated with salinity. In
summer and premonsoon periods the oxygen is generally
less (3.15 ml/l). But during day time due to high
production of phytoplankton, higher values (6.11 ml/l)
were also encountered. The dissolved oxygen content
is more during monsoon period due to the influx of fresh-
water. After the monsoon, in the postmonsoon period,
as the salinity improved, there was a reduction in
oxygen content. The endowment of various aquatic
biotopes in and around the two study areas provides an
ideal setting for the development of the above complexes
for aquacultural purposes. While a beginning has
already been made in and around Cochin backwaters, it
is expected from the latter in the near future.

1.4   RESEARCH APPROACH

Scrutiny of literature reveals glaring lacunae
in our knowledge on several aspects of edible crabs. To
know more about this fascinating group of organisms, an
attempt has been made presently to study comprehensively
the reproduction, age and growth, length-weight relation-
ship, larval development, effect of salinity on larval
development and proximate composition.

Species covered (Fig. 3):

The study was made on the following five
species and one subspecies of crabs; three species and
one subspecies from Cochin (west coast of India) and
two species from Porto Novo waters (east coast of India).

1) **Portunus pelagicus** (Linnaeus)

This is exclusively marine in habitat and is
caught in large quantities by trawlers. Its distribution
ranges from east coast of Africa, Mediterranean, Red
Sea, Persian Gulf, Pakistan, India, Ceylon, Mergui
Archipelago, Singapore, Philippines to Australia,
New Zealand, Tahiti, China Sea and Japan. In India, it
contributes fishery in all the maritime states and
dominates the catches frequently (Rao et al., 1973).

2) **P. sanguinolentus** (Herbst)

This marine species also contributes to the
fishery in all the maritime states of India and is
fished from the inshore and brackish water regions in
large quantities throughout the year. It is distri-
buted from east coast of Africa, Red Sea, Persian Gulf,
Pakistan, India, Ceylon, Andamans to Hong Kong, Hawaii
and Australia.

3) *Scylla serrata* (Forskal)

This is the largest among the food crabs of India. It occurs in large numbers in estuaries, back-waters and mangrove swamps. It enjoys a wide distribution all over the Indo-Pacific region from east coast of Africa through Red sea, Pakistan, coasts of India to Japan, Tahiti, Australia and New Zealand.

4) *S. serrata serrata* .Radhakrishnan and Samuel

This subspecies was validated by the above authors recently. It occurs in Cochin backwaters and 20% of the crabs belonging to this genus *Scylla* belongs to this subspecies here. This is found along with *Scylla serrata* but has a preference for low saline waters.

5) *Podopthalmus vigil* (Fabricius)

This marine crab inhabits the bottom with sand or sandy mud. It has been reported from both west and east coasts of India. This species became economically important recently and it contributes to the fishery only in Porto Novo region (Srinivasagam and Natarajan, 1976). It is Indo-Pacific in distribution.

6) *Thalamita crenata* (Latreille)

This estuarine crab inhabits mud flats, sandy

beaches and mangroves. It is eaten by fishermen during lean periods. Indo-Pacific in distribution, it extends from east coast of Africa right upto Hawaii.

The findings of the present study are presented in seven chapters. The first chapter deals with the general introductory part with a preface, description of study area, review of literature and research approach.

Second chapter pertains to reproduction in five species and one subspecies of crabs and includes information on size frequency distribution, size at first maturity, sex ratio, fecundity and annual reproductive cycle.

Third and fourth chapters relate to age and growth and length-weight relationship in five species and one subspecies of crabs listed above respectively.

In the fifth chapter larval life history of T. crenata is described and illustrated.

Sixth chapter presents the influence of salinity on the larval life history of T. crenata.

Seventh chapter covers the proximate composition of the crab T. crenata in relation to size and sex.

Findings of the present study are given in a nutshell in summary which is followed by the list of references. The publications of the author are also appended.

Fig 1. Map of Cochin backwaters

Fig 2. Map of Vellar-Coleroon estuarine complex
(with Pichavaram mangrove) (Figure not
drawn to scale)

Fig 3. a - _Portunus pelagicus_

b - _P. sanguinolentus_

c - _Scylla serrata_

d - _S. serrata serrata_

e - _Podopthalmus vigil_

f - _Thalamita crenata_

FIG. I

AZHEEKODE

SOUTH INDIA

WEMBANAD LAKE

10'

NARAKKAL

10°

ERNAKULAM

FORT COCHIN

THEVARA

AROOKUTTY

50'

VAIKOM

ARABIAN SEA

SHERTHALAI

9°40'

KUMARAKOM

ALLEPPEY

76°10'   20'   30'
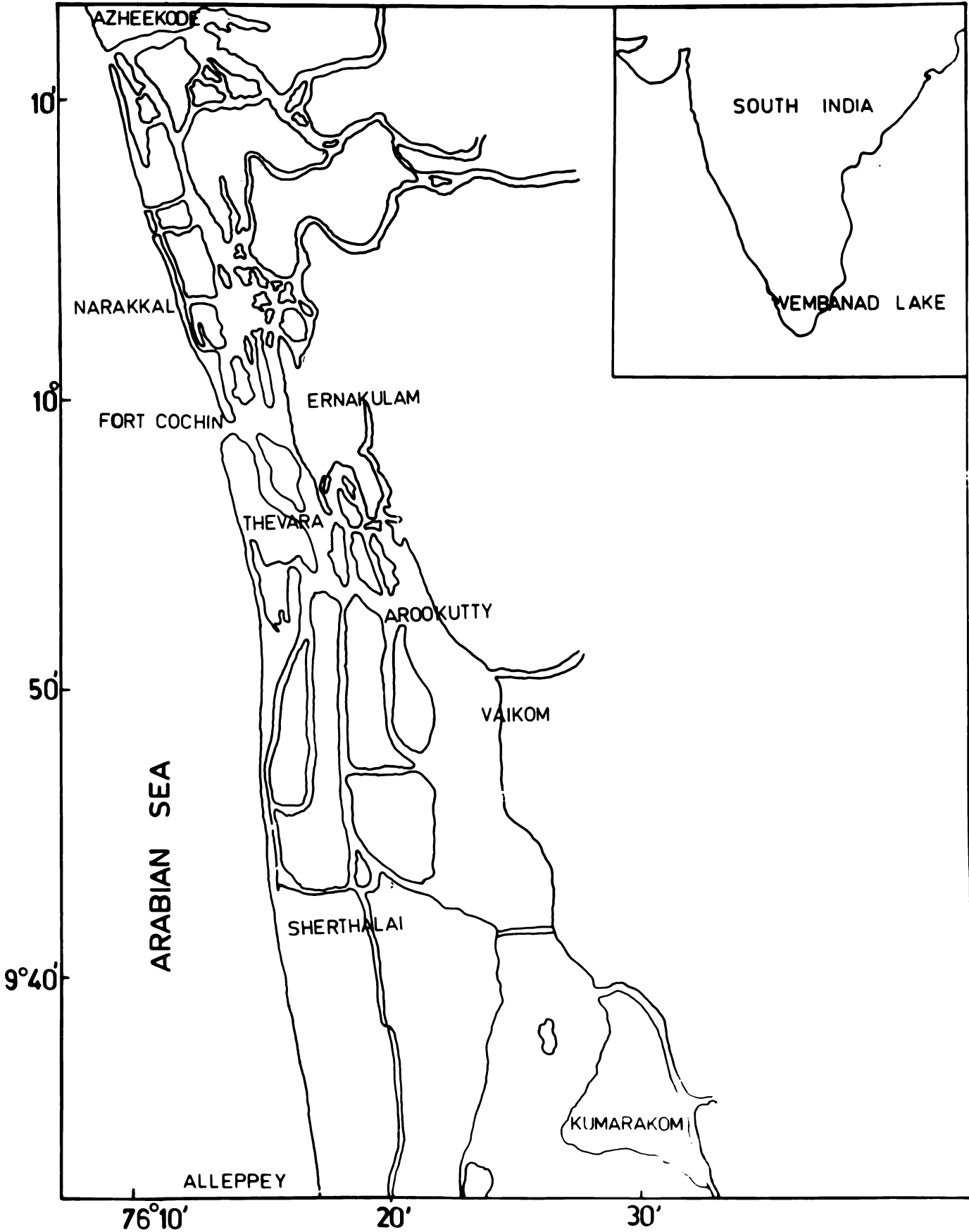
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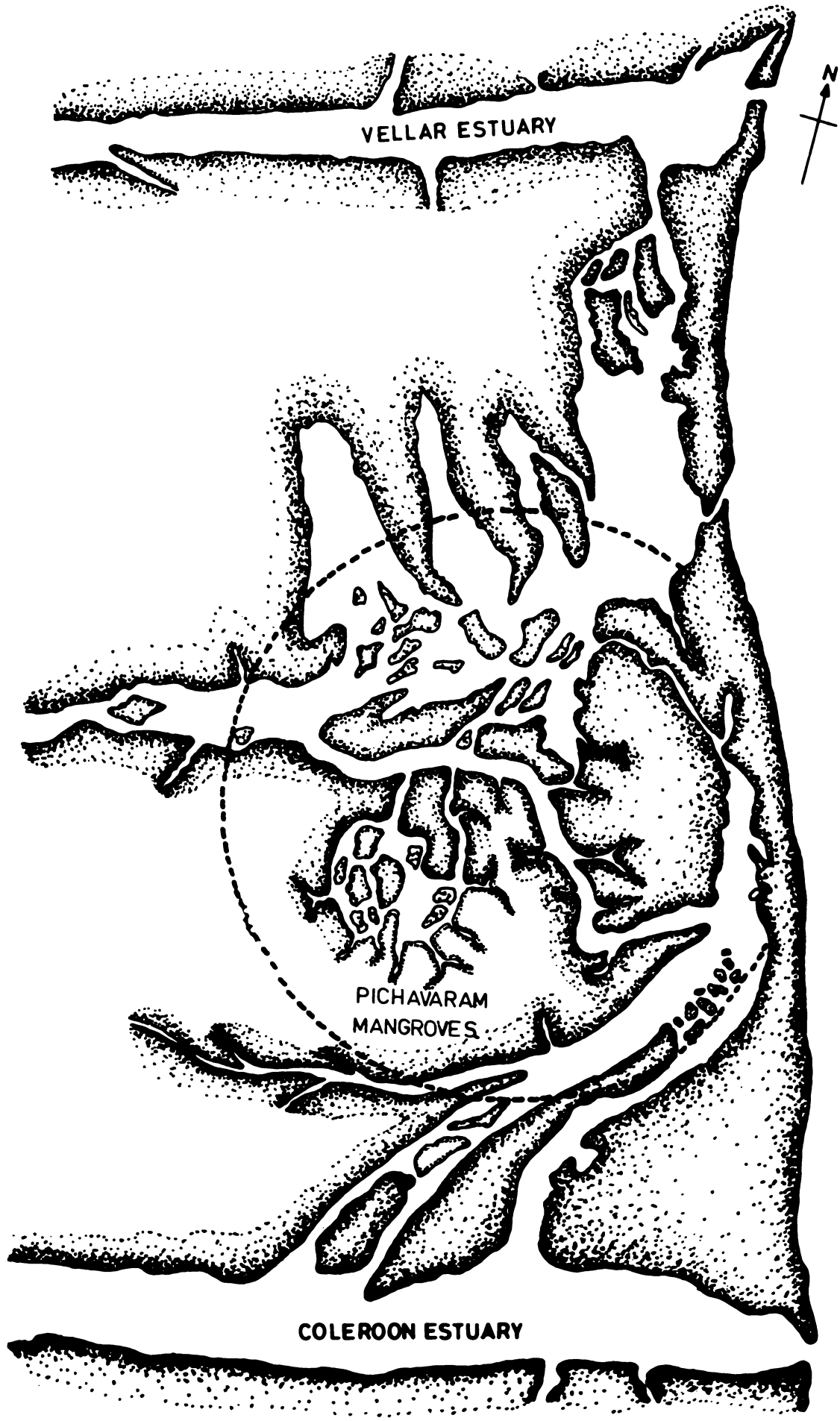
VELLAR ESTUARY

BAY OF BENGAL

PICHAVARAM MANGROVES

COLEROON ESTUARY

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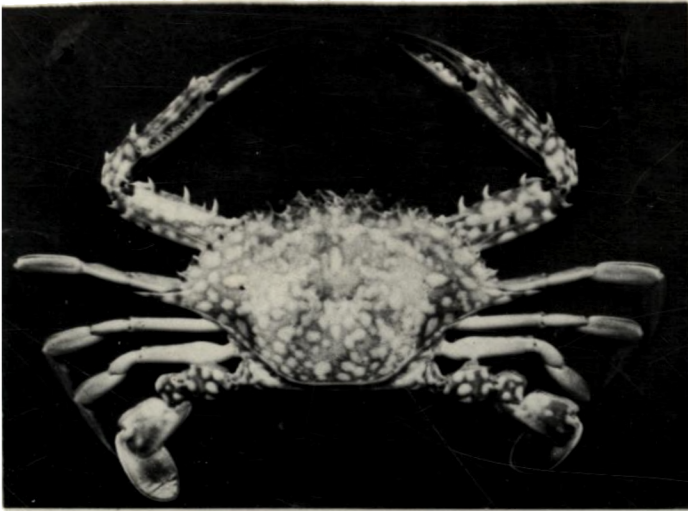
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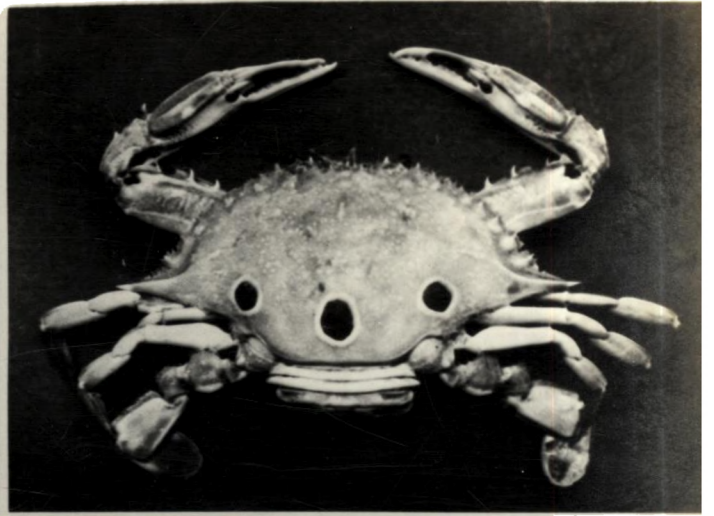
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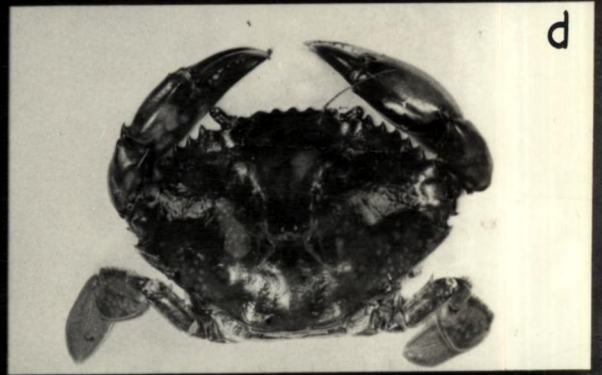
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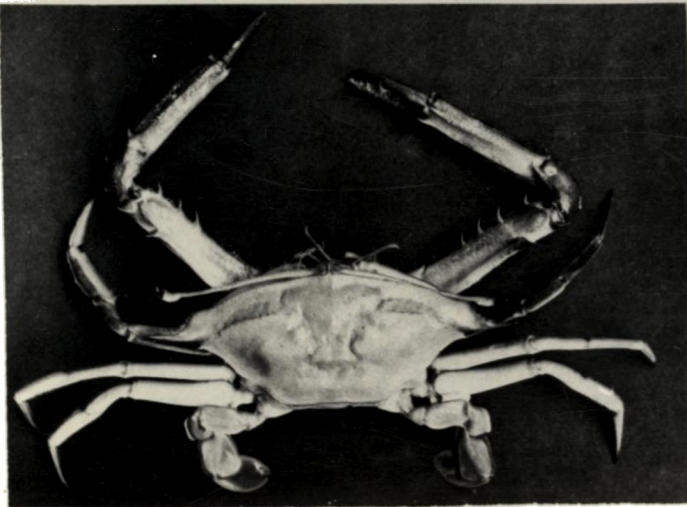
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Fig. 3

REPRODUCTION

2.1   INTRODUCTION

Knowledge of reproductive pattern is basic for
profitable aquaculture practices in cases of commercially
important forms. Besides, this also provides the base-
line information regarding size at first maturity, sex
ratio, reproductive cycle etc. which are quite essential
for judicious and effective management of these renewable
biological resources. So our ability to manage these
biological resources rationally and responsibly and also
our future efforts to increase their productivity at
cheaper rates to meet ever increasing demand for low cost
protein through commercial culture of these animals will
be determined largely by the extent to which we can
answer the basic questions pertaining to the reproductive
strategies.

Crustaceans occupy an unassailable position
at the top in the export market of our country and form
the mainstay among the 30 marine items exported from
India, by constituting 80% in terms of quantity and
95% in terms of value for the year 1982 (total earnings
Rs.342.24 crores in foreign exchange). It is therefore
doubly important that they be paid the attention they
deserve. With sophistication in methodology and
comprehensive programme of work many problems tackled

less intensively in reproduction could be probed into with greater insight and more lucid solutions. Among crustaceans, information on reproductive biology in crabs is restricted to very few forms only (Section 1.2). Hence the present study on reproductive biology of five species and one subspecies of commercially important crabs. Of these, in two species (_Podopthalmus vigil_ and _Thalamita crenata_) and one subspecies (_Scylla serrata serrata_), it is for the first time that studies on breeding biology was attempted.

2.2   MATERIALS AND METHOD

Of the five species and one subspecies of crabs presently covered, three species and one subspecies namely (1) _Portunus pelagicus_ (2) _P. sanguinolentus_ (3) _Scylla serrata_ and (4)   _S. serrata serrata_ were collected from Cochin waters and the other two species namely (1) $\underline{\text{Podopthalmus}}$ / $\underline{\text{vigil}}$ and (2) $\underline{\text{Thalamita}}$ / $\underline{\text{crenata}}$ from Porto Novo waters. This study was done during July 1980 to June 1981 in Cochin waters and during September 1978 to August 1979 in Porto Novo waters.

In Cochin waters specimens were collected from Fishing habour, Thevara market, Ernakulam market, Murikumpadom, Vypeen and Narakkal. In the above places,

catches from all types of gears operated in the inshore and backwater areas are landed. So weekly random samplings were made in all the above places. As collection of specimens from a single gear will have its own bias, effort was made for sampling from all gears operated for these crabs. The gears operated in the inshore waters are purse seines and trawl nets. P. pelagicus and P. sanguinolentus were largely caught by the above gears. At times these species also occurred in the catches of Chinese dip nets which are located in the mouth region of Cochin backwaters. In backwater proper, line and bait, cast net and traps are used. S. serrata and S. serrata serrata are caught exclusively by these gears. Occasionally they also occurred in the catches of Chinese dip nets. At the time of collection; the source of material was enquired and as far as possible samples from different types of gears were obtained for this study. Thus every month collection included specimens from all the above gears.

In Porto Novo waters P. vigil was collected mainly from trawl catches. Small numbers were also collected from other indigenous gears operated in the inshore waters. T. crenata was obtained by operating cast net, drag net and velon screen.

2.2.1   <u>Size frequency analysis</u>:

The carapace width of the specimens was used for this analysis. Each species was grouped into 10 mm interval size groups and histograms were plotted to arrive at the size frequency distribution pattern.

2.2.2   <u>Size at first maturity</u>:

To determine the size at first maturity, the following methods are employed in crabs (1) By observing the changes in the morphology of the pleopods and the colouration of the animal, size at first maturity could be determined. (2) Pairing could be observed in the precopulatory stage, thereby determining the stage at first maturity. (3) By noting the condition of the gonad also, size at first maturity could be determined. (4) By plotting the incidence of berried females against different size groups also, it could be found out. Presently the last method was used to find out the size at first maturity. Condition of the ovary was noted and the incidence of different stages of maturity based on the classification given by Adiyodi and Adiyodi (1970) was observed and used as a supporting evidence. The following is the classification of ovary used in the present study:

and weighed accurately and the number of eggs in the weighed sample was counted. Then total number of eggs present in the brood was calculated by the following equation:

$$\text{Fecundity} = \frac{\text{No.of eggs in the known sample x Total weight of berry}}{\text{Weight of the known sample}}$$

2.2.5   Annual reproductive cycle:

The mature females and males collected every week were weighed individually after drying it and weight of the gonad was determined after dissecting it out from the animal. The gonado.somatic index was calculated by the following formula:

$$\text{GSI} = \frac{\text{Weight of the gonad}}{\text{Weight of the animal}} \times 100$$

The hepatopancreas was also dissected and weighed to calculate the hepato.somatic index by the following formula:

$$\text{HSI} = \frac{\text{Weight of the hepatopancreas}}{\text{Weight of the animal}} \times 100$$

Incidence of ovigerous females, (percentage) gonado somatic index and hepato somatic index were used to determine the annual reproductive cycle in the five commercial species and one subspecies of crabs

presently covered. Incidence of ovigerous females
to determine annual reproductive cycle was used by
Churchill (1919), Stephenson (1934), Broekhuysen
(1936,'41), Hiatt (1948), Boolootian et al. (1959),
Pillay and Nair (1971), Ajmalkhan and Natarajan (1977,'81)
and Radhakrishnan (1979) while gonado somatic index
method by Giese (1959), Rahaman (1967), Chandran (1968),
Pillay and Nair (1971), Ajmalkhan and Natarajan (1977,'81)
and Radhakrishnan (1979).

2.3   RESULTS AND DISCUSSION

2.3.1   Size frequency analysis:

Among commercially important forms size
frequency study is basic and is useful in so many ways.
Besides providing the basic information as what size
group is contributing to the fishery, we can also know,
whether the size group represented in the catches is
juveniles or adults; mature or immature and also about
their age and thereby enables us to suggest ways and
means for the proper management of that fishery. The
following is the size range in the five species and
one subspecies of crabs presently studied (total number
of animals observed given in parentheses):

Portunus pelagicus	31 - 170 mm (662)
P. sanguinolentus	31 - 150 mm (663)
Scylla serrata	31 - 210 mm (769)
S. serrata serrata	61 - 140 mm (332)
Podopthalmus vigil	51 - 120 mm (672)
Thalamita crenata	11 - 70 mm (611)

Among the above crabs, S. serrata is growing
to the largest size and the maximum size decreases
in other forms in the order given above. Size frequency
distribution is depicted in Fig.4. Both in P. pelagicus
and P. sanguinolentus the mode was found in 91 - 100 mm
size group, in S. serrata, 151-160 mm group, 111 - 120mm
group in S. serrata serrata, 81-90 and 41-55 mm group
in P. vigil and T. crenata respectively. By reinforcing
the information derived through sections of size at
first maturity (2.3.2) and age and growth (Chapter 3) it
could be inferred that, matured forms and older groups
contributed much to the fishery than immature or 0 year
group forms.

2.3.2   Size at first maturity (Fig.5)

P. pelagicus

Below 80 mm size, no animal was found to be
berried (Fig. 5a). Berried females appeared first in

the size group 81-90 mm and increased gradually and the incidence in 121-130 mm size group was found to be cent percent. The 50% level in the curve which may be taken to represent the mean size at which this crab attained maturity was found to be 92 mm.

Corroborating this with incidence of different stages of ovary maturation (Table 1), it could be seen that in animals upto 70 mm in carapace width, no development of ovary could be seen. Maturation of ovary was noticed in the 71-80 mm size group and still advanced stages of maturation were observed in the 81-90 mm group. It is in this group that incidence of berried females was noticed for the first time. In higher size groups (101 mm onwards), stage one was absent and the ovary was in different stages of maturity. Thus incidence of maturity stages of ovary supports the finding of the incidence of berried females.

By reinforcing the age and growth data, it could be seen that 92 mm size is attained during the second year of its life span. So, P. pelagicus attains sexual maturity after one year, i.e., during its second year of life (Probability plot).

Thompson (1961) reported a carapace width of 105 mm for the smallest berried crab of P. pelagicus

in Australian waters. Prasad and Tampi (1953) observed that the smallest P. pelagicus in Mandapam waters with eggs measured 106 mm in carapace width. The present study (92 mm) more or less supports the finding of Pillay and Nair (1971), who reported a carapace width of 95 mm for the smallest berried crab of this species from Cochin waters. Dhawan et al. (1976) reported that the females of this species attain maturity at a smaller size in Zuary estuary. They did not mention the exact size. Radhakrishnan (1979) reported 113 mm as the carapace width for the smallest berried crab of this species from Porto Novo waters. Pillay and Nair (1971) did not substantiate their finding with corroborative evidences as has been done in the present study. Size at first maturity may vary in the same species collected from different locations due to environmental influence, etc.

P. sanguinolentus

Below 50 mm size, no animal was found to be berried (Fig. 5b) and in the size group 51-60 mm, 10.3% of the females was found to be berried. The incidence gradually increased in higher size groups and cent percent was observed in 91-100 mm size group. The 50% level was found to be 62.5 mm.

In incidence of maturity stages of ovary in different size groups (Table 2), upto 50 mm all the animals observed were immature. Some stages of ovarian development occurred in the size group 51-60 mm and in 61-70 mm size group which showed incidences of berried females, all stages of ovarian development were seen. By combining information on age and growth with size at first maturity, it could be inferred that maturity is attained slightly earlier (size wise) than in P. pelagicus and it occurred during the first year of its life (Probability plot).

Radhakrishnan (1979) reported 75 mm as the size of the smallest berried female. In the present study, it was found to be at the size of 62.5 mm.

S. serrata

Below 100 mm, no animal was found to be berried (Fig. 5c). In size group 101-110 mm, 36.36% of the females was found to be berried. Cent percent incidence of berried females was observed in the 141-150 mm size group. The 50% level was found to be 114.5 mm. Incidence of maturity stages (Table 3) also supported the above findings as in the case of previous two species. The animal was found to attain maturity at an age of 1 (Probability plot).

Arriola (1940) and Hill (1975) observed mating
to occur in the size range of 10.3 - 12.3 cm and
10.3 - 12.6 cm respectively. The above observations
support the present result on size at first maturity.

S. serrata serrata

Below 75 mm, no animal was found to be berried
(Fig. 5d). In the size group 76-80 mm, 25% of the
females was found to be berried and cent percent
occurrence of berried females was observed in the 101-105 mm
size group. The 50% level was found to be 85 mm. Incidence
of maturity stages (Table 4) also supported the above
result. The animal was found to attain maturity at the
earlier part of 1 year (Probability plot).

Radhakrishnan and Samuel (1982) validated this
subspecies. Biological studies done presently also
support this. While S. serrata was found to attain maturity
at a size of 114.5 mm, this species was found to attain
maturity at a length of 85 mm. The distribution of
these two species overlaps in Cochin waters and the
biological evidence as found above gives credence to
the separate identity of this species.

P. vigil

Below 60 mm, no animal was found to be berried
(Fig. 5e). In the size group 61-65 mm, 10.3% of the

females was found to be berried. Cent percent incidence of berried females was noticed in the size group 81-85 mm. The 50% level was found to be 65 mm. So this species attains sexual maturity at 65 mm size which happens to be attained in the early part of 1 year of its life (Probability plot). Incidence of maturity stages of ovary (Table 6) was found to corroborate the above finding.

Srinivasagam and Natarajan (1976), reported a carapace width of 58 mm for the smallest berried crab. However in the present study the smallest berried crab was found to measure 62 mm in carapace width.

T. crenata

In this estuarine crab, no animal was found to be berried below 20 mm size (Fig. 5f). In the size group 21-25 mm, 12.5% of the females was found to be berried. Cent percent berried females was found in the size group 46-50 mm. The 50% level was found to be 27.5 mm. It is found to attain maturity during the early part of 1 year of its life (Probability plot). Incidence of maturity stages of ovary (Table 6) also supports the above results. Prasad and Tampi (1957) hatched the larval stage of T. crenata from a berried female. But they did not mention about the size of that berried female.

2.3.3   Sex ratio:

The topic of sex ratio among animals has received an increasing amount of attention in recent years (Wenner, 1972). Emphasis has however differed somewhat according to a researcher's interest. Some investigators stressed the selective advantage in most population of having an equal frequency of males and females at birth or at the time of initial independence from parents (Mac Arthur, 1961; Leigh, 1970) while so many investigators emphasized apparent deviations from the expected 1 : 1 sex ratio (Wenner, 1972).

According to Fisher's theory of sex ratio (Fisher, 1930; Kolman, 1960) natural selection, favours a 1 : 1 parental expenditure on offspring of the two sexes. However differential mortality between the two sexes and other factors which create a differential in the costs of producing offspring of each sex, such as differential growth rates or size difference between sexes during the period of parental care, can produce various skewed sex ratios. Restricted nutrition, activeness of one sex than the other, outmigration of one sex and utilization of different habitats by the sexes have all been suspected of being responsible for an apparent alteration of the sex ratio (Darnell,1962).

Sex ratio in commercially important crabs is helpful in understanding whether any differential fishery exists, its possible bearing on fish stock and also in predicting sexual congregation during breeding.

P. pelagicus

The percentage of males in the population was high from April to August while in other months females were higher (Table 7; Fig. 5a). But statistically, the sex ratio conformed to the expected 1 : 1 ratio both monthwise and when the data were pooled for the whole year. Sex ratio was also calculated sizewise (Table 8; Fig. 6a) and here also in all size groups the sex ratio conformed to the expected 1 : 1 ratio.

Thompson (1951) observed 4.3 males to a female from Australian waters. Prasad and Tampi (1953) reported 2.4 males to a female in Mandapam waters. Dhawan et al. (1976) in their short term study encountered more males than females (males constituted 67.5% and females 32.46%) and reported that males were dominant at a size of 115 mm and females 105 mm. However Radhakrishnan (1979) found the sex ratio to conform to the expected 1 : 1 ratio from Porto Novo waters as it has been observed presently from Cochin waters.

P. sanguinolentus

Sex ratio calculated monthwise is given in Table 9 (Fig. 6b). Females were slightly more than that of males in the whole year. Monthwise, females had a slight edge over males from November to March and the males from April to October. But statistically the deviation was not found to be significant monthwise and for the whole year with the ratio conforming to the expected 1 : 1 ratio. When calculated size wise (Table 10; Fig. 6b) the ratio conformed to the 1 : 1 ratio in all the size groups except the highest size group where the males predominated and the deviation was also statistically significant (P< 0.01).

Radhakrishnan (1979) reported significant deviation in the sex ratio of this species (1.06 males for a female, P < 0.05) from Porto Novo waters. But here monthwise and size wise (except in the highest size group) the sex ratio was 1 : 1. Skewness in sex ratio of species with differential growth rate between the sexes (as has been observed presently) is quite common in crustaceans (Wenner, 1972).

S. serrata

Sex ratio calculated monthwise and for the whole year conformed to the expected 1 : 1 ratio (Table 11; Fig. 6c). When calculated size wise (Table 12; Fig.6c)

in all the size groups except in the highest size
group the ratio conformed to the 1 : 1 ratio. In the
highest size group, as in the case of P. sanguinolentus
the deviation from the expected 1 : 1 ratio was signi-
ficant. It is due to the differential growth rate
between the sexes. In the highest size group (191-200 mm)
the males predominated over females, indicating that
males grow to a larger size than females.

S. serrata is distributed in estuaries and
backwaters and the females were reported to migrate to
the sea for larval spawning. Arriola (1940) reported
the above phenomenon from Philippines water. Ong (1966)
observed that in Malasia, berried females of this are
found only in the sea and not in the estuaries. Brick
(1974) also reported that the females migrate to the
sea prior to larval spawning in Hawaii. Seaward migration
of females was believed to maximise larval survival.
Hill (1975) proved it experimentally and confirmed
that below 20% salinity survival rate of larvae was
less. If such seaward migration is true, then during
                    deviate from 1:1. But in the present study it
the peak breeding season, the sex ratio will certainly never
deviated in any month from the expected 1 : 1 ratio.
So in large bodies of brackish water as Cochin waters
where neritic influence is much pronounced, then the

females do not migrate for larval spawning. This fact
is supported by the collection of berried females from
the study area. Ezhilarasi (1982) also collected
berried females from Pulicat area.

S. serrata serrata

The results were more or less the same as in
the case of S. serrata. Monthwise and for the whole
year the sex ratio conformed to the expected 1 : 1
(Table 13; Fig. 7a). When calculated size wise (Table 14;
Fig. 7a) except in the highest two size groups, the
ratio conformed to 1 : 1. In the highest two size
groups, only males were encountered indicating that the
maximum size attained by the female is less than that
of males.

P. vigil

There was no significant deviation in the sex
ratio of this species month wise (except on December)
and for the whole year (Table 15; Fig. 7b). The deviation
in December was due to the females. When calculated
monthwise (Table 16; Fig. 7b), in the highest two size
groups and in the size group 81-85 mm, the deviation
was significant. The deviation in the highest two size
groups is probably due to differential growth rate
between the sexes and the deviation in the size group

81-89 mm and in December may be due to sampling error.

Srinivasagam and Natarajan (1976) reported about the fishery of this species. But they have not mentioned anything about sex ratio. So for this species, information on sex ratio is given here for the first time.

T. crenata

Sex ratio when calculated monthwise and for the whole year did not deviate significantly from the expected 1 : 1 ratio (Table 17; Fig. 7c). However, when calculated size wise, it conformed to the 1 : 1 ratio in the lower size groups and in the highest size groups, incidence of the male was more, indicating differential growth rate.

Remarks

Among the crabs presently studied, 3 species are marine (P. pelagicus, P. sanguinolentus and P. vigil) and the remaining are estuarine (S. serrata, S. serrata serrata and T. crenata). Monthwise and for the whole year the observations largely conformed to the 1 : 1 ratio. Size wise, the deviation was significant in the highest size groups indicating differential growth rate between sexes in all the crabs except P. pelagicus. So the sex ratio in all the crabs except P. pelagicus appears as a function of size (Wenner, 1972).

2.3.4   Fecundity

The term fecundity refers to prolificness
or the capacity of the animal to reproduce. The magnitude
of production of eggs, their survival rate indirectly
helps us to assess the population dynamics or stock.
It could be seen that, animals with special parental
care are less fecund and animals which do not possess
this adaptation are good fecunds. With advances in
techniques for rearing of larvae, good fecund animals
could be advantageously used for culture purposes.
For decapod crustaceans, the larval survival in the
wild has been estimated as 0.02%. But in controlled
conditions it could be maximised to 90%. So animals
which do not possess special mechanism as parental
care and good fecunds can be effectively utilised in
culture purposes.

Earlier works on the fecundity of commercially
important crabs are less from Indianwaters. Pillay
and Nair (1968) and Radhakrishnan (1979) studied
about fecundity in some commercially important crabs.
The present study covers four species and one subspecies
of crabs (P. pelagicus, P. sanguinolentus, S. serrata,
S. serrata serrata and P. vigil).

P. pelagicus

The number of eggs produced by a female increased from 67,540 (carapace width 84 mm) to 10, 41,600 (carapace width 166 mm). The correlation coefficient value (0.69) of fecundity against abdominal width was found to be significant (P < 0.001). The 'r' value for fecundity against abdominal width was 0.46 (P < 0.01).

Prasad and Tampi (1953) studied the fecundity of this species from Mandapam waters and in their study, the fecundity varied from 1,91,000 to 4,55,000 eggs. In the study of Radhakrishnan (1979) from Porto Novo waters, it was found to vary from 34,720 to 10,42,614 eggs. But in the subsequent study by Kannaiah (1981) from the same waters, it was found to be very high and it varied from 9,35,777 to 31,57,000 eggs. Present study on fecundity more or less agrees with that of Radhakrishnan (1979).

P. sanguinolentus

This species was found to be less fecund than P. pelagicus and the number of eggs in the clutch varied from 45,792 to 7,98,340. The correlation coefficient value (0.71) between fecundity against

carapace width was found to be significant (P < 0.001).
The 'r' value (0.49) against abdominal width was
also found to be significant (P < 0.001).

In Ryan's (1967) observation, fecundity for
this species was high and it varied from 9,60,000 to
22,50,000 eggs (highest reported for this species).
But Radhakrishnan (1979) found it to be less (15,314 -
1,48,800 eggs). Kannaiah (1981) found fecundity to vary
from 5,20,743 to 19,85,634 eggs. The present observation
comes in between the observations of the latter two.

S. serrata

This is the largest crab among the crabs presently
covered. So naturally the fecundity should also be high.
But, while the lowest number of eggs produced (2,35,250)
were found to be higher than that of the other two
species previously described, the highest number of eggs
produced (6,14,575) was found to be lower. The 'r' value
(0.86) for fecundity against carapace width was highly
significant (P < 0.001). The significance of it against
abdominal width was at 2% level (r = 0.370, P < 0.02).

Arriola (1940) reported that this species
can produce about 2 million eggs. Varikul et al. (1972),
reported that the clutch size varied from 10,77,211 to
27,13,858 eggs. Escritor (1972) found the fecundity to

below (4,57,790 - 9,37,723 eggs). In Kannaiah's
(1981) finding, the fecundity varied from 15,08,925 to
27,13,858 eggs. The present study reports the lowest
fecundity rate for this species.

S. serrata serrata

In this species the number of eggs produced
by an animal varied from 1,52,140 to 3,16,250. The
correlation value between fecundity and carapace width
(0.740 P< 0.001) and fecundity and abdomen width (0.500
P < 0.01) was found to be significant.

This species was recently validated by
Radhakrishnan and Samuel (1982). Biological evidence
will go a long way in upholding the above validation
of this species. Information on fecundity (it was found
to be lower than that of S. serrata) lends support to it.

P. vigil

In this species the number of eggs produced
by a berried female increased from 37,817 to 8,15,436.
The correlation coefficient value between fecundity and
carapace width (0.710 P< 0.001) and fecundity and
abdominal width (0.673 P < 0.001) was found to be
significant.

Srinivasagam and Natarajan (1976) while
reporting about the fishery of this species gave also

the data regarding fecundity which varied from 14,640
to 30,517 eggs. Kannaiah (1981) also studied the
fecundity in this species and it was found to be very
high (5,01,485 - 15,72,357 eggs). The present study
comes in between the above two studies.

General remarks

For the same species of crabs, different workers
have reported different fecund rate. Perhaps the clutch
size may vary in the same species occurring in different
places. But differences in the fecund rate of a species
occurring in the same locality but observed during
different years is quite interesting.

2.3.5   Annual reproductive cycle:

Studies on the reproductive cycle of tropical
marine invertebrates are of much interest, since the
time Semper (1881) and Orton (1920) postulated that,
under stenothermal conditions of the tropics, the
animals may breed continuously throughout the year.
On the contrary Stephenson (1934) reported the existence
of periodicities in the breeding of tropical marine
invertebrates and described four patterns of breeding
cycles in the invertebrates of Great Barrier Reef.
Hornell (1910), Mortensen (1921), Nicholls (1931),

Malpas (1933), Moorehouse (1933), Galtsoff (1934),
Panikkar and Aiyar (1939), Paul (1942), Boolootian et al.
(1959), Prasad (1959), Lewis (1960), Durve (1964),
Rao (1965), Krishnaswamy and Krishnan (1967), Akumfi
(1975), Nagabhushanam and Mane (1975a,b), Ajmalkhan
and Natarajan (1977,'81) reported the existence of
definite breeding periodicities in many species of
tropical marine invertebrates, which showed that
breeding need not be continuous, in many tropical species
as suggested originally. Giese (1959) reviewed extensively
the question of reproduction in marine invertebrates and
the complexity of controlling factors. The influence
of local ecological conditions on the reproductive cycle
of the invertebrates was sharply brought into focus by
Reese (1968). The studies of Pillay and Nair (1971,'73b)
are also in support of the above indicating that the
planktonic larvae will have a better chance of survival
if released at a time of favourable environmental
conditions.

The present study on reproductive cycle of
six commercially important crabs was intended to add
further information on this aspect.

P. pelagicus

One year observation on the reproductive

cycle was made (July 1980 - June 1981). It became
evident that breeding in this animal extended over
several months of the year from August to June with
three peaks, one in October, second in December and
the third in April (Fig. 8a). The peak in December was
much pronounced and peak in April was the least
pronounced.

The gonado somatic index in females also
showed three peaks in correlation with incidence of
berried females (Fig. 8b). But the peaks here appeared
one month earlier than in the incidence of berried
females. The peak in November was much pronounced
and the peak in March was the least pronounced.

The hepato somatic index calculated for one
year in females also showed fluctuations (Fig. 8b).
During peak breeding months when the gonado somatic index
was high, hepato somatic index was low. Thus there
was a very good negative correlation between the two
indices in females.

In males, the gonado somatic index was high
in November (Fig. 8c). This corresponded with the
high gonado somatic index in females also. Other
than this, there was no any corresponding increase or
decrease between the gonado somatic and hepato somatic

indices in males as seen in the case of females.

A reasonably reliable picture could be obtained regarding the annual reproductive cycle of this species through incidence of ovigerous females and gonado somatic index. Gonado somatic index was more reliable in females than in males. Hepato somatic index also showed negative relationship with gonado somatic index in females and not in males. So for these studies, only females could be relied upon. While the incidence of berried females is the direct evidence for breeding, gonado somatic index in females gives an idea about the stage by stage changes undergone by the females during the annual reproductive cycle. A low value represents the quiescent or unriped or spent condition of the ovary, while a high index indicates the ripeness of the ovary. So gonado somatic index in females facilitates a quantitative assessment of reproductive activity.

Earlier works on the reproductive aspect of this species are those of Rahaman (1967) and Radhakrishnan (1979) from east coast, Pillay and Nair (1971) from west coast. Rahaman (1967) and Radhakrishnan (1979) observed that P. pelagicus in east coast breeds continuously. But Pillay and Nair (1971) observed

that this species breeds for an extended period but not round the year in the west coast. Such spatial variation in breeding in the same species was attributed to differences in hydrological factors (Pillay and Nair, 1971). The present study also from the west coast, explores whether there will be any temporal variation also. Except minor differences (peak months of breeding activity) the pattern is consistent.

P. sanquinolentus

Percentage of berried females plotted against time revealed that this species was a continuous breeder (Fig. 8d) with three peaks, one in October, second in January and the third in April. The peak in January was much pronounced and the peaks in October and April are more or less similar and of minor nature.

The gonado somatic index in females (Fig. 8e) also showed three peaks like incidence of berried females. Here also the peaks appeared one month earlier than in the incidence of berried females. The peak in December was much pronounced than the other two peaks. The variations in hepato somatic index could not however be correlated with that of gonado somatic index.

In males, the gonado somatic index showed a distinct peak in December which could be correlated with

that of the female (Fig. 8f). Other than this, the pattern of gonado somatic and hepato somatic indices was erratic.

Menon (1952) and Pillay and Nair (1968, '73b) studied reproduction in this species and found it to be discontinuous and continuous breeder respectively. Radhakrishnan (1979) also opined that this species was a continuous breeder in Porto Novo waters. The present study also supports the finding of Pillay and Nair (1968, '73b) and Radhakrishnan (1979). So P. sanguinolentus breeds throughout the year in Cochin waters, but the activity is less during monsoon months.

S. serrata

Percentage of berried females plotted against time is shown in Fig. 9a. This species also just like P. pelagicus breeds for an extended period, but from July through April with quiescent period in May and June when berried females did not occur. There were three peaks, a minor one in July, a moderate peak in November and a highly pronounced peak in February.

Gonado somatic index (Fig. 9b) in females showed two peaks one in October and the other in January. So peaks here preceded the peak incidence of berried females by one month. Hepato somatic index behaved erratic.

Gonado somatic index in males also showed
two peaks one in October and the other in January (Fig.9c).
So there was perfect correlation between the peaks
in gonado somatic index of females and males. Just
like in the case of females, here also, hepato somatic
index behaved erratic.

Pillay and Nair (1973b) observed this species
to breed continuously all through the year. Here this
species is found to be a discontinuous breeder. Thus
this study supports temporal variations in the breeding
activity of this species. Moreover another subspecies
S. serrata serrata also occurs in the same area where
Pillay and Nair (1973b) carried out their work.
Specimens of this subspecies also must have got included
in their samples. Now this subspecies is separated
from S. serrata.

S. serrata serrata

Percentage of berried females (Fig. 9d)
plotted against time showed three peaks, one in August,
the second one in October and the third one in January.
The peak in October was much pronounced, August peak
least pronounced and the peak in January moderate.
It is found to be a continuous breeder with reduced

breeding activity during monsoon months (southwest monsoon).

Gonado somatic index (Fig. 9e) in females showed only two peaks. These two peaks could be correlated with the October and January peaks of the berried females. Peaks here occurred one month earlier than the peaks in the former. Hepato somatic index showed a trough in September and this could be correlated with the highest peak in gonado somatic index of the same month.

Gonado somatic index and hepato somatic index in males did not show any correlation with those in the females (Fig. 9f). However it could be seen that the values were higher in the postmonsoon months.

Pillay and Nair (1973b) who studied the breeding biology in S. serrata observed that to be a continuous breeder. But in the present study while S. serrata was found to be a discontinuous breeder, S. serrata serrata which has been recently separated from the former was found to be a continuous breeder. Their contention about the reproductive cycle of S. serrata is probably due to intermingling of these two forms.

P. vigil

The reproductive pattern of this crab differs sharply from other crabs in that the peak period of occurrence and breeding happens just prior to and during monsoon months. There was a single peak in the incidence of berried females (Fig. 10a) and this was just prior to monsoon in October. From February to June the activity was less. Even though this is found to be an extended breeder, it has distinct peak breeding activity extending from July to December or January.

Gonado somatic index (Fig. 10b) in females showed perfect correlation with breeding activity. This index was high during July to February and was low from March to June. In hepatic index, the values were generally high from March to July and generally lower from September to January which is the peak period of breeding.

In males (Fig. 10c) also the gonado somatic index was high from July to December. From January to June, when the breeding activity was less, the values were also lower. The hepato somatic index however did not reveal any change in relation to gonado somatic index.

T. crenata

Percentage of berried females (Fig. 10d) plotted against time revealed that this species is an extended breeder, from January though October with quiescent period in November and December. There were two peaks, one in February (postmonsoon month in Porto Novo) and the other in August (premonsoon month in Porto Novo). The peak in February was more pronounced than the peak in August.

Gonado somatic index in females (Fig. 10e) showed two peaks one in January and the other in July. Thus peaks in gonado somatic index in female occurred one month earlier than the peak incidence of berried females. Hepato somatic index also showed two peaks but it could not be correlated with changes in gonado somatic index.

Gonado somatic index in females (Fig. 10f) also showed two peaks as in females, one in January and the other in July and thus there was a very good correlation between changes in gonado somatic indices of both the sexes. The behaviour of hepato somatic index in relation to gonado somatic index was erratic.

Remarks

The present study on reproductive biology in

five species and one subspecies of crabs, viz.,
P. pelagicus, P. sanguinolentus, S. serrata, S. serrata
serrata from Cochin waters and P. vigil and T. crenata
from Porto Novo waters revealed some interesting facts
(Fig. 11). In Cochin waters (southwest coast of India),
while P. sanguinolentus and S. serrata were found to be
continuous breeders, P. pelagicus and S. serrata were
found to breed for an extended period of time, but it
was not through the whole year (discontinuous) and
there was some respite during the monsoon months. But
in the other two species from Porto Novo waters the
pattern was quite opposite. While P. vigil was found
to be an extended breeder having distinct peak period
of breeding activity prior to monsoon and during monsoon,
the other species T. crenata was not found to breed
during monsoon.

Influence of environmental parameters on
reproduction in marine invertebrates has been discussed
much in depth and length (Giese, 1959; Reese, 1968;
Pillay and Nair, 1971,'73b; Ajmalkhan and Natarajan,
1977, '81). Through the above works it has become
increasingly apparent that salinity is the most proximate
environmental factor influencing reproduction in coastal
marine and estuarine invertebrates. Salinity influences
the reproduction in the following ways:

a) long range seasonal fluctuations in salinity leads to synchronisation of the gametogenic cycle.

b) extreme levels of salinity inhibit gameto- genic activity and thereby influence the reproductive pattern and

c) rapid salinity changes stimulate spawning (Stephen and Shetty, 1981).

All the animals studied presently in Cochin waters and adjacent seas were found to breed either, continuously (P. sanguinolentus and S. serrata serrata) or for an extended period of time not lasting the whole year (P. pelagicus and S. serrata). Even in P. sanguinolentus and S. serrata serrata the intensity of breeding was less during monsoon months. Among the two species covered from Porto Novo waters, one species was not breeding during monsoon time (T. crenata) and the other species was breeding just prior to and during monsoon months (P. vigil). Studies on the influence of salinity: on the ovarian development, embryonic development, larval development and on X and Y organs will go a long way in facilitating better understanding of the reproductive strategy of these crabs.

Table 1. Incidence of maturity stages of ovary in different size groups of Portunus pelagicus in Cochin waters (July 1980 to June 1981)

Size group (in mm)	Stages of Ovary					Total
	1	2a	2b	2c	3	
31-40	10	-	-	-	-	10
41-50	26	-	-	-	-	26
51-60	26	-	-	-	-	26
61-70	22	-	-	-	-	22
71-80	20	2	1	-	-	23
81-90	21	9	5	2	2	39
91-100	10	14	12	5	2	43
101-110	-	15	16	5	4	40
111-120	-	2	4	6	12	24
121-130	-	-	8	5	12	25
131-140	-	-	-	4	11	15
141-150	-	-	-	3	17	20
151-160	-	-	-	5	6	11
161-170	-	-	-	-	2	2

Table 2. Incidence of maturity stages of ovary in different size groups of
          Portunus sanguinolentus in Cochin waters (July 1980 to June 1981)

Size group (in mm)	Stages of Ovary					
	1	2a	2b	2c	3	Total
31-40	13	--	--	--	--	13
41-50	30	--	--	--	--	30
51-60	20	5	4	--	--	29
61-70	12	10	6	5	3	36
71-80	4	14	10	8	7	43
81-90	--	3	10	9	17	39
91-100	--	--	4	21	20	45
101-110	--	--	4	9	31	44
111-120	--	--	6	7	24	37
121-130	--	--	4	2	20	26
131-140	--	--	--	2	7	9

Table 3. Incidence of maturity stages of ovary in different size groups of
Scylla serrata in Cochin waters (July 1980 to June 1981)

Size groups (in mm)	Stages of Ovary						Total
	1	2a	2b	2c	3	
71-80	16	--	--	--	--	--	16
81-90	16	--	--	--	--	--	16
91-100	18	5	2	--	--	--	25
101-120	15	6	6	4	2		33
121-130	3	19	8	7	6		43
131-140	3	5	12	8	7		35
141-150	--	2	6	10	20		38
151-160	--	2	6	8	16		32
161-170	--	3	7	6	22		38
171-180	--	--	2	6	9		17
181-190	--	--	--	--	1		1
191-200	--	--	--	--	2		2

Table 4. Incidence of maturity stages of ovary in different size groups of
Scylla serrata serrata in Cochin waters (July 1980 to June 1981)

Size groups (in mm)	Stages of Ovary					Total
	1	2a	2b	2c	3	
66-70	6	--	--	--	--	6
71-75	8	3	2	1	1	15
76-80	9	5	4	4	3	25
81-85	2	6	5	5	4	22
86-90	--	2	4	6	7	19
91-95	--	1	3	4	5	13
96-100	--	2	3	2	2	9
101-105	--	2	3	4	5	14
106-110	--	2	3	7	10	22
111-115	--	1	2	3	12	18
116-120	--	2	3	4	11	20
121-125	--	--	--	2	5	7

Table 5. Incidence of maturity stages of ovary in different size groups of *Podopthalmus vigil* in Porto Novo waters (September 1978 to August 1979)

Size groups (in mm)	Stages of Ovary					
	1	2a	2b	2c	3	Total
51-55	32	—	—	—	—	32
56-60	38	5	3	1	—	47
61-65	26	8	6	5	3	48
66-70	2	12	9	8	6	37
71-75	—	31	6	14	7	58
76-80	—	4	12	9	15	40
81-85	—	5	8	9	26	48
86-90	—	5	12	23	12	52
91-95	—	—	9	2	38	49
96-100	—	—	2	4	5	11
101-105	—	—	—	—	9	9

Table 6. Incidence of maturity stages of ovary in different size groups of _Thalamita crenata_ in Porto Novo waters (September 1978 to August 1979)

Size groups (in mm)	Stages of Ovary					Total
	1	2a	2b	2c	3	
11-15	17	--	--	--	--	17
16-20	19	2	--	--	--	21
21-25	7	5	3	4	1	20
26-30	--	9	13	15	7	44
31-35	--	9	8	12	11	40
36-40	--	6	5	14	15	40
41-45	--	4	4	21	19	48
46-50	--	--	8	15	30	53
51-55	--	--	5	16	14	35
56-60	--	--	9	11	20	40
61-65	--	--	2	4	9	15

Table 7. Sex ratio in Portunus pelagicus (month wise) in Cochin waters

Month	Female	Male	Total	% of female	% of male	Ratio F : M	Chi-square value	P
July, 1980	25	34	59	42.37	57.62	0.74:1	1.37	> 0.05
August	20	29	49	40.82	59.18	0.69:1	1.65	> 0.05
September	30	25	55	54.55	45.45	1.20:1	0.45	> 0.05
October	34	31	65	52.31	47.69	1.10:1	0.14	> 0.05
November	32	26	58	55.17	44.83	1.23:1	0.62	> 0.05
December	29	21	50	58.00	42.00	1.38:1	1.28	> 0.05
January, 1981	36	29	65	55.38	44.62	1.24:1	0.75	> 0.05
February	27	24	51	52.94	47.06	1.12:1	0.18	> 0.05
March	25	24	49	51.02	48.98	1.04:1	0.02	> 0.05
April	29	31	60	48.33	51.67	0.94:1	0.07	> 0.05
May	21	23	44	47.73	52.27	0.91:1	0.09	> 0.05
June	27	30	57	47.37	52.63	0.90:1	0.18	> 0.05
Total	335	327	662	50.60	49.40	1.02:1	0.10	> 0.05

Table 8. Sex ratio in _Portunus pelagicus_ (size wise) in Cochin waters

Size group (in mm)	Female	Male	Total	% of female	% of male	Ratio F : M	Chi-square value	p
31-40	10	13	23	43.48	56.52	0.77:1	0.39	> 0.05
41-50	26	27	53	49.06	50.94	0.96:1	0.02	> 0.05
51-60	26	28	54	48.15	51.85	0.93:1	0.07	> 0.05
61-70	22	26	48	45.83	54.17	0.85:1	0.33	> 0.05
71-80	23	21	44	52.27	47.73	1.10:1	0.09	> 0.05
81-90	39	28	67	58.21	41.79	1.39:1	1.81	> 0.05
91-100	43	33	76	56.58	43.42	1.30:1	1.32	> 0.05
101-110	40	29	69	57.97	42.03	1.38:1	1.75	> 0.05
111-120	26	25	51	50.98	49.02	1.04:1	0.02	> 0.05
121-130	28	24	52	53.85	46.15	1.17:1	0.31	> 0.05
131-140	19	22	41	46.34	53.66	0.86:1	0.22	> 0.05
141-150	20	22	42	47.62	52.38	0.91:1	0.10	> 0.05
151-160	11	20	31	35.48	64.52	0.55:1	2.61	> 0.05
161-170	2	9	11	18.18	81.82	0.22:1	4.45	< 0.05
Total	335	327	662	50.60	49.40	1.02:1	0.10	> 0.05

Table 9. Sex ratio in Portunus sanguinolentus (month wise) in Cochin waters

Month	Female	Male	Total	% of female	% of male	Ratio F : M	Chi-square value	P
July, 1980	24	28	52	45.15	53.85	0.86:1	0.31	> 0.05
August	22	24	46	47.83	52.17	0.92:1	0.09	> 0.05
September	27	29	56	48.21	51.79	0.93:1	0.07	> 0.05
October	25	28	53	47.17	52.83	0.89:1	0.17	> 0.05
November	33	29	62	53.23	46.77	1.15:1	0.26	> 0.05
December	26	22	48	54.17	45.83	1.18:1	0.33	> 0.05
January, 1981	32	26	53	55.17	44.83	1.23:1	0.62	> 0.05
February	31	26	57	54.39	45.61	1.19:1	0.44	> 0.05
March	36	30	66	54.55	45.46	1.20:1	0.55	> 0.05
April	26	27	53	49.06	50.94	0.96:1	0.02	> 0.05
May	27	33	60	45.00	55.00	0.82:1	0.60	> 0.05
June	25	27	52	48.08	51.92	0.93:1	0.08	> 0.05
Total	334	329	663	50.38	49.62	1.02:1	0.04	> 0.05

Table 10. Sex ratio in _Portunus_ _sanguinolentus_ (size wise) in Cochin waters

Size group (in mm)	Female	Male	Total	% of female	% of male	Ratio F : M	Chi-square value	P
31-40	13	16	29	44.83	55.17	0.81:1	0.31	> 0.05
41-50	30	34	64	46.88	53.12	0.88:1	0.25	> 0.05
51-60	29	28	57	50.88	49.12	1.04:1	0.018	> 0.05
61-70	36	32	68	52.94	47.06	1.12:1	0.24	> 0.05
71-80	34	27	61	55.74	44.26	1.26:1	0.80	> 0.05
81-90	31	26	57	54.39	45.61	1.19:1	0.44	> 0.05
91-100	45	36	81	55.56	44.44	1.25:1	1.00	> 0.05
101-110	44	35	79	55.70	44.30	1.26:1	1.03	> 0.05
111-120	37	29	66	56.06	43.94	1.28:1	0.97	> 0.05
121-130	26	30	56	46.43	53.57	0.87:1	0.29	> 0.05
131-140	9	26	35	25.71	74.29	0.35:1	8.26	< 0.01
141-150	3	7	10	-	100.00	-	-	-
Total	334	329	663	50.38	49.62	1.02:1	0.04	> 0.05

Table 11. Sex ratio in Scylla serrata (month wise) in Cochin waters

Month	Female	Male	Total	% of female	% of male	Ratio F : M	Chi-square value	P
July, 1980	28	29	57	49.12	50.88	0.97:1	0.02	>0.05
August	24	25	49	48.99	51.01	0.96:1	0.02	>0.05
September	20	24	49	40.81	59.19	0.69:1	0.36	>0.05
October	33	30	63	52.38	47.62	1.10:1	0.14	>0.05
November	26	24	50	52.00	48.00	1.08:1	0.08	>0.05
December	32	31	63	50.79	49.21	1.03:1	0.02	>0.05
January, 1981	27	39	66	40.91	59.09	0.69:1	2.18	>0.05
February	28	40	68	41.18	58.82	0.70:1	2.12	>0.05
March	35	48	83	42.17	57.83	0.73:1	2.64	>0.05
April	30	39	69	43.48	56.52	0.77:1	1.17	>0.05
May	40	45	85	47.06	52.94	0.89:1	0.29	>0.05
June	35	37	72	48.61	52.39	0.95:1	0.06	>0.05
Total	358	411	769	46.55	53.45	0.87:1	3.65	>0.05

Table 12. Sex ratio in Scylla serrata (size wise) in Cochin waters

Size group (in mm)	Female	Male	Total	% of female	% of male	Ratio F : M	Chi-square value	P
71-80	16	13	29	55.17	44.83	1.23:1	0.31	> 0.05
81-90	16	18	34	47.06	52.94	0.89:1	0.12	> 0.05
91-100	25	23	48	52.08	47.92	1.09:1	0.08	> 0.05
101-110	33	28	61	54.10	45.90	1.18:1	0.41	> 0.05
111-120	35	30	65	53.85	46.15	1.17:1	0.38	> 0.05
121-130	48	40	88	54.55	45.45	1.20:1	0.73	> 0.05
131-140	35	43	78	44.87	55.13	0.81:1	0.82	> 0.05
141-150	40	55	95	42.11	57.89	0.73:1	2.37	> 0.05
151-160	41	55	96	42.71	57.29	0.75:1	2.04	> 0.05
161-170	40	55	95	42.11	57.89	0.73:1	2.37	> 0.05
171-180	21	29	50	42.00	58.00	0.72:1	1.28	> 0.05
181-190	5	12	17	29.41	70.59	0.42:1	2.88	> 0.05
191-200	2	10	12	16.67	83.33	0.20:1	5.33	< 0.05
Total	357	411	768	46.48	53.52	0.87:1	3.80	> 0.05

Table 13. Sex ratio in Scylla serrata serrata (month wise) in Cochin waters

Month	Female	Male	Total	% of female	% of male	Ratio F : M	Chi-square value	P
July, 1980	18	16	34	52.94	47.06	1.12:1	0.12	> 0.05
August	17	16	33	51.52	48.48	1.06:1	0.03	> 0.05
September	11	7	18	61.11	38.89	1.57:1	0.89	> 0.05
October	15	16	31	48.39	51.61	0.94:1	0.03	> 0.05
November	10	8	18	55.56	44.44	1.25:1	0.22	> 0.05
December	10	12	22	45.45	54.55	0.83:1	0.18	> 0.05
January, 1981	9	13	22	40.91	59.09	0.69:1	0.73	> 0.05
February	12	20	32	37.50	62.50	0.60:1	2.00	> 0.05
March	14	17	31	45.16	54.84	0.82:1	0.29	> 0.05
April	12	13	25	48.00	52.00	0.92:1	0.04	> 0.05
May	16	20	36	44.44	55.56	0.8:1	0.44	> 0.05
June	16	14	30	53.33	46.67	1.14:1	0.13	> 0.05
Total	160	172	332	48.19	51.81	0.93:1	0.43	> 0.05

Table 14. Sex ratio in <u>Scylla serrata serrata</u> (size wise) in Cochin waters

Size group (in mm)	Female	Male	Total	% of female	% of male	Ratio F : M	Chi-square value	P
66-70	6	8	14	42.86	57.14	0.75:1	0.28	> 0.05
71-75	14	12	26	53.85	46.15	1.17:1	0.15	> 0.05
76-80	12	11	23	52.17	47.83	1.09:1	0.04	> 0.05
81-85	10	7	17	58.82	41.18	1.43:1	0.53	> 0.05
85-90	8	10	18	44.44	55.56	0.80:1	0.22	> 0.05
91-95	13	15	28	46.43	53.57	0.87:1	0.14	> 0.05
96-100	11	12	23	47.83	52.17	0.92:1	0.04	> 0.05
101-105	14	12	26	53.85	46.15	1.17:1	0.15	> 0.05
106-110	22	21	43	51.16	48.84	1.05:1	0.02	> 0.05
111-115	22	19	41	53.66	46.34	1.16:1	0.22	> 0.05
116-120	21	20	41	51.22	48.78	1.05:1	0.02	> 0.05
121-125	7	11	18	38.89	61.11	0.64:1	0.89	> 0.05
126-130	-	6	6	-	100.00	-	-	-
131-135	-	8	8	-	100.00	-	-	-
Total	160	172	332	48.20	51.80	0.93:1	0.43	> 0.05

Table 15. Sex ratio in _Podopthalmus vigil_ (month wise) in Porto Novo waters

Month	Female	Male	Total	% of female	% of male	Ratio F : M	Chi-square value	P
September, 1978	42	29	71	59.15	40.85	1.45:1	2.38	> 0.05
October	40	26	66	60.61	39.39	1.54:1	2.97	> 0.05
November	25	17	42	59.52	40.48	1.47:1	1.52	> 0.05
December	24	17	41	58.54	41.46	1.41:1	1.20	> 0.05
January 1979	41	24	65	63.08	36.92	1.71:1	4.45	< 0.05
February	24	20	44	54.55	45.45	1.20:1	0.36	> 0.05
March	21	22	43	48.84	51.16	0.95:1	0.02	> 0.05
April	17	26	43	39.52	60.47	0.65:1	1.88	> 0.05
May	39	37	76	51.32	48.68	1.05:1	0.05	> 0.05
June	28	34	62	45.16	54.84	0.82:1	0.58	> 0.05
July	27	33	60	45.0	55.0	0.82:1	0.60	> 0.05
August	32	27	59	54.24	45.76	1.19:1	0.42	> 0.05
Total	360	312	672	53.57	46.43	1.15:1	3.42	> 0.05

Table 16. Sex ratio in Podopthalmus vigil (size wise) in Porto Novo waters

Size group (in mm)	Female	Male	Total	% of female	% of male	Ratio F : M	Chi-square value		P
56-60	38	32	70	54.29	45.71	1.19:1	0.51	>	0.05
61-65	29	25	54	53.70	46.30	1.16:1	0.30	>	0.05
66-70	30	22	52	57.69	42.31	1.36:1	1.23	>	0.05
71-75	32	26	58	55.17	44.83	1.23:1	0.62	>	0.05
76-80	48	29	77	62.34	37.66	1.66:1	5.50	<	0.05
81-85	49	.40	89	55.06	44.94	1.23:1	0.91	>	0.05
86-90	51	38	89	57.30	42.70	1.34:1	1.90	>	0.05
91-95	49	32	81	60.49	39.51	1.53:1	3.57	>	0.05
96-100	25	21	46	54.35	45.65	1.19:1	0.35	>	0.05
101-105	9	20	29	31.03	68.97	0.45:1	4.17	<	0.05
105-110	-	14	14	-	100.00	-	-		
111-115	-	13	13	-	100.00	-	-		
	360	312	672	53.57	46.43	1.15:1	3.43	>	0.05

Table 17. Sex ratio in _Thalamita crenata_ (month wise) in Porto Novo waters

Month	Female	Male	Total	% of female	% of male	Ratio F : M	Chi-square value	P
September, 1978	15	16	31	48.39	51.61	0.94:1	0.03	> 0.05
October	31	28	59	52.54	47.46	1.11:1	0.15	> 0.05
November	22	24	46	47.83	52.17	0.92:1	0.09	> 0.05
December	37	41	78	47.44	52.56	0.90:1	0.21	> 0.05
January, 1979	42	30	72	56.94	43.06	1.32:1	2.0	> 0.05
February	25	15	40	62.50	38.50	1.62:1	2.50	> 0.05
March	25	22	47	53.19	46.81	1.15:1	0.19	> 0.05
April	23	24	47	48.94	51.06	0.96:1	0.02	> 0.05
May	31	28	59	52.54	47.46	1.11:1	0.15	> 0.05
June	22	24	46	47.83	52.17	0.92:1	0.09	> 0.05
July	23	25	48	47.92	52.08	0.92:1	0.08	> 0.05
August	18	20	38	47.37	52.63	0.90:1	0.11	> 0.05
Total	315	297	611	51.55	49.45	1.04:1	0.59	> 0.05

Table 18. Sex ratio in _Thalamita crenata_ (size wise) in Porto Novo waters

Size group (in mm)	Female	Male	Total	% of female	% of male	Ratio F : M	Chi-square value	P
21-25	8	9	17	47.06	52.94	0.89:1	0.05	> 0.05
26-30	29	28	57	50.88	49.12	1.04::1	0.02	> 0.05
31-35	40	35	75	53.33	46.67	1.14:1	0.33	> 0.05
36-40	40	43	83	48.19	51.81	0.93:1	0.11	> 0.05
41-45	48	42	90	53.33	46.67	1.14:1	0.40	> 0.05
46-50	53	40	93	56.98	43.02	1.32::1	1.82	> 0.05
51-55	41	36	77	53.25	46.75	1.14::1	0.32	> 0.05
56-60	40	35	75	53.33	46.67	1.14::1	0.33	> 0.05
61-65	15	22	37	40.54	59.45	0.68:1	1.32	> 0.05
66-70	0	7	7	-	100.00	-	-	
Total	314	297	611	51.39	48.61	1.06:1	0.47	> 0.05

Fig 4. Size frequency distribution in

a - _Portunus pelagicus_

b - _P. sanquinolentus_

c - _Scylla serrata_

d - _S. serrata serrata_

e - _Podopthalmus vigil_

f - _Thalamita crenata_

Fig 5. Size at first maturity in

        a - _Portunus pelagicus_

        b - _P. sanguinolentus_

        c - _Scylla serrata_

        d - _S. serrata serrata_

        e - _Podopthalmus vigil_

        f - _Thalamita crenata_

Fig 6. Sex ratio (monthwise and sizewise) in

a - Portunus pelagicus

b - P. sanguinolentus

c - Scylla serrata

Fig 7. Sex ratio (monthwise and sizewise) in

    a -' Scylla serrata serrata

    b - Podopthalmus vigil

    c - Thalamita cronata

Fig 8.   Annual reproductive cycle in
         Portunus pelagicus

              a - Percentage of berried females
                  against time

              b - Gonado and hepato somatic indices
                  in female

              c - Gonado and hepato somatic indices
                  in male

         Annual reproductive cycle in
         P. sanguinolentus

              d - Percentage of berried females
                  against time

              e - Gonado and hepato somatic indices
                  in female

              f - Gonado and hepato somatic indices
                  in male

Fig 9. Annual reproductive cycle in <u>Scylla serrata</u>

    a - Percentage of berried females
       against time

    b - Gonado and hepato somatic indices
       in female

    c - Gonado and hepato somatic indices
       in male

Annual reproductive cycle in
<u>S. serrata serrata</u>

    d - Percentage of berried females
       against time

    e - Gonado and hepato somatic indices
       in females

    f - Gonado and hepato somatic indices
       in males

Fig 10. Annual reproductive cycle in
Podopthalmus vigil

     a - Percentage of berried females
       against time

     b - Gonado and hepato somatic indices
       in females

     c - Gonado and hepato somatic indices
       in males

Annual reproductive cycle in
Thalamita crenata

     d - Percentage of berried females
       against time

     e - Gonado and hepato somatic indices
       in female

     f - Gonado and hepato somatic indices
       in males

Fig 11. Breeding pattern in

a - _Portunus pelagicus_

b - _P. sanguinolentus_

c - _Scylla serrata_

d - _S. serrata serrata_

e - _Podopthalmus vigil_

f - _Thalamita crenata_

REPRODUCTION

FIG.4

FIG. 5

FIG. 6

FIG. 7

FIG. 8
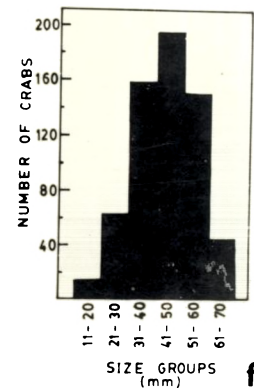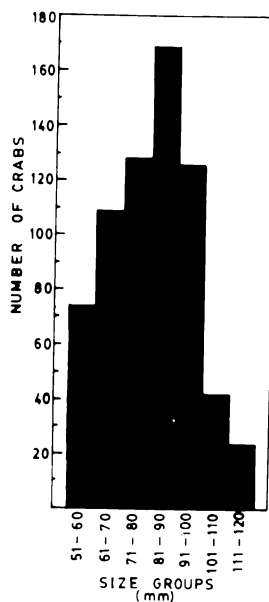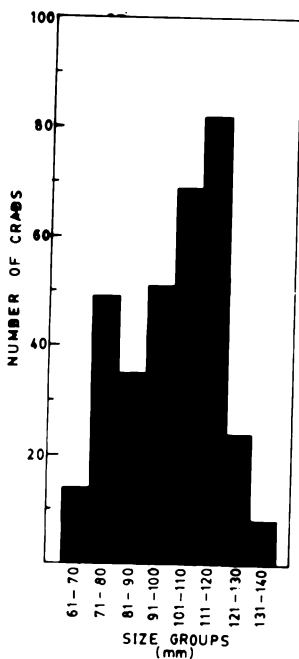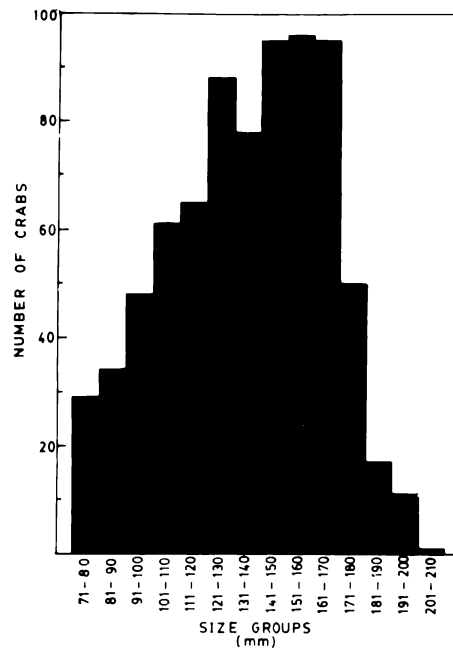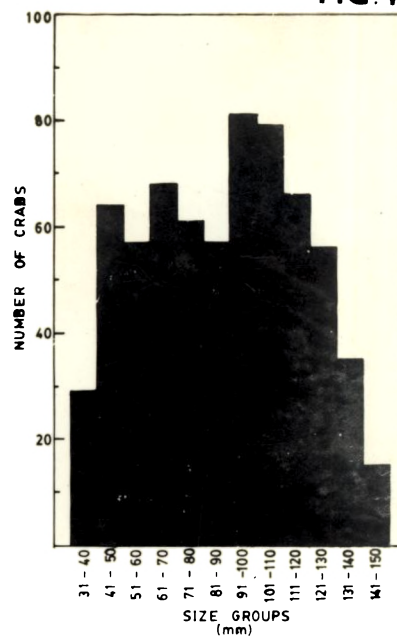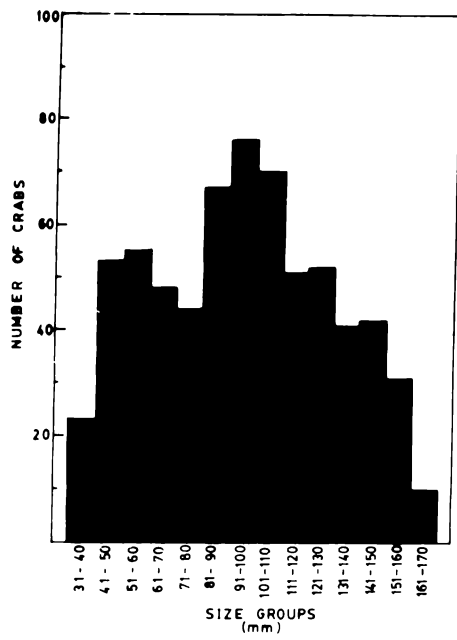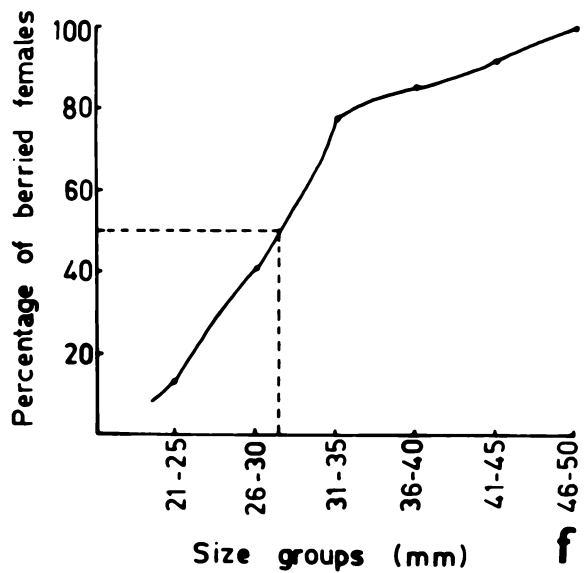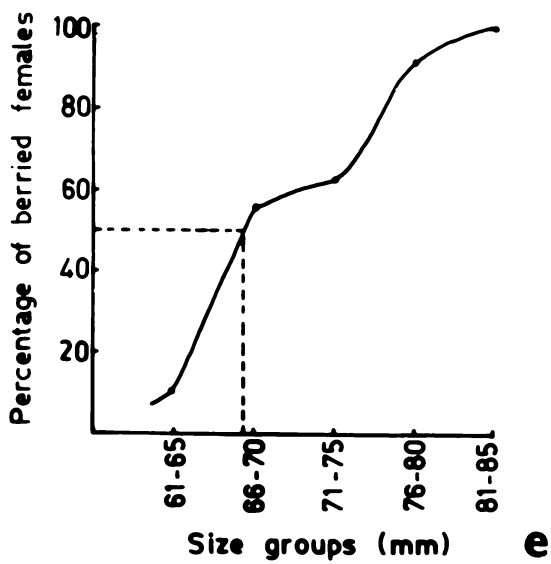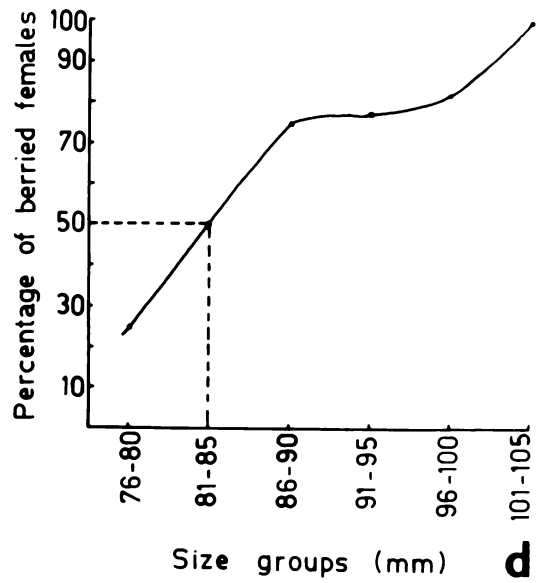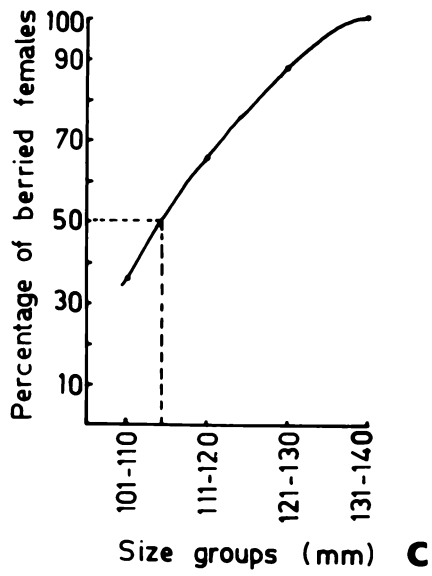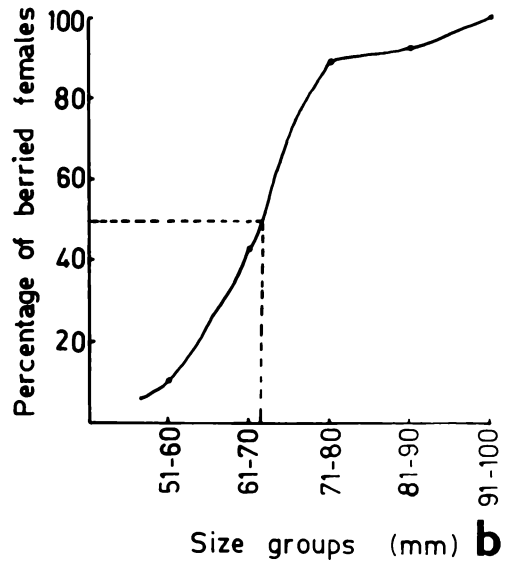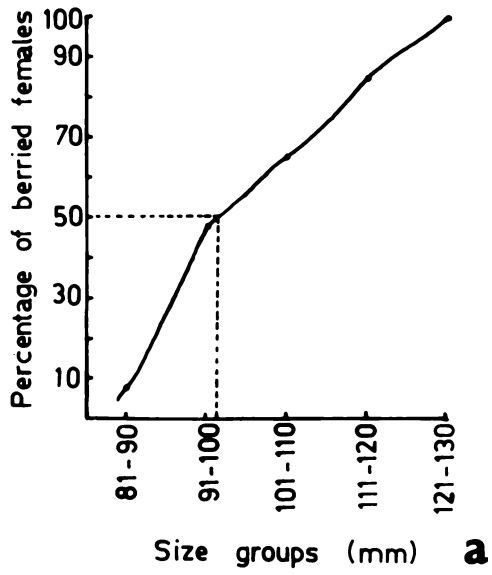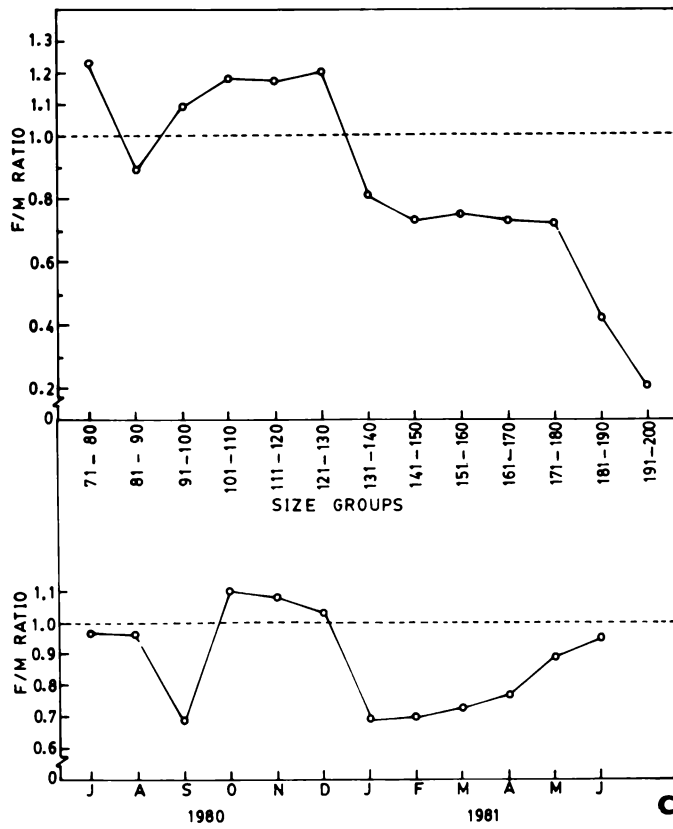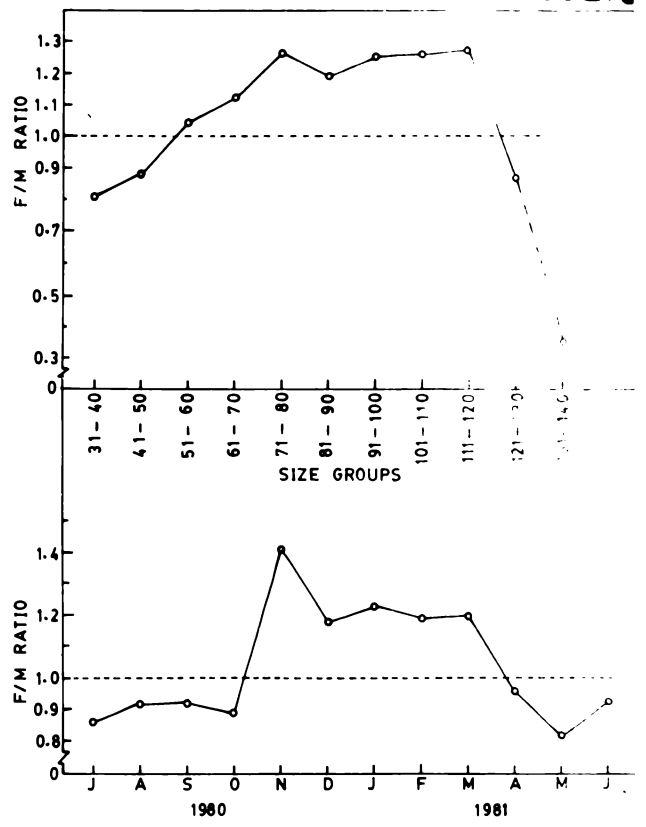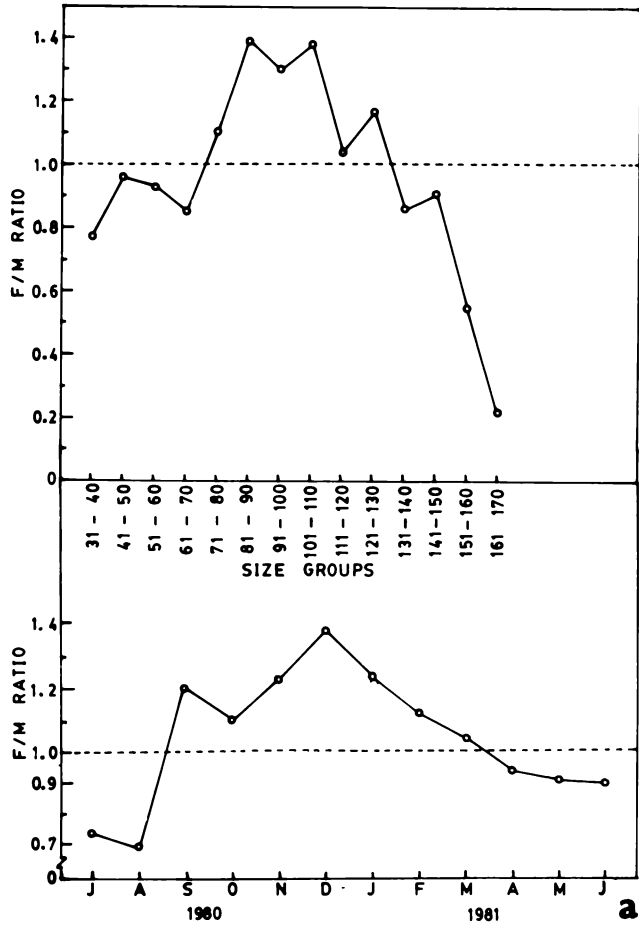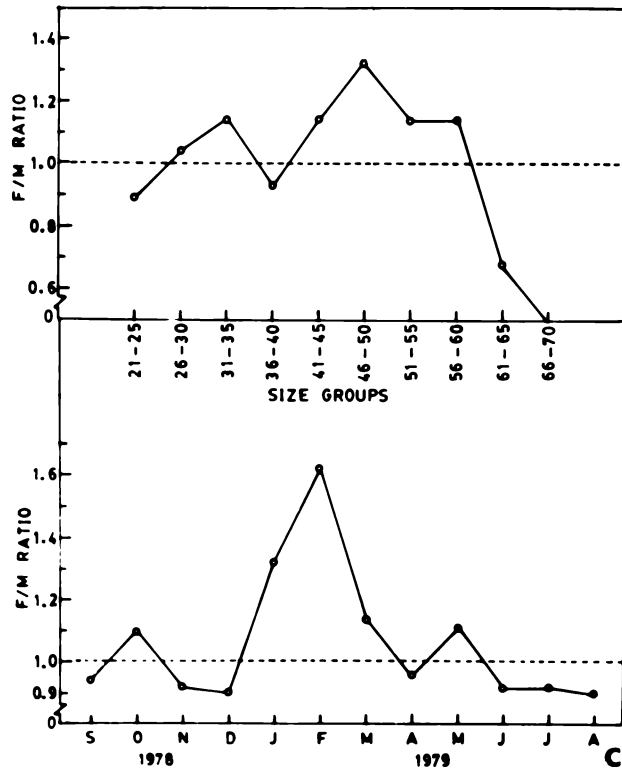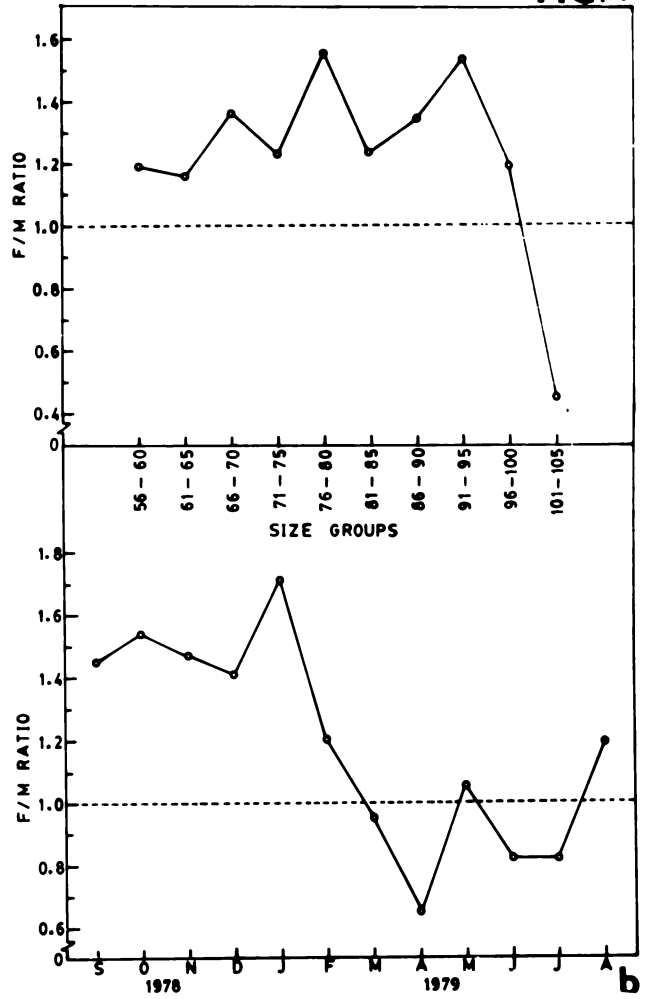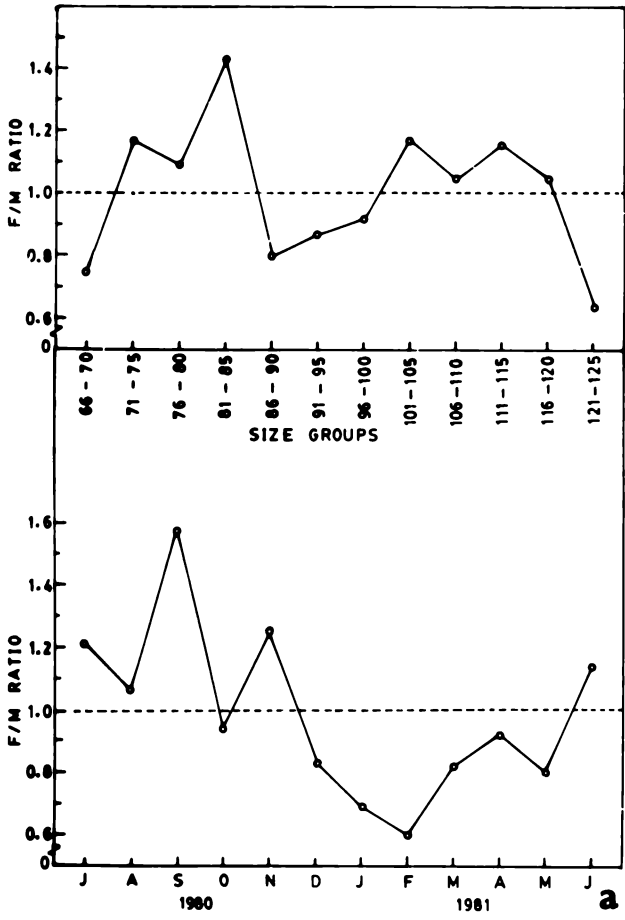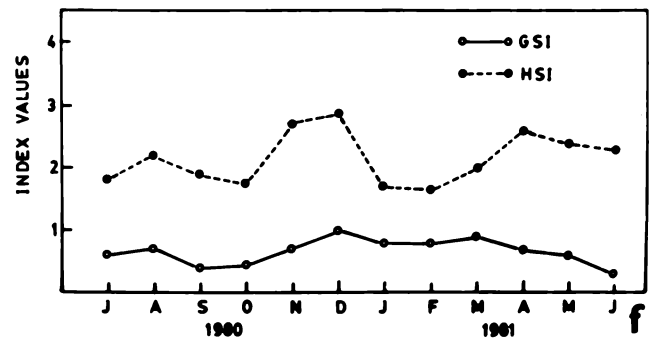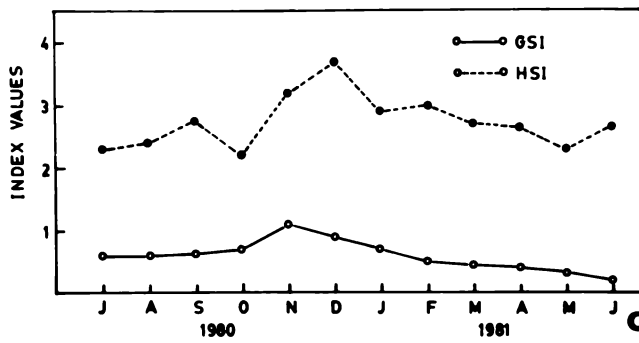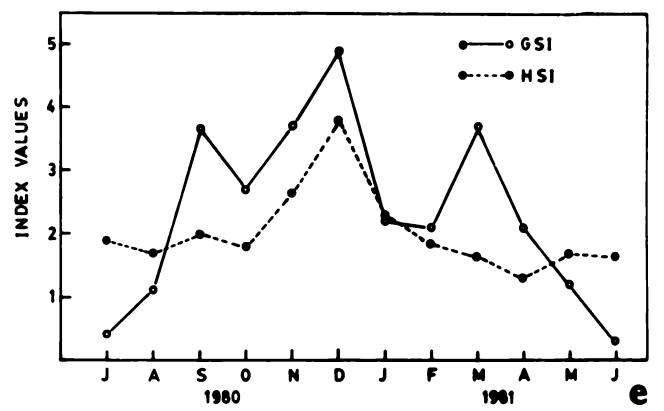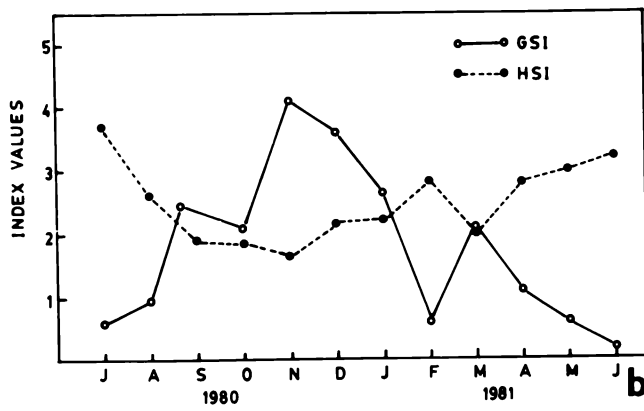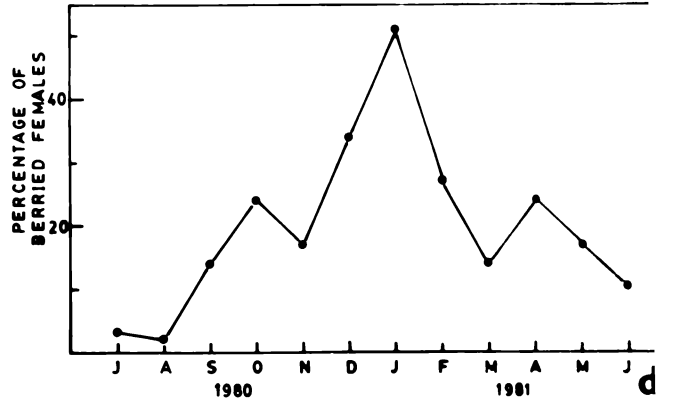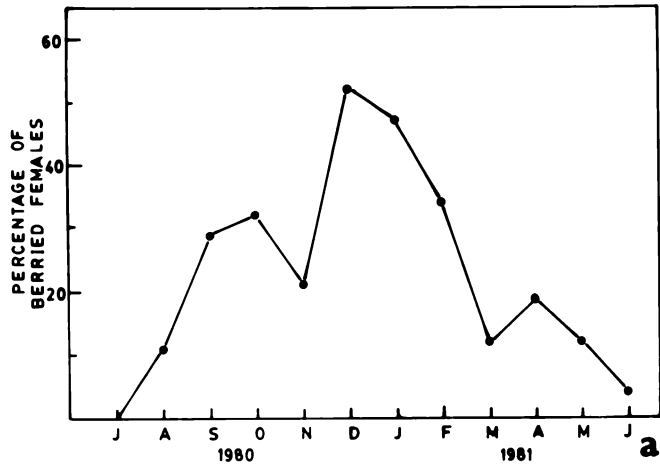
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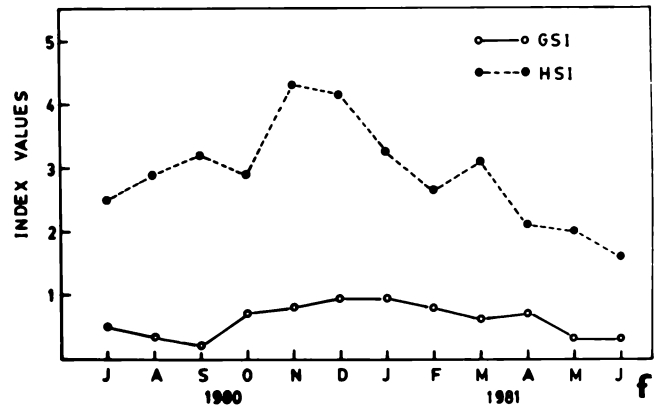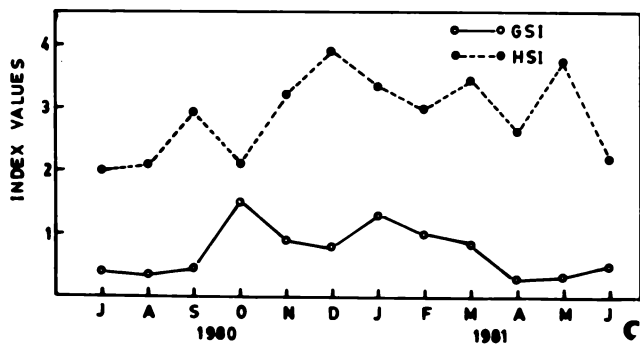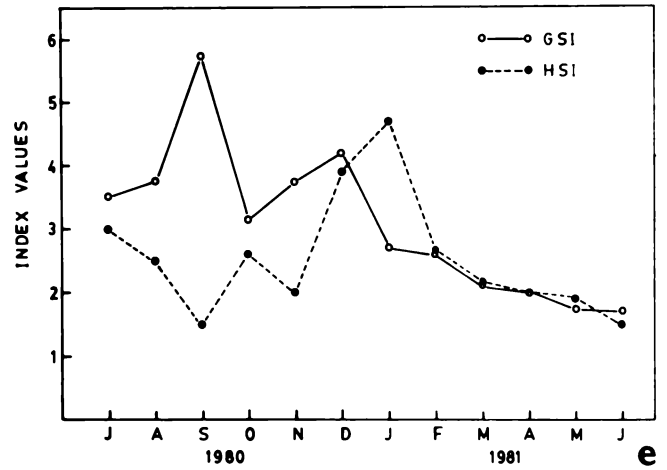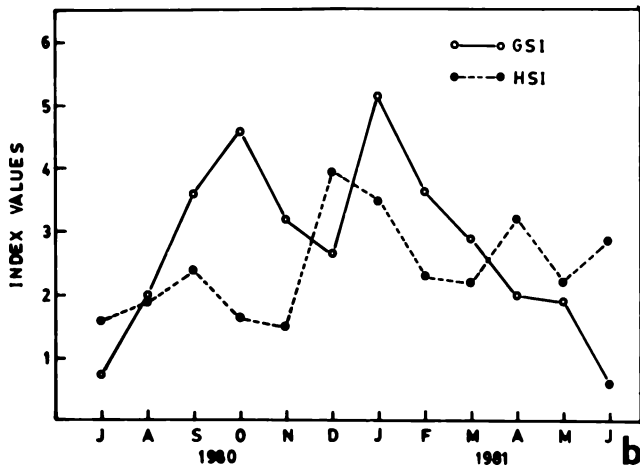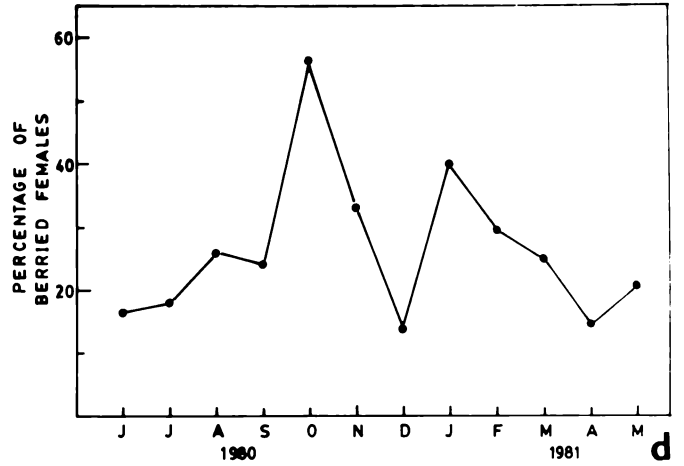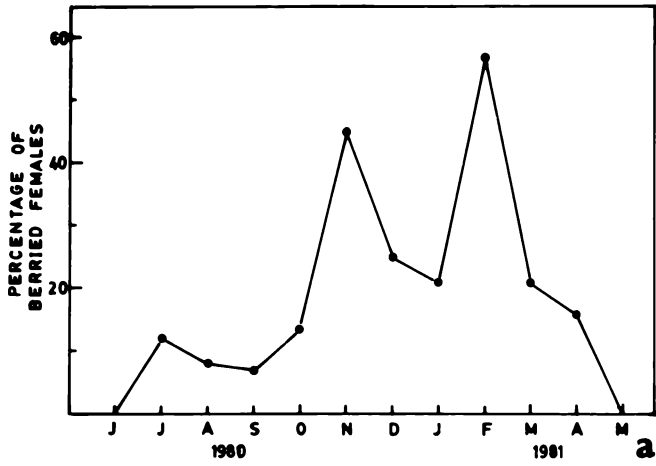
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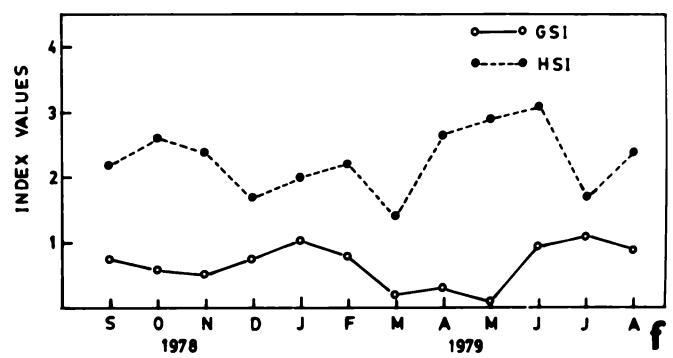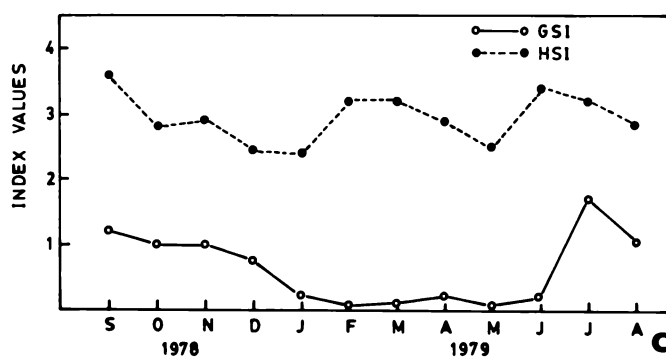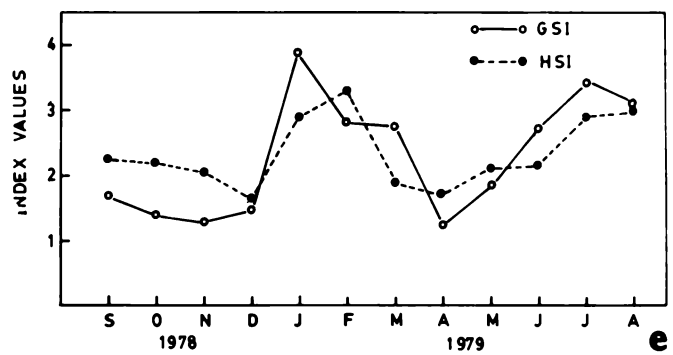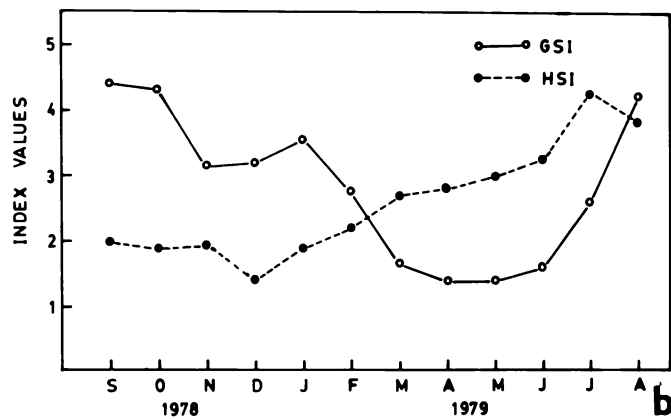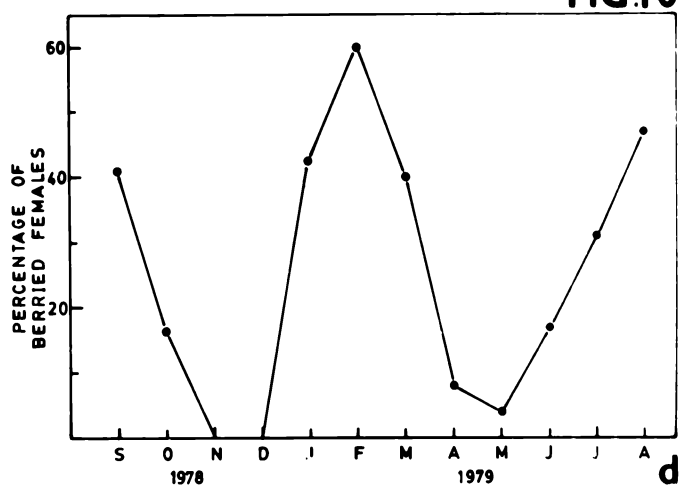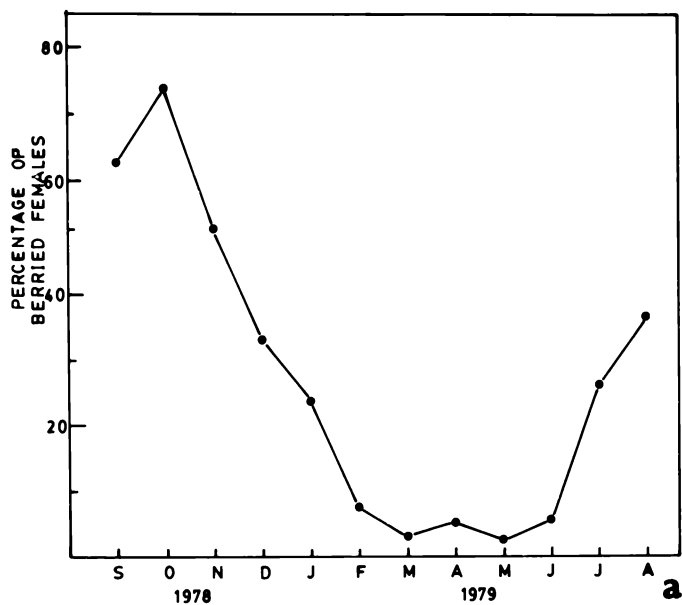
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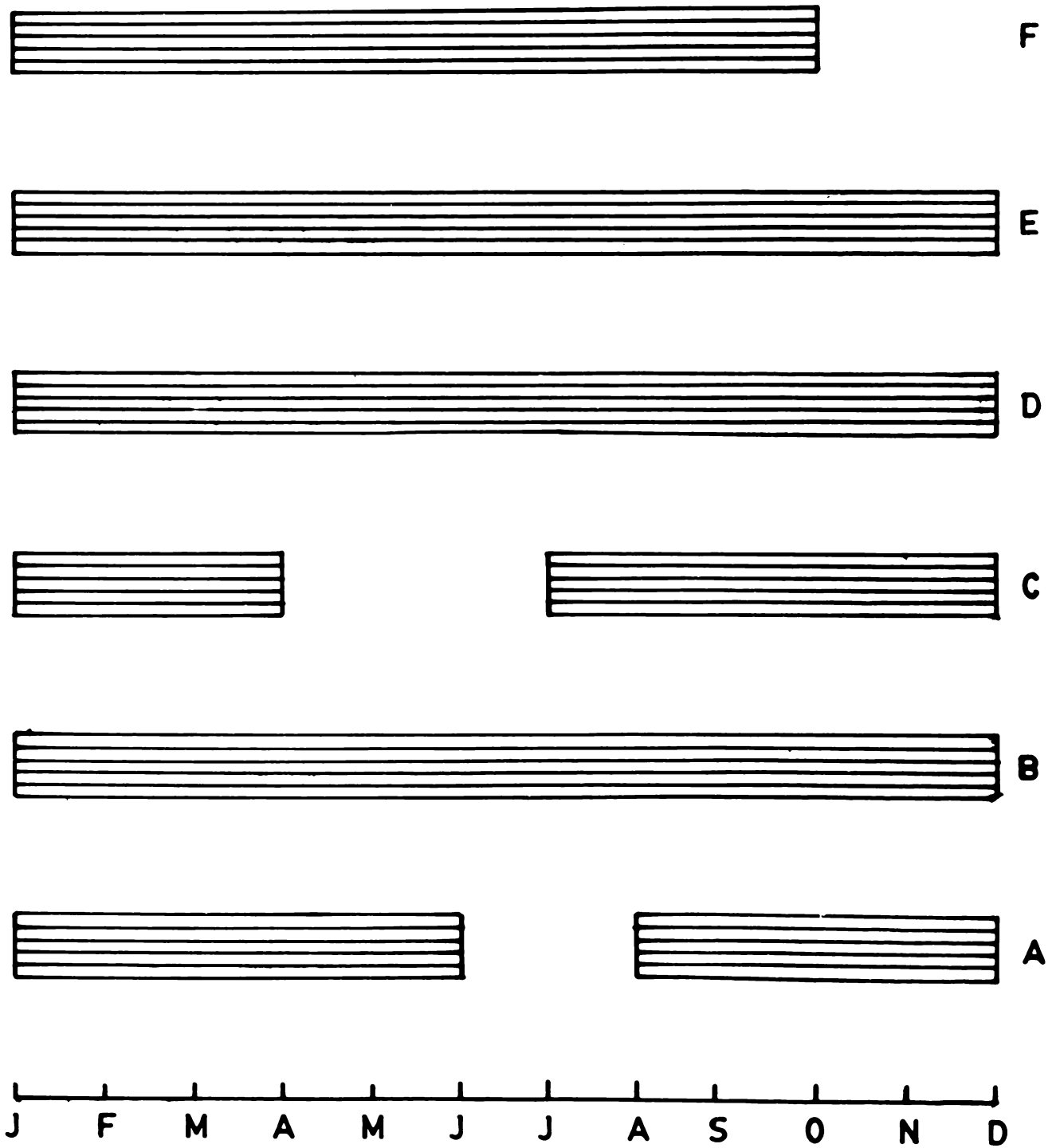
AGE AND GROWTH

3.1   INTRODUCTION

Perusal of age and growth studies is aimed at understanding the nature of the stock and the role played by various year classes in the nature of the fishery. It also forms the basis for calculations leading to our knowledge on growth, mortality, survival rate, recruitment and dynamics of the population.

Age and growth studies in crabs have the following implications:

(1) The age at which the crab attains sexual maturity, duration of breeding and how soon a fresh stock of young ones reproduce?

(2) It may help to know about the effects of environmental parameters through comparision of the rates of growth in different bodies of water.

(3) It can indicate suitability of the rate of stocking.

(4) Continuous study on age and growth in particular bodies of water will reveal the fluctuations from year to year and over period of years.

Three general methods for determining the growth of crabs are available:

(1) Length frequency distribution;

(2) Rearing individuals in ideal field conditions;

and (3)Marking studies.

Since crabs, just like any other marine inverte-
brates lack hard parts like otoliths or scales as in
fishes, the above methods are only used.

Age and growth studies in crabs have been done
in the following species: Halicarcinus australis (Lucas
and Hodgekin, 1970), Cyclograpsus punctatus (Broekhuysen,
1941), Aratus pisoni (Warner, 1967), Rithropanopeus
harrisii (Turaboyski, 1973), Pachygrapsus crassipes (Hiatt,
1948), Carcinus maenas (Crothers, 1967), Callinectes
sapidus (Tagatz, 1968), Paralithodes camtschatica (Hoopes
and Karinen, 1972), Cancer magister (Butter, 1961) and
C. pagurus (Bennet, 1974). All the above works are from
foreign waters. From Indian waters, no detailed study
on age and growth is available for crabs. Hence the
present study on five species and one subspecies of
commercially important crabs.

The size frequency method, months mode curve,
probability plot and von Bertalanffy's method were
presently used to assess the growth and life span in five
species and one subspecies of crabs. The reason for taking
up these crabs is in lieu of their commercial importance.
Vital information regarding age and growth will go a long
way in the development and management of the fishery
constituted by these animals.

3.2   MATERIALS

For the present study, the materials were collected from the commercial catches. Commercial catches from Cochin and Porto Novo waters included specimens caught by different gears and thus the samples presently collected did not involve any bias that may be introduced by collection of samples from a single gear. As the carapace width is a more reliable character than the carapace length in the case of crabs, the former was used for this study. The animals were conveniently divided into 15-20 size groups and the percentage frequency of each size group was calculated and used in the analyses.

METHOD

Age Evaluation

Size frequency method (Petersen, 1891)

This method has been widely employed for age and growth studies. The principle underlying this method may be summarized as follows:

(1)The lengths of individuals of each age group or brood are approximately 'normally' distributed ideally in a population with restricted spawning season.

(2)Growth is such that the modes of the length distribution of successive age groups or broods in samples taken from the population are separated along the length

axis and may be readily distinguished.

(3)When length frequency distribution of a sample containing a number of age groups or broods is drawn, a polymodal curve is obtained; the separate modes represent the approximate mean size of the constituent age groups.

This method is useful to find the average size of the earlier year classes; with advance in age, growth slows down which results in overlapping of modes and makes it difficult to separate them in the case of forms without a short or restricted spawning. A possible way is however to trace the monthly growth rate in different stages and to compute from this, approximately the average size for different ages.

Presently the percentage frequency of occurrence was plotted against size groups to trace the average size of different year classes of crabs.

Months mode curve:

The length frequency method based on a scatter diagram of modes as adopted by Devaraj (1977) and Sriraman (1978) has been followed to identify various broods in a year and their rate of growth. By fixing a free hand line, the course of progression of the mode lying closest to the time axis was traced and then in order to trace the time of brood origin this line was extrapolated with reference to the intermodal slope so as to intersect the

time axis. This trend line leading from the time axis to
the highest modal value in the series was the first guide-
line for tracing the growth history of the still older
broods. When many similar trend lines were fitted, each
one acted as a guideline for tracing the growth history of
the much older broods.

Probability technique

Length frequency analysis has recently been
given a wider applicability by the use of 'Probability
Paper' to help separate age groups (Ricker, 1968).
Harding (1949) described a method by which probability
paper could be made use of in solving bimodal or polymodal
frequency distribution. This method was later improved by
Cassie (1954) whose work eliminated some of the difficul-
ties encountered earlier. A greater degree of success and
accuracy was attained in sorting out different size groups,
resulting from the contribution of various broods. By
using probability paper, which gives a wider range of
points for fitting a curve, many of the overlapping flanks
could be easily detected. The saw tooth form of frequency
polygon assume a regular appearance since the points auto-
matically assume regular appearance when plotted following
this technique.

The data collected for Petersen's method for all
the crabs were utilised for this technique. In this study

the percentage frequency of occurrence during all months
of the year were pooled separately for each species. The
cumulative percentage occurrence for different size groups
was plotted in the arithmatic probability paper in order
to note the points of inflexion.

Growth Evaluation

von Bertalanffy's equation:

Fitting of growth curves by mathematical expres-
sion is of particular advantage in interpolation and extra-
polation, in addition to their utility in production computa-
tions (Pantalu, 1963). von Bertalanffy (1938, '49, '57)
derived a mathematical model to calculate the length of
animals at any given time. This equation is based on the
concept of growth as the net result of the interaction of
two opposing processes such as those tending to increase
the mass (anabolism) and those tending to decrease it
(catabolism), thus giving a growth curve fitting well with
the growth rates of many species of organisms (Beverton,
1954; Beverton and Holt, 1957). The equation can be
written as: $Lt = L\infty(1-e^{-k(t-to)})$

where   Lt = Length at age t

   $L\infty$ = asymptotic length

   e   = base of Neparian or natural logarithm

   k   = coefficient of catabolism

t = age of fish

to = arbitrary origin of growth curve

This equation was fitted to find the growth rate in five species and one subspecies of crabs.

Ford-Walford Graph:

The geometric interpretation of growth in length has been developed independently by Ford (1933) and Walford (1946), which is similar in pattern to that given by von Bertalanffy. Ford-Walford method is based on the assumption that the successive increments added to the length, decrease in magnitude in geometric progression till a limiting total length is approached. To fit this growth equation to length at age data, an empirical expression was developed by substituting Lt + 1' for 't'. The equation can then be written as

$$Lt + 1 = L\infty(1-e^{-k}) + e^{-k} \ lt$$

By plotting 'Lt+1' against 'Lt', a graph represented well by a straight line for all the five species and one subspecies of crabs was drawn. A least square line has been fitted and the point of intersection of least square line with the bisector drawn through the origin, gave the estimate of L∞. The value of 'to' was calculated by the formula

$$- to = 1/k \ (log \ e \ L \ -log \ e \ (L\infty -Lt)-t$$

3.3   RESULTS

Age evaluation

Length frequency method:

P. pelagicus: The length frequency curves for the period
July 1980 - June 1981 is shown in Fig. 12 in the form of
histograms. In this species new modes appeared every month
out of which the earliest mode at 42.5 mm in May 1981 could
be traced upto the mode at 132.5 mm again in May, attain-
ing a length of 90 mm in a period of 12 months. Because
of the recruitment for an extended period it was not
possible to trace other modes.

P. sanguinolentus: Length frequency distribution for the
period July 1980 to June 1981 is shown in the form of
histograms (Fig. 13). Here also modes appeared every
month due to the continuous breeding habit of this crab.
Among them the earliest mode at 47.5 mm in May 1981 could
be traced upto a size of   127.5 mm again in May thus
registering a growth of 80 mm in an year. Further modes
could not be traced due to the continuous recruitment.

S. serrata: Length frequency distribution for the period
of one year is shown in the form of histograms (Fig. 14).
This species was found to breed for an extended period
of time and modes could be seen for all the months. So
modal tracing in this species could not be done.

66

S. serrata serrata: Percentage distribution of different size groups for the one year period (July 1980 - June 1981) is given in Fig. 15 in the form of histograms. Due to the continuous breeding habit of this crab modes could be seen every month. In this the earlier mode at 72.5 mm in July 1980, was traced upto 117.5 mm in January, showing a growth of 45 mm in 6 months, thus registering a growth of 90 mm in one year. For the second year, the brood was traced from 92.5 mm in January to 117.5 mm again in January showing a growth of 25 mm in an year. This added with I year growth comes to 115 mm in II year. Further modes could not be traced.

P. vigil: Length frequency distribution for the period of one year from September 1977 to August 1978 is given in the form of histograms (Fig. 16). This species was found to breed continuously, the intensity of breeding being heavy just prior to and during northeast monsoon and the modes were found in all the months. So modal tracing in this species was not possible.

T. crenata: Percentage frequency distribution of different size groups for the period of one year from September 1977 to August 1978 is given in the form of histograms (Fig. 17). This species was found to breed for an extended period of time not lasting the whole year round. Due to extended

breeding of this species modes could be seen in all the months. In this, the earliest mode noted in the size group 21-23 mm in November, 1977 could be traced to a mode in the size group of 48-50 mm during August 1978, thus indicating a growth of 27 mm in 9 months thereby showing a growth rate of 36 mm in the first year. Subsequent modes could not be traced due to continuous recruitment. Thus presently length frequency distribution studies in crabs yielded some clue regarding age in three species and one subspecies of crabs (P. pelagicus, P. sanguinolentus, S. serrata serrata and T. crenata) and in other two species (S. serrata and P. vigil) age could not be traced.

Hence other methods were followed to compare and check the findings of one method over the other.

Months mode curve:

The progression of modes through successive months along a series of trend lines, representing the rate of growth of various broods is summarised for all the five species and one subspecies of crabs in Figs. 18-20. Mean growth based on the value of various broods and the missing values found from the fitted line can be read from the figures.

P. pelagicus (Fig. 18a,b): As per findings of this method, the size attained by this species was 72, 108 and 150 mm

during the I, II, III year of life respectively. The time (in days) involved between successive broods and the mean time value between the successive brood origins could also be derived. It can be seen that there were 3 broods in an year.

P. sanguinolentus (Fig. 18c,d): Through this method, a growth of 65, 105 and 141 mm was derived for I, II and III year of the life respectively. Here also there were 3 broods in an year.

S. serrata (Fig. 19a,b): A growth of 112,5, 151,5 and 187,5 mm was derived for I, II and III year of life respectively, 3 broods were noticed in an year.

S. serrata serrata (Fig. 19c,d): A growth of 88,5, 110 and 130 mm was derived for I, II and III year of life respectively. 3 broods were noticed in an year.

P. vigil (Fig. 20a,b): The growth was 73, 89 and 104 mm for I, II and III year of life respectively. Here also as in the case of all the previous species, 3 broods were noticed for an year.

T. crenata (Fig. 20c,d): The life span of this crab appears to be 3 years and above but below 4 years. Three broods could be seen per year. The size attained was 34, 51 and 64 mm during I, II and III year of life respectively.

The problems usually encountered in the interpretation of modes are:

(1)Length frequency distribution of each group is not always uniform and normal, as a result of which the separation of modes is difficult. The prolonged breeding and selection of a particular gear also cause variation. However length frequency distribution on large random samples, as done presently and collected from different gears over a long period, often may be fairly reliable.

(2)Unless the age at first capture by sampling gear is known, it is difficult to assign successive modes to specific broods.

Probability plot:

This method is quite ideal for species with prolonged breeding season, as this is not possible by Petersen method. Secondly, certain year classes may not be represented in the commercial catches and overlapping of distribution of older size groups is likely to yield erroneous results by Petersen method. Hence this method.

P. pelagicus: In this species, the probability curve showed points of inflexion at 20, 60 and 92 (Fig. 21a). It was found that the I modal size value representing the '0' year class was 44 mm. The II, III and IV modes at

82, 123.5 and 152.5 mm represented the I, II and III year age groups respectively.

P. sanquinolentus: The probability curve showed points of inflexion at 20, 60 and 94 (Fig. 21b). It was found that the first modal size value representing the 'O' year class was 42.5 mm. The II, III and IV modes at 74, 109.5 and 133 mm represented the I, II and III year age groups respectively.

S. serrata: Points of inflexion in the probability curve were seen at 10, 60 and 95 (Fig. 21c). It could be seen that the first modal size value at 81.5 mm represents 'O' year. Further modes at 117, 157 and 182 mm represented I, II and III year age groups respectively.

S. serrata serrata: 22, 60 and 94 (Fig. 22a) were the points of inflexion in the probability curve modal size values at 71, 95.5, 112 and 126 mm representing O, I, II and III year of age in life respectively.

P. vigil: The points of inflexion in the probability curve were seen at 26, 70 and 94 (Fig. 22b). Modal size values at 59.5 mm represented the O year class. The II, III, IV modes at 79, 95 and 108 mm represented the I, II and III year age groups respectively.

T. crenata: The probability plot produced from the length frequency data (Fig. 22c) shows that the life span of crab is 3 years and above. 0 year class attained 24 mm, I year class 35.2 mm, II year class 52 mm and III year class 62.2 mm.

This technique suffers from the set back in distinguishing the points of inflexion in the cumulative percentage curve. In some cases, arbitrary choice of the limits of component groups would have to be made if these points are not distinct. Pantulu (1962) stated that, despite limitation, this is still a useful tool. By trial and error, a fairly accurate choice of points is however possible. Once the points of inflexion are determined the rest of the process is easy and purely mechanical as found presently.

Growth evaluation

von Bertalanffy's equation:

Based on the values of parameters the growth equation for all the crabs have been calculated.

P. pelagicus: By using this equation, asymptotic length or maximum length attainable was found to be 394.68 mm; age at the origin of growth curve -0.9675 and coefficient of katabolism 0.1231. Presently age and corresponding length of animals obtained from probability plot method has been used to von Bertalanffy's growth curve. The

von Bertalanffy's equation for growth in this species can
be given as

$$Lt = 394.68 (1-e^{-0.1231} (t+0.9675))$$

The theoretical growth curve for this species is presented
in Fig. 23a. From this growth curve it can be observed
that the I year crabs attain 72 mm, II year ones 130 mm
and III year specimens 154 mm.

In the same way the following is the von
Bertalanffy's growth equation for all the other crabs:

P. sanguinolentus

$$Lt = 318.63 (1-e^{-0.1327} (t+1.0793))$$

S. serrata

$$Lt = 359.00 (1-e^{-0.1510} (t+1.7071))$$

S. serrata serrata

$$Lt = 162.94 (1-e^{-0.3031} (t+1.8796))$$

P. vigil

$$Lt = 166.18 (1-e^{-0.2021} (t+2.1935))$$

T. crenata

$$Lt = 78.21 (1-e^{-0.4941} (t+0.2110))$$

From the theoretical growth curves (Fig. 23) of above
five crabs, it can be observed that P. sanguinolentus
attains growth of 77, 107 and 133 mm at the age of I,
II and III years respectively, S. serrata 118, 162 and
180 mm at the age of I, II and III respectively S. serrata
serrata, 96, 114 and 126 mm at the age of I, II and III

respectively, P. vigil, 75, 92, 105 mm at the age of I, II and III respectively and T. crenata, 35.29, 52.17 and 62.57 mm at the age of I, II and III respectively.

Ford-Walford Graph:

Through this method L_∞ was determined for all the six crabs presently (Fig. 23). The L_∞ for P. pelagicus, P. sanguinolentus, S. serrata, S. serrata serrata, P. vigil and T. crenata was found to be 395, 318, 360, 160, 160 and 78 mm respectively.

3.4   DISCUSSION

Determination of age and growth based on a single method has its own limitation especially when the determination of age and growth is through

indirect methods or through statistical analysis as this. So, presently age and growth study in five species and one subspecies has been done through five statistical methods so that the outcome of one method will act as a check and control over the other. For easy comparison, the results of age and growth by different methods in all the five species and one subspecies of crabs are presented in Tables 19-24. Age and growth estimated by various methods showed that the information derived agree in two or more methods. The empirical length at different ages, made by

von Bertalanffy's growth equation show some agreement with the estimates by other methods, showing that, in the length ranges studied, the theoretical growth equation adequately describes actual growth. When comparing the growth rate of all the crabs, growth rate of S. serrata was more than any other species though the life span for all the species is 3 years. Warner (1977) compiled information regarding the size of (Carapace width) full grown males with their age. In most of the crabs age was found to vary from 1 to 5 years. But in two crabs the age was found to be as much as 17 or 15-20 years (Paralithodes camtschatica - 17 years and Cancer pagurus -15-20 years).

Both these species happen to be temperate forms (Hoopes and Karinen, 1972; Bennet, 1974) and it has been documented well that, temperate and polar forms live for more number of years than those of the tropics. In the present study from tropics, it could be seen that all the six crabs life for 3 years.

The consequences of the presence of an exoskeleton in crustaceans is that in these forms growth proceeds in steps by a series of moults or ecdyses. This makes the study of crab growth under natural condition quite difficult since it is not possible to mark individuals and successfully follow them through several moults. The number of moults a crab undergoes before becoming full

grown depends on the increment at each moult and the
frequency of moulting. The increment at each moult is
generally expressed as a percentage of a premoult dimension
such as carapace width. A common increment is 25% in crabs.
But increments vary between 3 and 44% (Hartnoll, 1965) and
within a species do not remain constant during growth.
Usually the growth increments become smaller as crab
becomes larger.

Presently age and growth has been studied in
five species and one sub-species of crabs through indirect
statistical method. Direct information regarding number
of moults a crab undergoes in its life, volume of increase
in size due to moult will give a correct picture. Experi-
mental studies in this line will add quite a lot of
valuable clue to the phenomenon of age and growth in crabs.

Table 19. Mean size (carapace width) in mm attained by <u>Portunus pelagicus</u> in different years of life as found out by various methods

Year Class	Petersen's method	Months mode curve	Probability plot technique	Von Bertalanffy's growth equation
0	-	-	44	0
1	90	72	82	72
2	-	108	123.5	130
3	-	105	152.5	154

Table 20. Mean size (carapace width) in mm attained by <u>Portunus sanguinolentus</u> in different years of life as found out by various methods

Year class	Petersen's method	Months mode curve	Probability plot technique	Von Bertalanffy's growth equation
0	-	-	42.5	0
1	80	65	74.0	77
2	-	105	109.5	107.0
3	-	141	133	133

Table 21. Mean size (carapace width) in mm attained by Scylla serrata in different years of life as found out by various methods

Year class	Petersen's method	Months mode-curve	Probability plot technique	Von Bertalanffy's growth equation
0	–	–	81.5	–
1	–	112.5	117.0	118.0
2	–	151.5	157.0	162.0
3	–	187.5	182.0	180.0

Table 22. Mean size (carapace width) in mm attained by Scylla serrata in different years of life as found out by various methods

Year class	Petersen's method	Months mode curve	Probability plot technique	Von Bertalanffy's growth equation
0	–	–	71	–
1	90	88.5	95.5	96
2	115	110.0	112.0	114
3	–	130.0	126	126

Table 23. Mean size (carapace width) in mm attained by <u>Podopthalmus</u> <u>vigil</u> in different

years of life as found out by various methods

Year class	Petersen's method	Months mode curve	Probability plot technique	Von Bertalanffy's growth equation
0	-	-	59.5	-
1	-	73	79	75
2	-	89	95	92
3	-	104	108	105

Table 24. Mean size (carapace width) in mm attained by <u>Thalamita</u> <u>crenata</u> in different

years of life as found out by various methods

Year class	Petersen's method	Months mode curve	Probability plot technique	Von Bertalanffy's growth equation
0	-	.	24	-
1	36	34	35.	35.3
2	-	51	52	52.2
3	-	64	62.	62.6

Fig 12. Size frequency histogram for
Portunus pelagicus

Fig 13. Size frequency histogram for
Portunus sanguinolentus

Fig 14. Size frequency histogram for
Scylla serrata

Fig 15. Size frequency histogram for
        Scylla serrata serrata

Fig 16. Size frequency histogram for
Podopthalmus vigil

Fig 17. Size frequency histogram for
Thalamita crenata

Fig 18. a – Scatter diagram of months – modes
            for Portunus pelagicus

       b– Growth of P. pelagicus based on
            scatter diagfam of months – modes

       c – Scatter diagram of months – modes
            for P. sanguinolentus

       d – Growth of P. sanguinolentus based on
            scatter diagram of months – modes

Fig 19. a - Scatter diagram of months - modes
         for Scylla serrata

       b - Growth of S. serrata based on scatter
           diagram of months - modes

       c - Scatter diagram of months - modes
           for S. serrata serrata

       d - Growth of S. serrata serrata based on
           scatter diagram of months - modes

Fig 20. a - Scatter diagram of months - modes
        for Podopthalmus vigil

        b - Growth of P. vigil based on scatter
            diagram of months - modes

        c - Scatter diagram of months - modes
            for Thalamita crenata

        d - Growth of T. crenata based on scatter
            diagram of months - modes

Fig 21. Probability plot curve of

a - *Portunus pelagicus*

b - *P. sanguinolentus*

c - *Scylla serrata*

Fig 22. Probability plot curve of

a - _Scylla serrata serrata_

b - _Podopthalmus vigil_

c - _Thalamita crenata_

Fig 23. Fort-Walford plot (1) and theoretical
growth curve (2) in

a - *Portunus pelagicus*

b - *P. sanguinolentus*

c - *Scylla serrata*
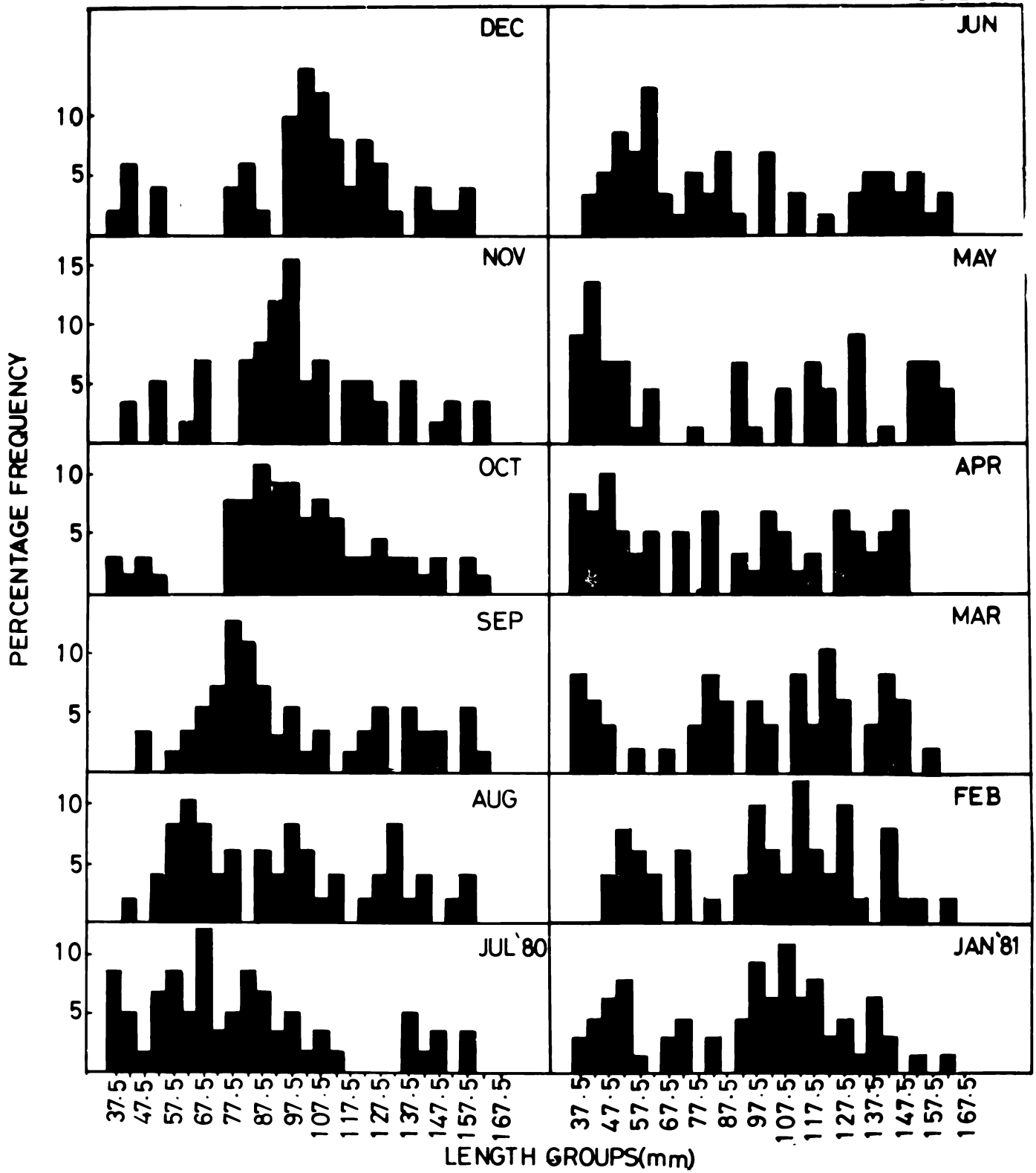
d - *S. serrata serrata*

e - *Podopthalmus vigil*

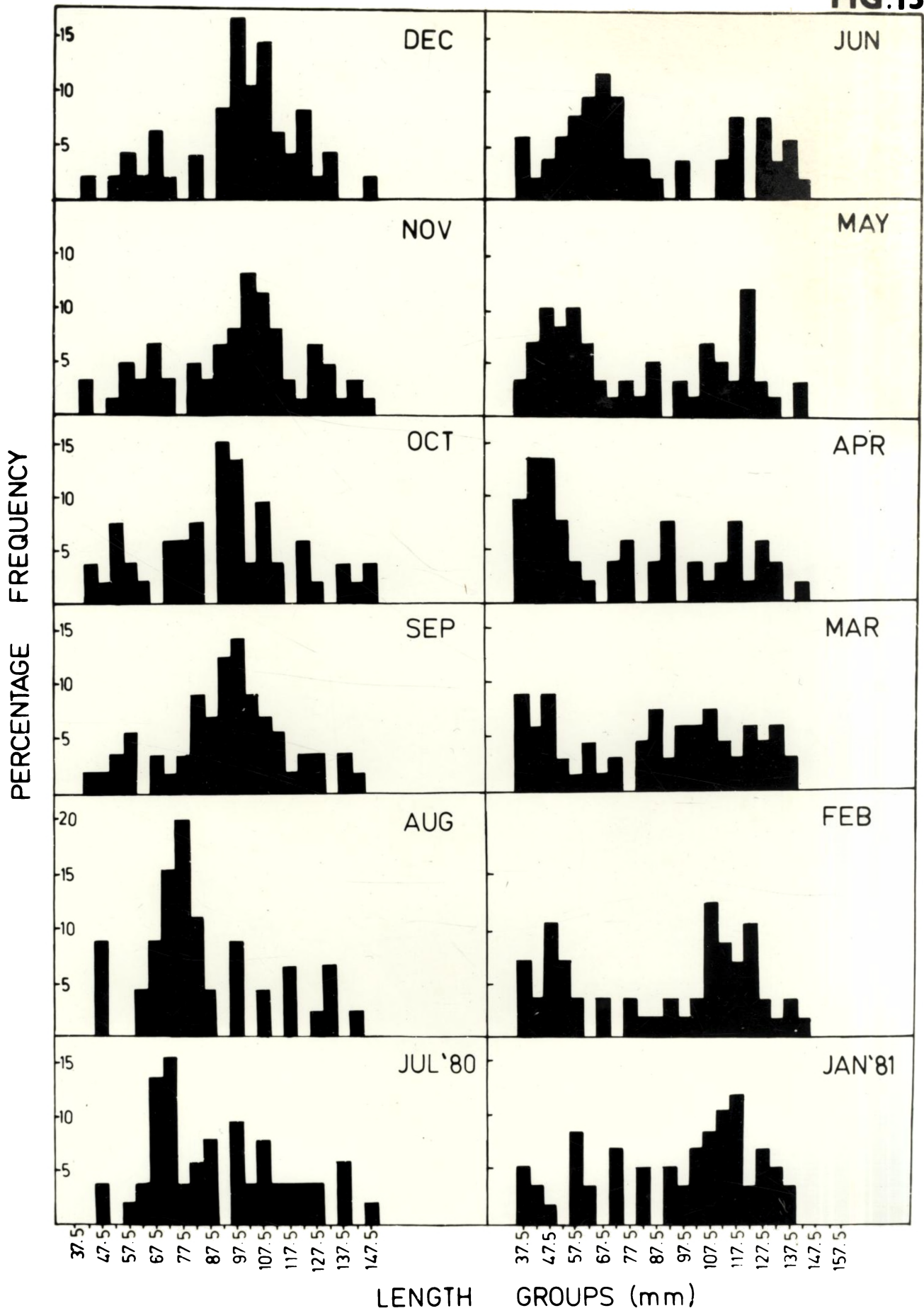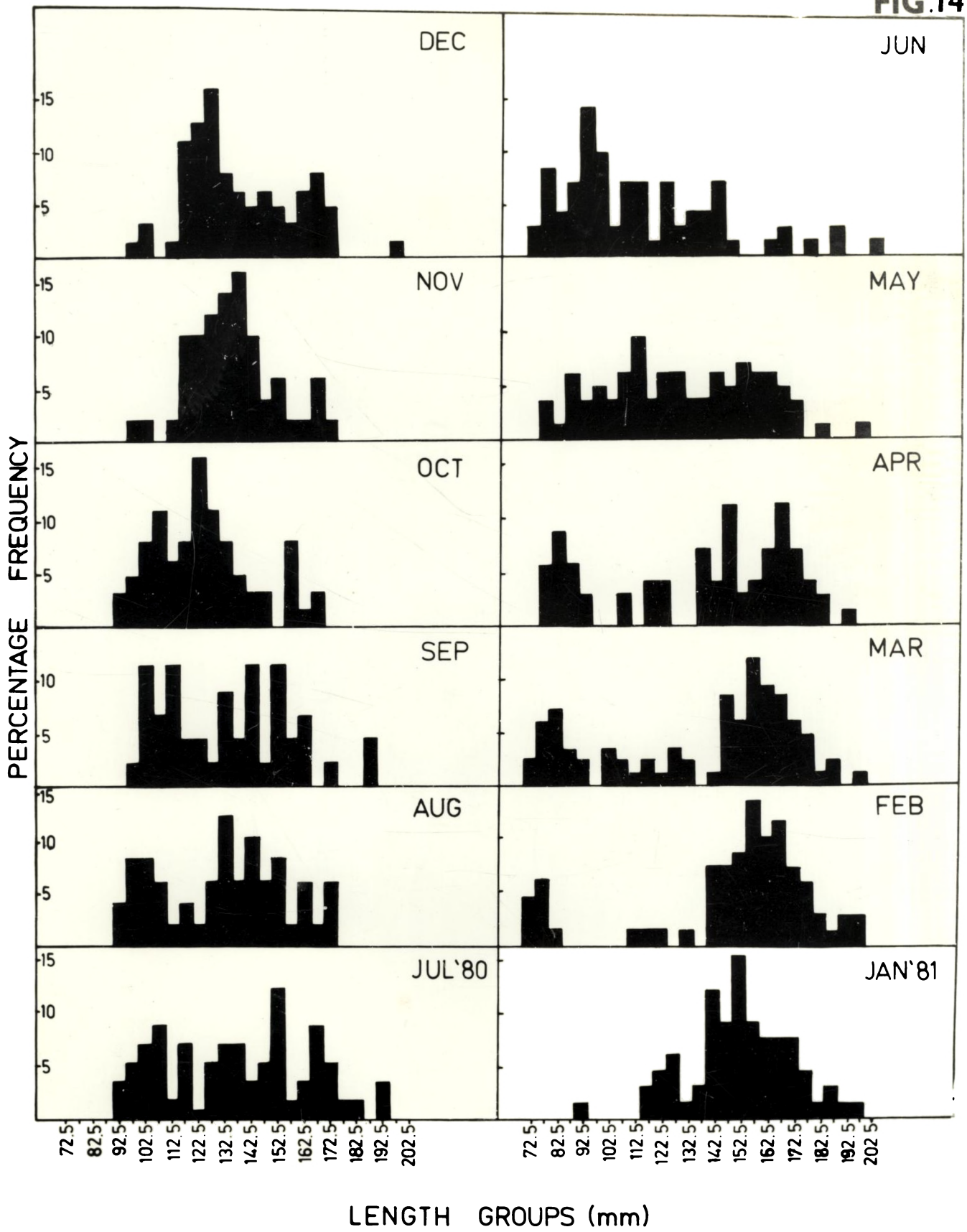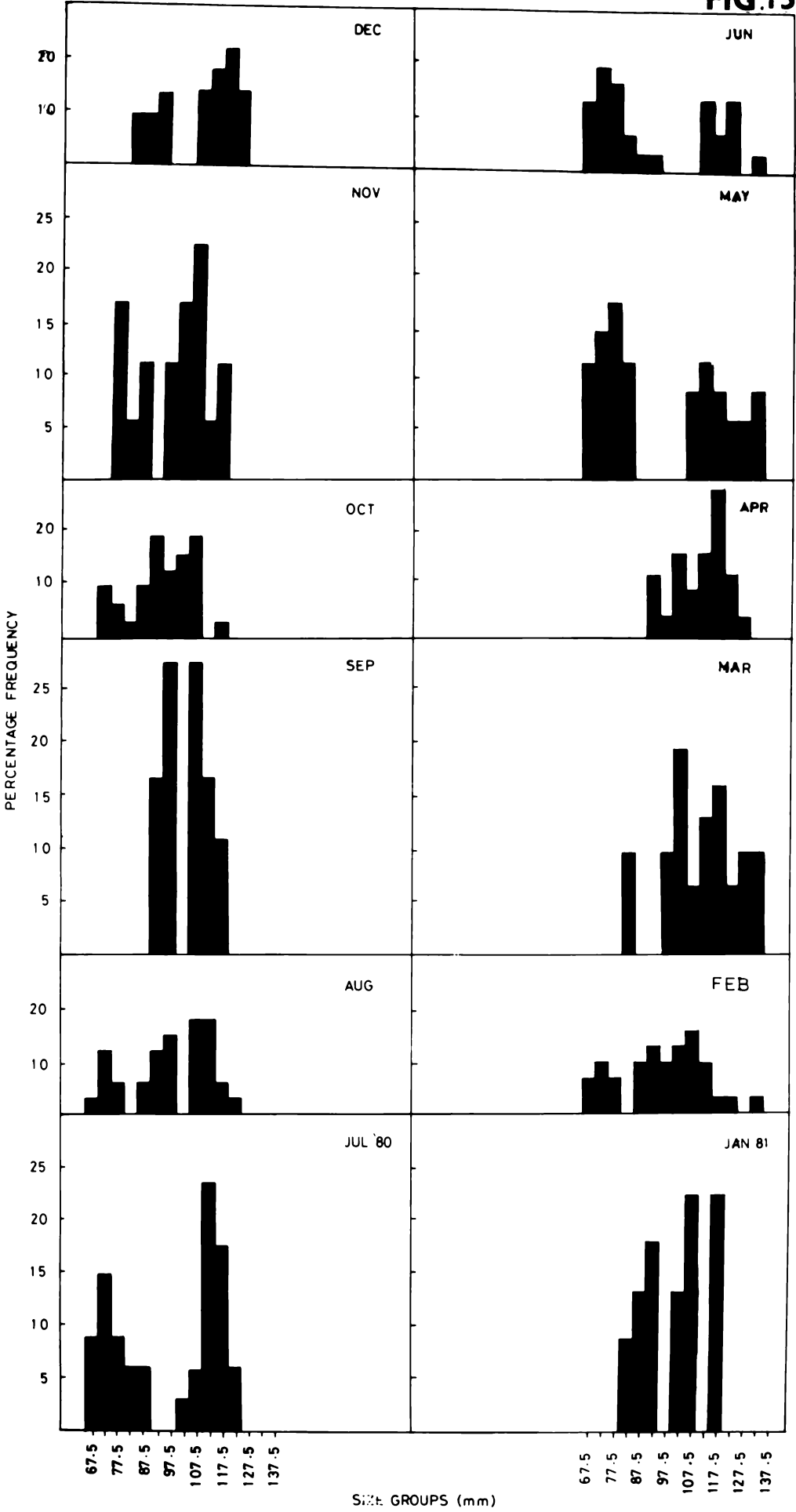f - *Thalamita crenata*

AGE AND GROWTH

FIG.12

FIG.13

FIG.14

FIG.15

FIG.16

LENGTH GROUPS (mm)
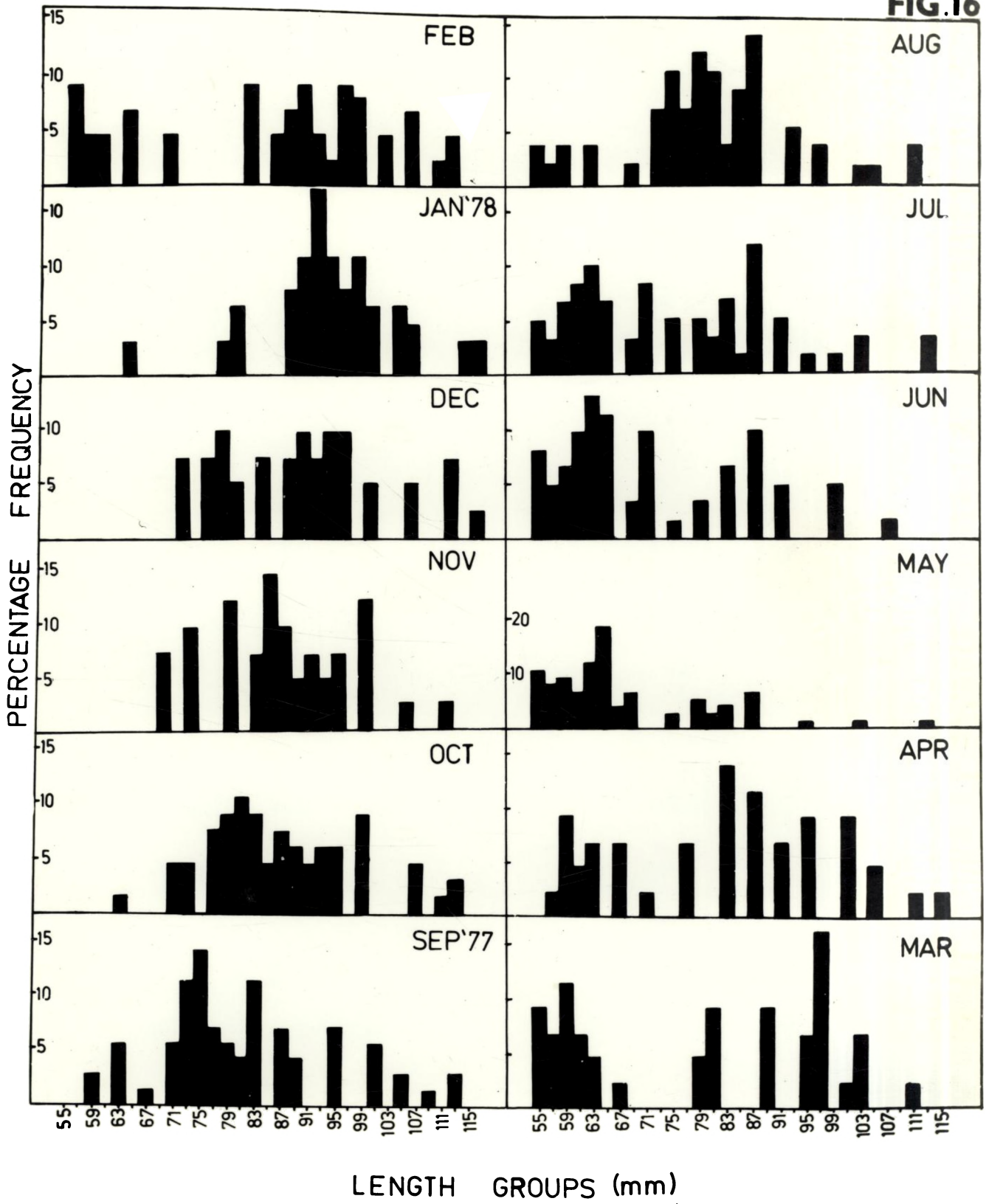
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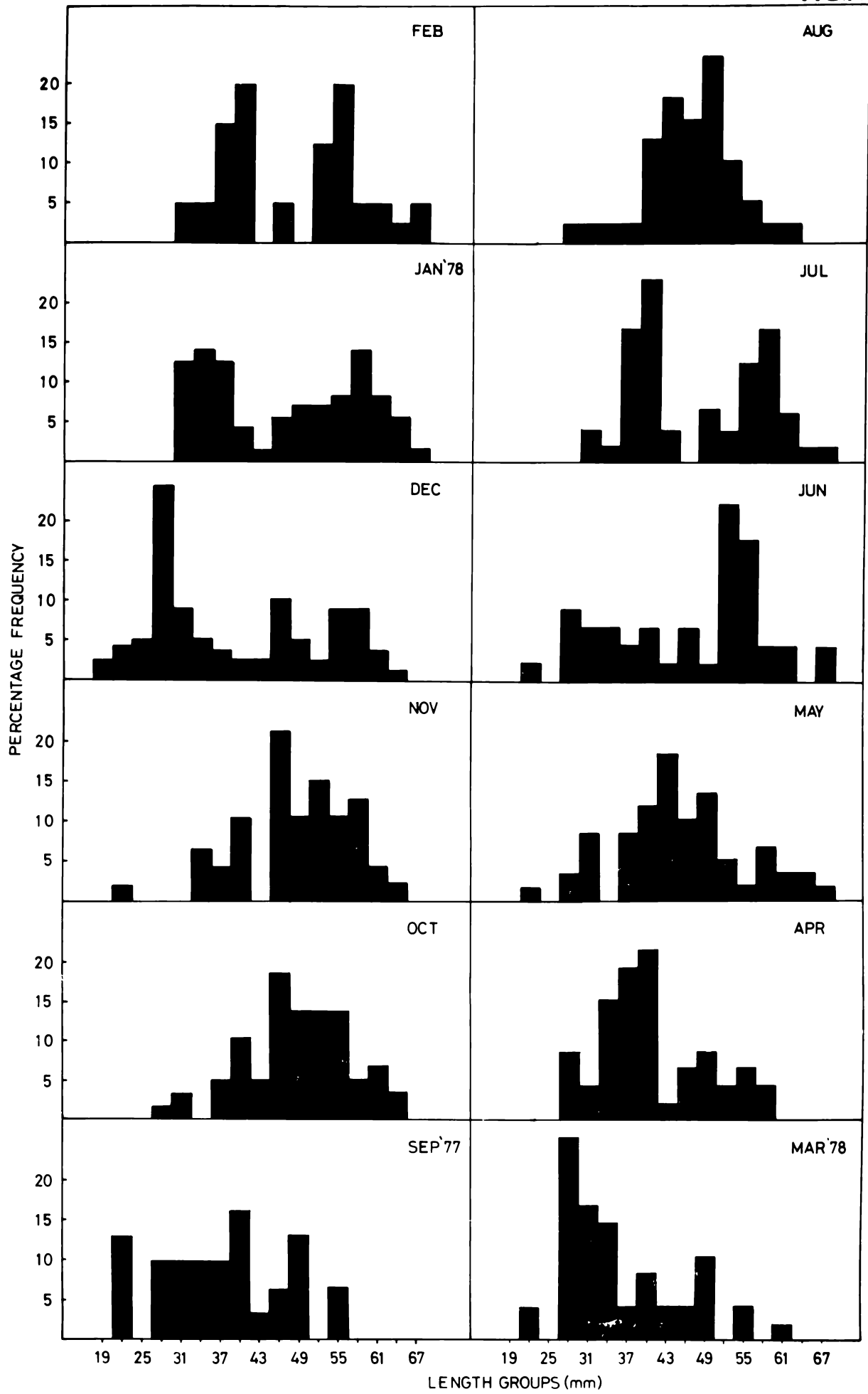
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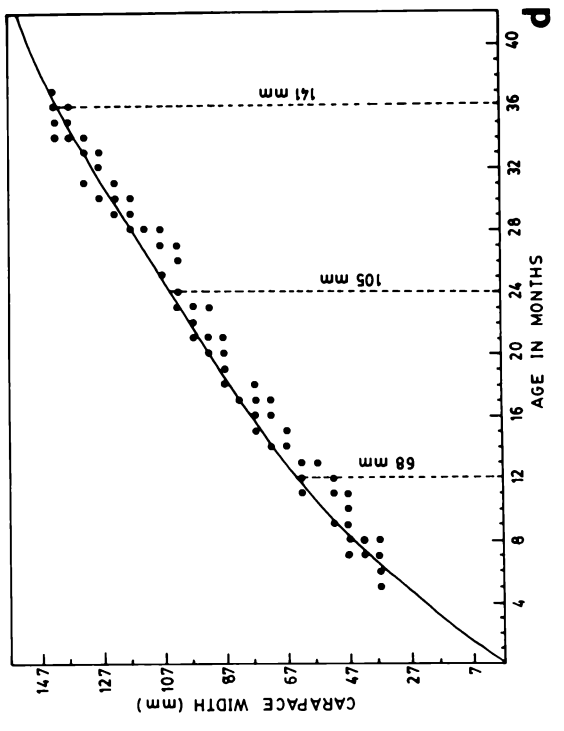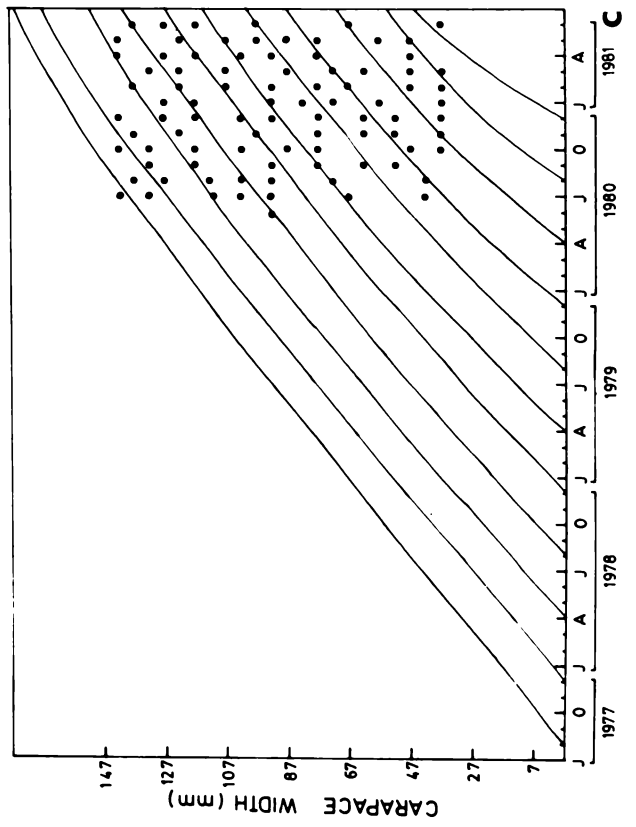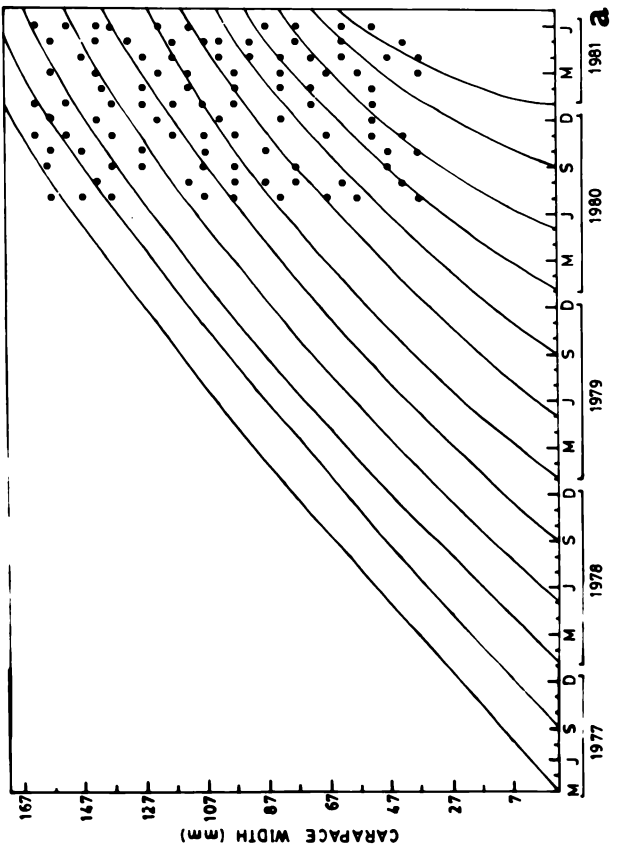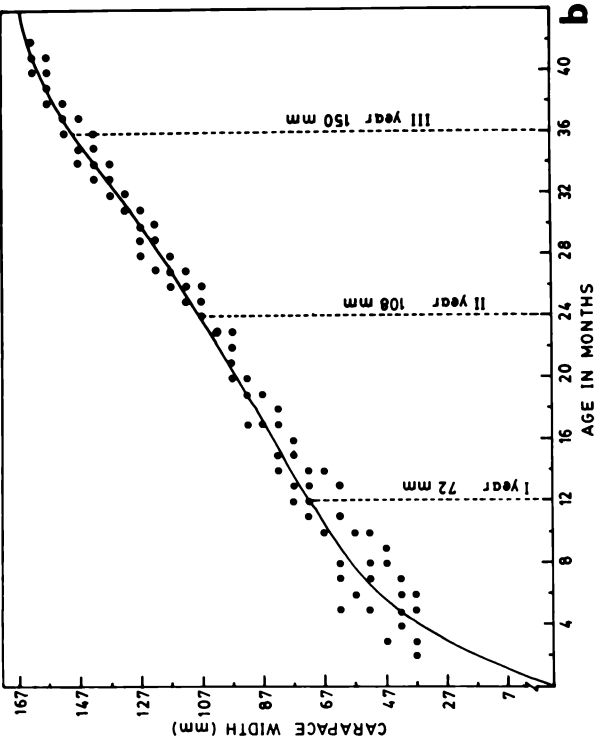
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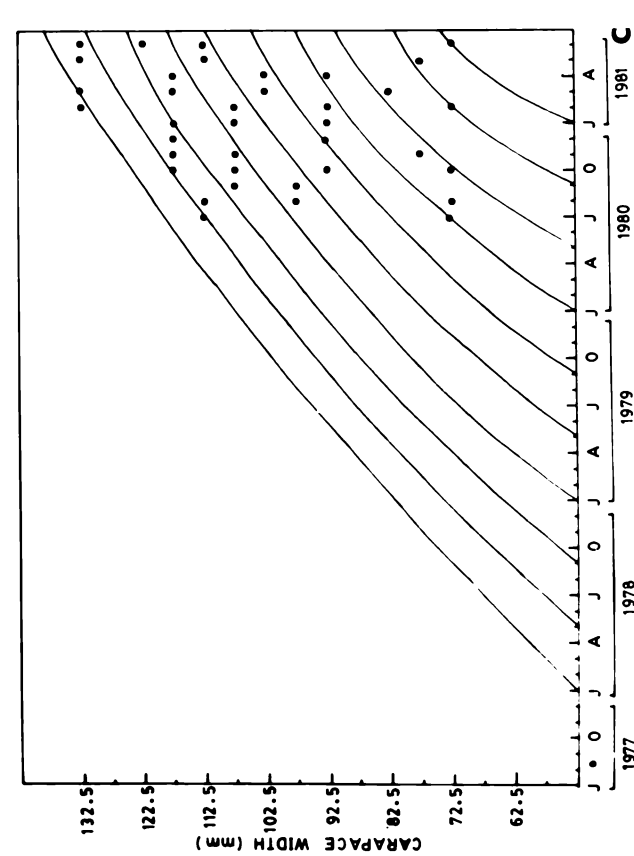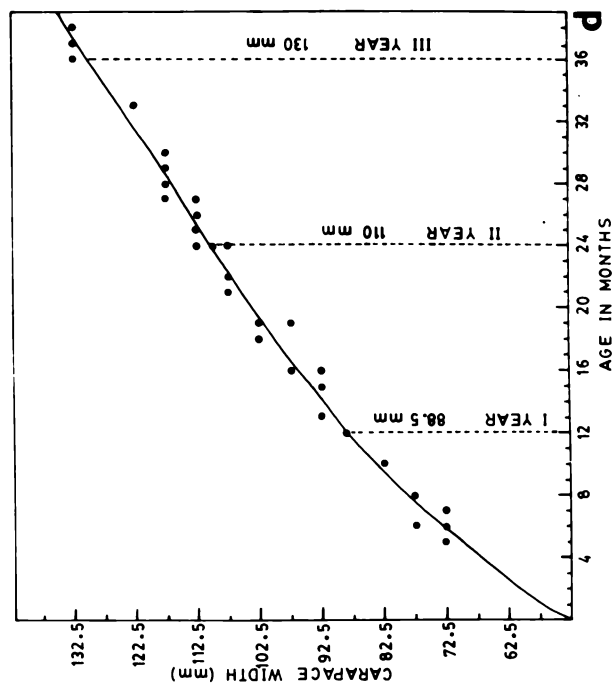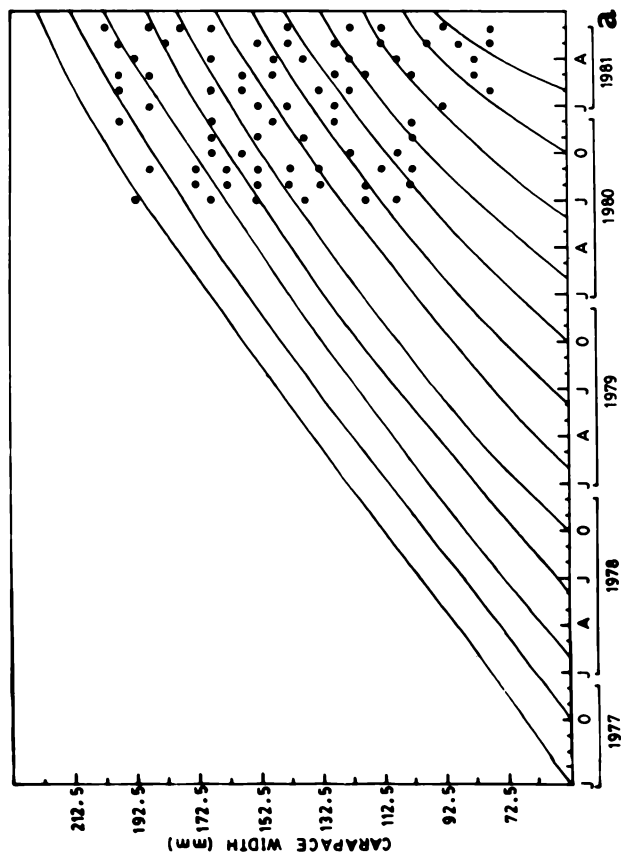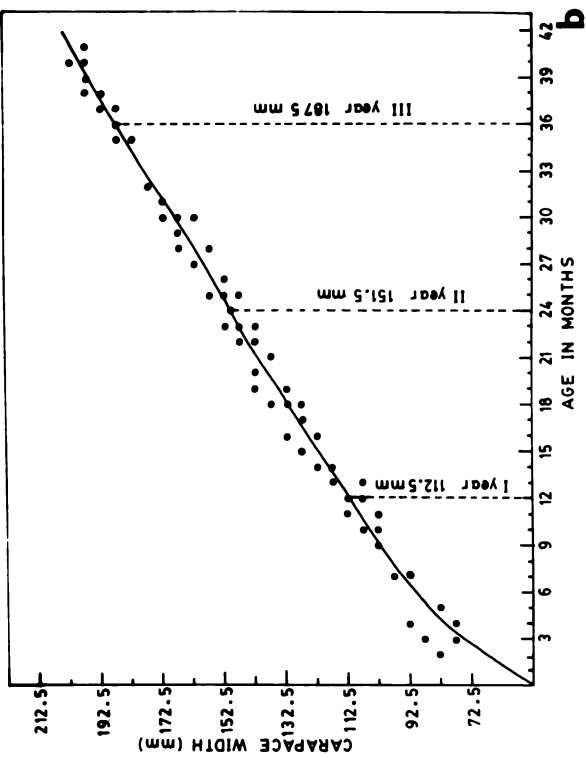
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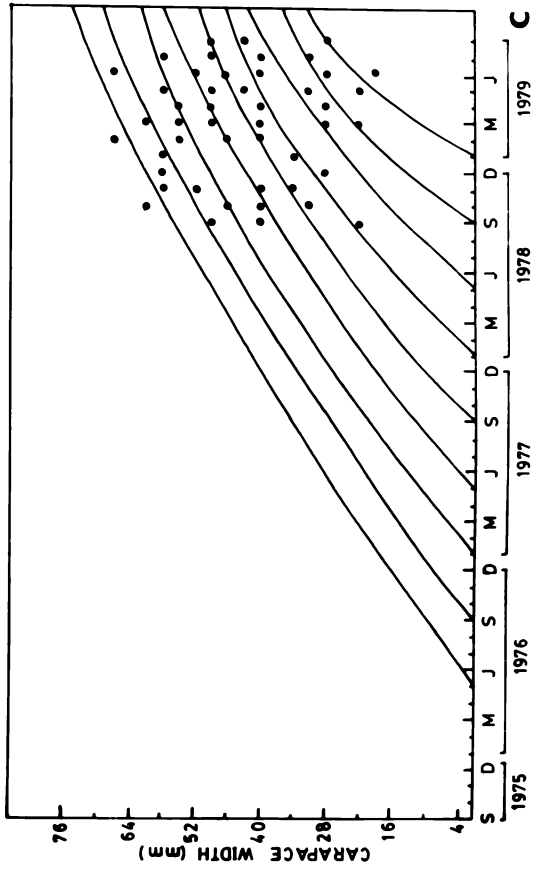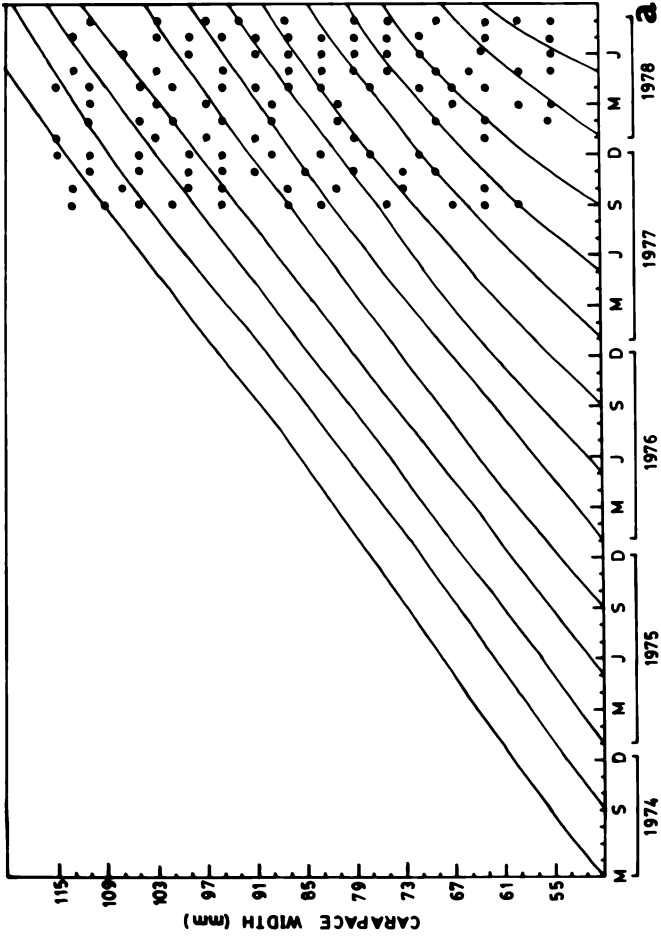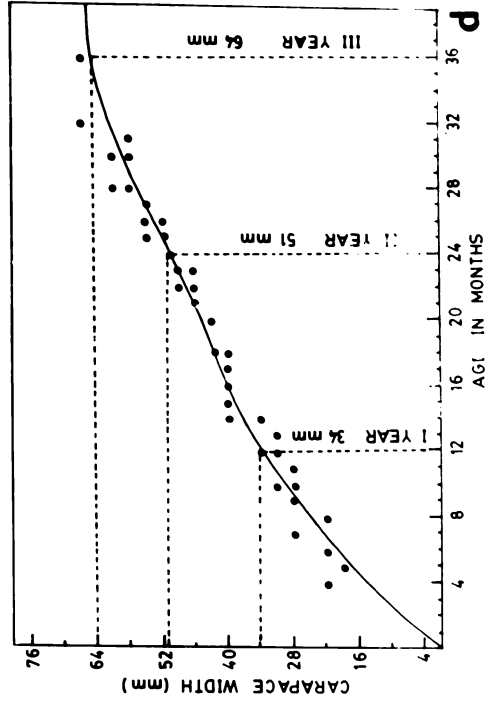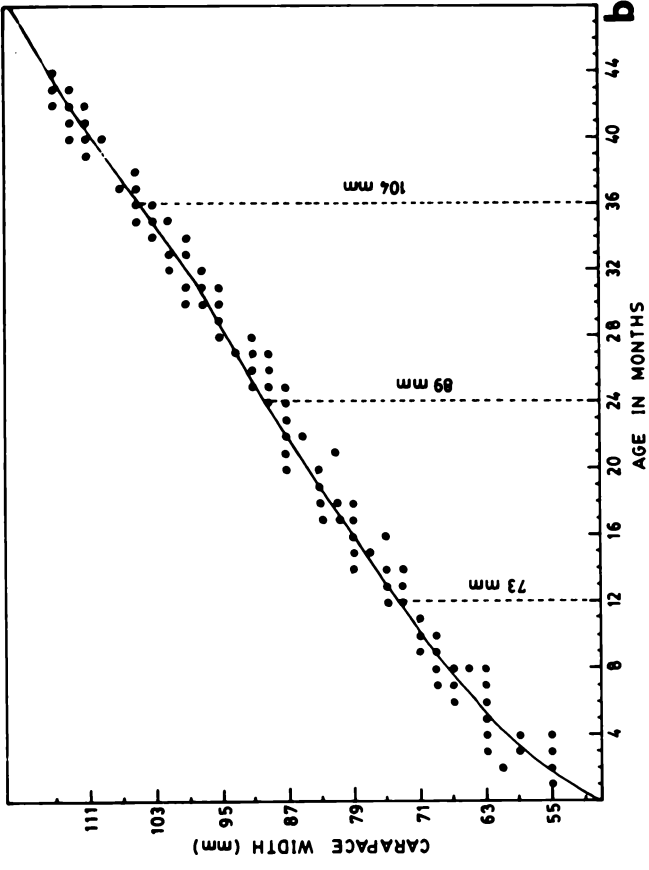
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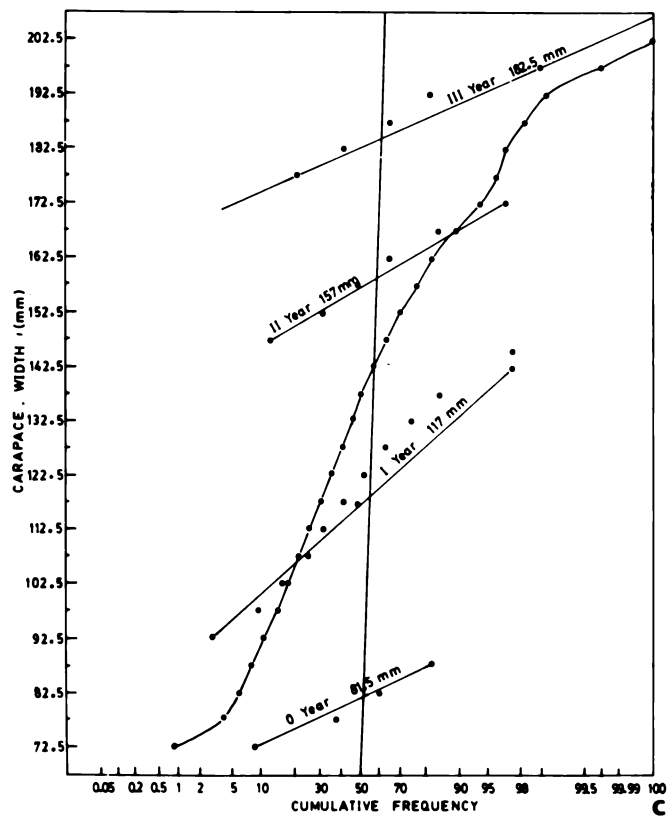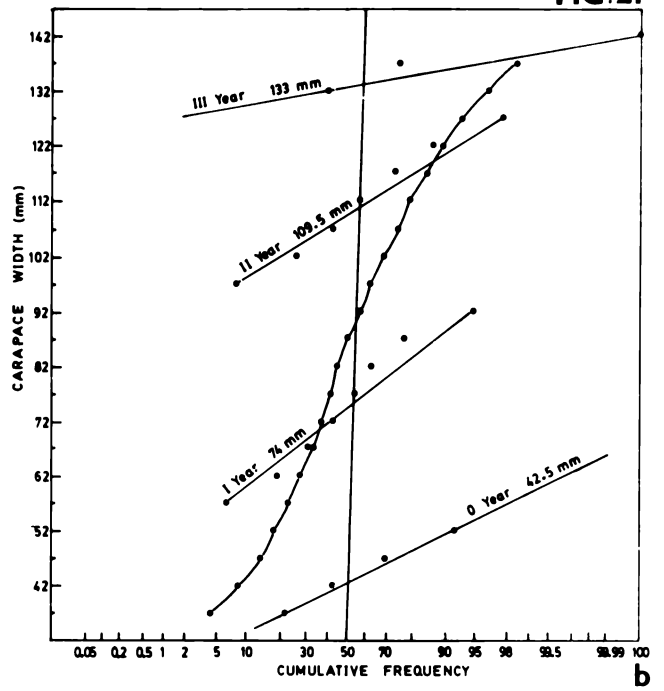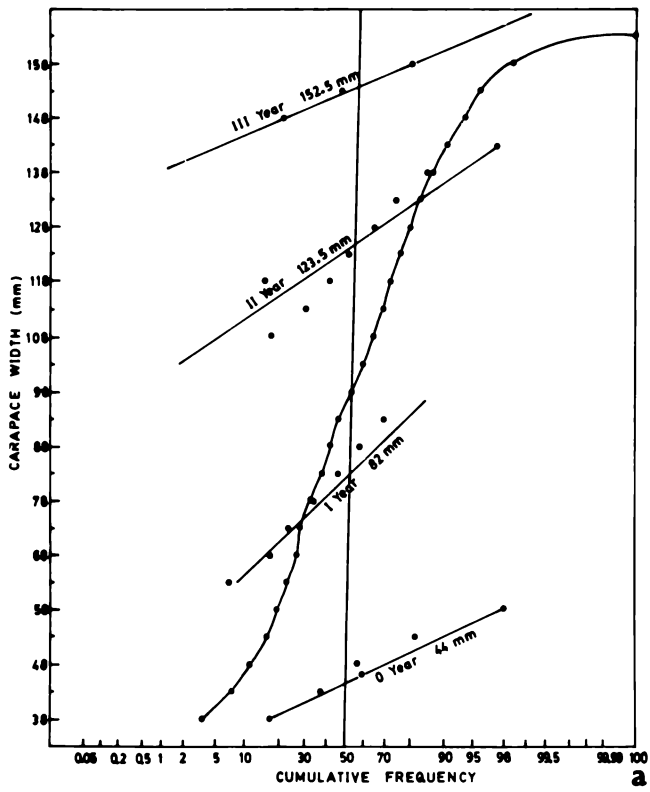
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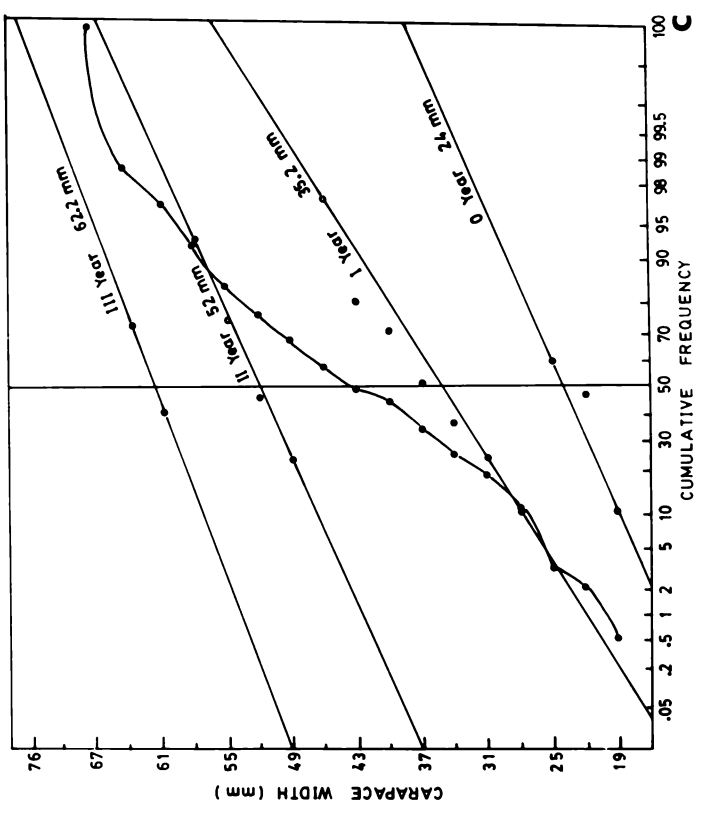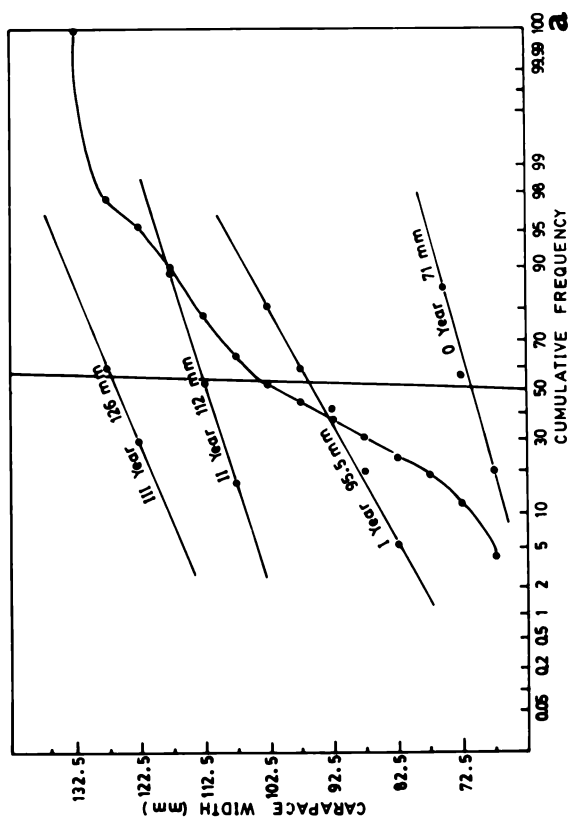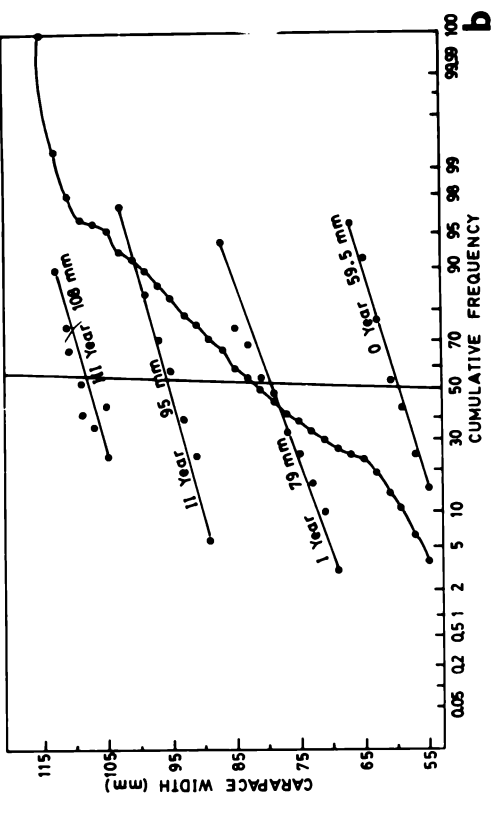
FIG.23
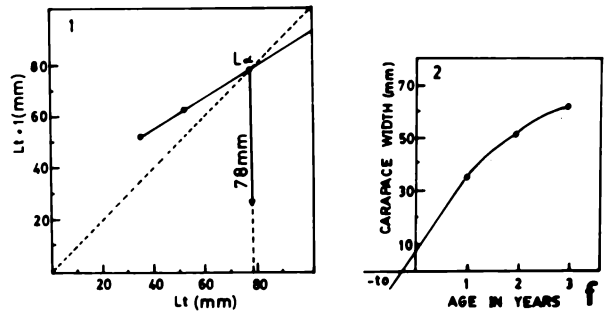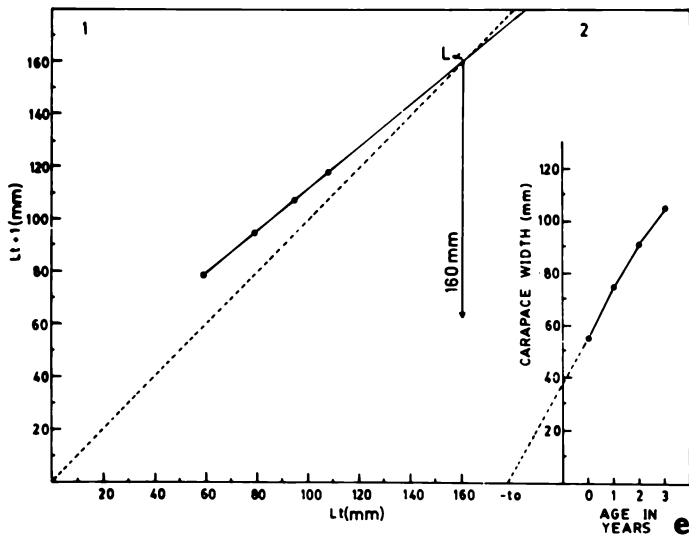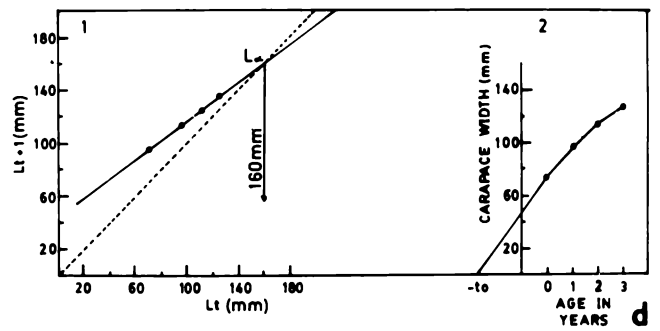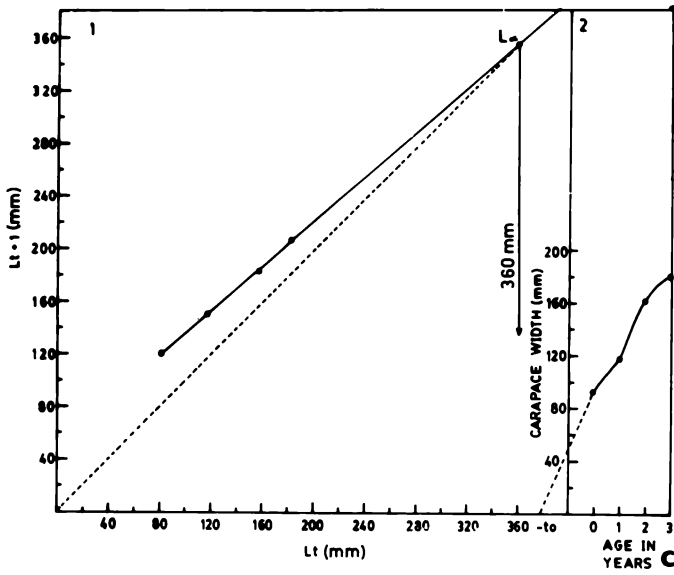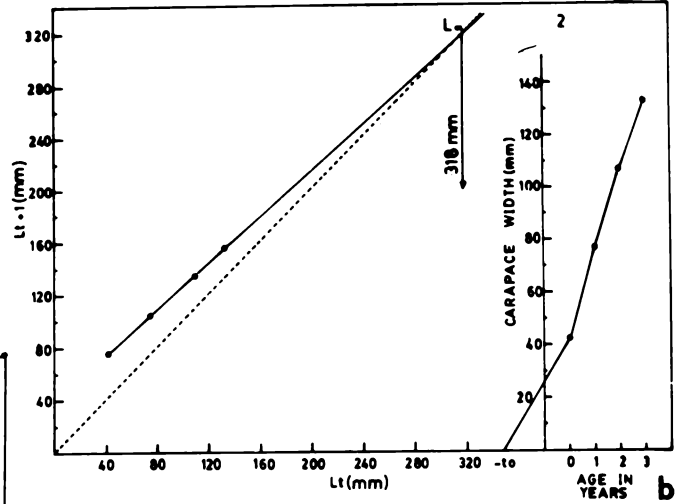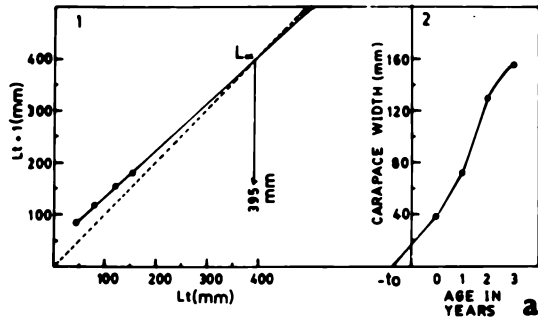
LENGTH - WEIGHT RELATIONSHIP

4.1   INTRODUCTION

The study of length-weight relationship is an important tool in fishery biology and according to Le Cren (1951) it is pursued with two objectives viz. (1)to establish a mathematical relationship between two variables namely to the length and the weight – so that if one is known the other could be computed and (2)to know whether variation from the expected weight, ,for the known length groups are indications of fatness, general "well being", gonad development and suitability of environment. The term length weight relationship is applied to the first category and the term "condition" is generally reserved for length-weight analysis of the second category.

Normal weight of an animal has a linear relation-ship with its length and it is observed that the length-weight relationship could be expressed by the hypothetical cube law $W = CL^3$ where 'W' is the weight, 'L' length and 'C' is a constant. This formula holds good if the density and form of the fish is constant. But most of the animals change their shape or form as they grow in length and in such cases the exponent may be altered (Martin, 1949). The formula therefore has to be modified as $W = al^n$ where 'W' and 'L' are weight and length respectively, 'a' is a constant equivalent to 'C' and 'n' is another

constant to be calculated empirically i.e. from the data. However, significant variations from isometric growth ('n' = 3) are found to be rare (Beverton and Holt, 1957) and for an ideal animal which maintains its body shape throughout, the value of 'n' will be '3' (Allen, 1938). The value of exponent 'n' in the equation is normally between 2.5 and 4.0 (Hile, 1936, Martin, 1949).

4.2   MATERIALS AND METHOD

For the present study, random samples belonging to different length groups were collected from the commercial fish landing centre at Cochin and Porto Novo. The length of crab was measured in mm and weight was recorded to the nearest mg.

The parabolic equation, $W = aL^n$ can be expressed in the logarithmic form as

Log $W = \log a + n \log L$ i.e.,

$Y = a + b x$ where

$a = \log 'a'$

$b = n$

$Y = \log W$ and

$X = \log L$ which is a linear relationship
                      between Y and X

This linear equation was fitted for males, females and

indeterminants separately for both the species and the estimates of parameters 'a' and 'b' for each category were obtained by the method of least squares.

4.3   RESULTS AND DISCUSSION

The regression lines fitted to the data, collected for males and females of all the crabs, showed a linear relationship between these two variables (Figs. 24-26). It can be seen from the figures that the points are very close to the line and hence can be presumed that there is a close relationship between length and weight. The correlation coefficient values were found to be highly significant and these values calculated sex wise and combined for all the crabs are given below:

Species name	Male	Female	Combined
P. pelagicus	.625P <.001	.935P <.001	.716P< .001
P. sanguinolentus	.925P <.001	.900P <.001	.913P< .001
S. serrata	.655P <.001	.960P <.001	.783P< .001
S. serrata serrata	.775P <.001	.765P <.001	.946P< .001
P. vigil	.979P <.001	.986P <.001	.975P< .001
T. crenata	.982P <.001	.974P <.001	.978P< .001

The regression equation for males and females of all the crabs presently studied can be expressed as follows:

__P. pelagicus__

For males	:	$\log W = -1.8457 + 2.7960 \log L$
For females	:	$\log W = -1.5246 + 2.5342 \log L$

__P. sanguinolentus:__

For males	:	$\log W = -1.9766 + 2.8593 \log L$
For females	:	$\log W = -1.9222 + 2.8319 \log L$

__S. serrata:__

For males	:	$\log W = -3.201 + 2.715 \log L$
For females	:	$\log W = -3.479 + 2.820 \log L$

__S. serrata serrata:__

For males	:	$\log W = -4.607 + 3.431 \log L$
For females	:	$\log W = -3.592 + 2.878 \log L$

__P. vigil:__

For males	:	$\log W = -3.718 + 2.788 \log L$
For females	:	$\log W = -4.277 + 3.097 \log L$

__T. crenata:__

For males	:	$\log W = -3.662 + 3.002 \log L$
For females	:	$\log W = -3.541 + 2.916 \log L$

In all the forms presently studied, the exponent values for both the sexes varied from 2.5342 to 3.431 suggesting that the increase in weight per unit increase in length is near 3 if not exactly 3 units.

With a view to know the differences between
regression coefficients of males and females of all the
crabs analysis of covariance was employed as followed by
James (1967), Narasimhan (1970), Rangarajan (1973) and
Hoda (1976). The results are given in Tables 25-48. No
significant differences could be found between males and
females of three species namely P. pelagicus, P. sanguino-
lentus and P. vigil. In the case of S. serrata, regres-
sion equations were calculated separately for intermoult
and premoult crabs of both the sexes and they were also
compared but, no significant differences could be found.
The data were therefore pooled together and the length-
weight equation was derived commonly for two species and
one subspecies of crabs as given below:

S. serrata:

$$\log W = -3.311 + 2.753 \log L$$

S. serrata serrata:

$$\log W = -4.223 + 3.216 \log L$$

T. crenata:

$$\log W = -3.616 + 2.969 \log L$$

Dhawan et al. (1976) studied the length-weight
relationship in P. pelagicus from Zuary estuary and
obtained exponent values above 3 for both the sexes
(males +3.636 and females 4.969). Presently, the

exponent values in P. pelagicus for both the sexes were
found to be less than 3. In the study of Varikul et al.
(1972) on S. serrata from Thailand, the exponent values
were 2.1377 for males and 1.6619 for females. In the
present study, the exponent values were found to be higher
than the above for both the sexes. Thus the exponent
values differed in the same species collected from
different areas.

Table 25. Statistics on the length-weight relationship of males and females of

Portunus pelagicus in Cochin waters (July 1980 to June 1981)

Sex	N	SK	SY	SX^2	SY^2	SXY
Male	50	103.4078	196.8450	217.4270	803.4088	417.0696
Female	59	126.3658	244.0050	274.8008	1036.3130	533.1289

N = Number of crabs

SX, SY = Sum of logarithmic values of length and weight respectively

SX^2, SY^2, SXY = Sum of squares and products

Table 26. Regression data for the length weight-relationship of males and females of
<u>P. pelagicus</u>

Sex	D.F.	Sum of squares and products			b	Errors of estimate	
		X^2	XY	Y^2		D.F.	S.S.
Male	49	3.5635	9.9634	28.4497	2.7960	48	0.5924
Female	58	4.1514	10.5206	27.1869	2.5342	57	0.5253
	107	7.7149	20.4840	55.6366		105	1.1177

D.F. = Degrees of freedom, b = regression coefficient; S.S = sum of squares

Table 27. Analysis of covariance

Source of variation	D.F.	Sum of squares	Mean square	Observed F
Deviation from individual regression	105	1.1177	0.0106	
Difference between regression	1	1.2491	1.2491	117.8396 **P<**.005

Table 28. Statistics on the length-weight relationship of males and females of _Portunus sanguinolentus_ in Cochin waters (July 1980 to June 1981)

Sex	N	SX	SY	SX^2	SY^2	SXY
Male	62	127.4996	242.0080	265.3918	971.2463	506.8141
Female	61	126.2397	240.2451	263.9307	968.0656	504.7696

N = Number of crabs

SX, SY = Sum of logarithmic values of length and weight respectively

SX^2, SY^2, SXY = Sum of squares and products

Table 29. Regression data for the length-weight relationship of males and females of

P. sanguinolentus

Sex	D.F.	Sum of squares and products				Errors of estimate	
		X^2	XY	Y^2	b	D.F.	S.S.
Male	61	3.1959	9.1379	26.60	2.8593	60	0.4756
Female	60	2.6772	7.3690	21.8737	2.8319	59	1.5905
	121	5.8731	16.5069	48.4769		119	2.0661

D.F. Degrees of freedom; b = regression coefficient; S.S. = Sum of squares

Table 30. Analysis of covariance

Source of variation	D.F.	Sum of squares	Mean square	Observed F
Deviation from individual regression	119	2.0661	0.0174	
Difference between regression	1	2.0748	2.0748	119.2414 $P < .005$

Table 31. Statistics on the length-weight relationship of males and females of _Scylla serrata_ in Cochin waters (July 1980 to June 1981)

Sex	N	SX	SY	SX^2	SY^2	SXY
Male	85	180.288	217.378	382.975	559.182	462.640
Female	102	217.265	257.867	463.443	657.380	551.128

N = Number of crabs

SX, SY = Sum of logarithmic values of length and weight respectively

SX^2, SY^2, SXY = Sum of squares and products

Table 32. Regression data for the length-weight relationship of males and females of S. serrata

Sex	D.F.	Sum of squares and products				Errors of estimate	
		x^2	XY	y^2	b	D.F.	S.S.
Male	84	.579	1.573	6.516	2.715	83	2.243
Female	101	.659	1.860	5.465	2.820	100	0.215
	185	1.238	3.433	11.981		183	2.458

D.F. = Degrees of freedom; b = regression coefficient; S.S. = sum of squares

Table 33. Analysis of covariance

Source of variation	D.F.	Sum of squares	Mean square	Observed F
Deviation from individual regression	183	3.043	.017	
Difference between regression	1	.002	.002	.1176 P > .05

Table 34. Statistics on the length-weight relationship of intermoult and premoult males of Scylla serrata in Cochin waters (July 1980 to June 1981)

Type	N	SX	SY	SX²	SY²	SXY
Intermoult	55	116.680	141.848	247.941	367.427	301.996
Premoult	30	63.607	75.530	135.035	191.755	160.632

N = Number of crabs

SX, SY = Sum of logarithmic values of length and weight respectively
SX², SY², SXY = Sum of squares and products

Table 35. Regression data for the length-weight relationship of intermoult and premoult males of S. serrata

Type	D.F.	Sum of squares and products				Errors of estimate	
		X^2	XY	Y^2	b	D.F.	S.S.
Intermoult	54	0.408	1.070	4.831	2.625	53	2.025
Premoult	29	0.172	0.501	1.595	2.921	28	0.136
	83	0.580	1.571	6.426		81	2.161

D.F. = Degrees of freedom; b = regression coefficient; S.S. = sum of squares

Table 36. Analysis of covariance

Source of variation	D.F.	Sum of squares	Mean square	Observed F
Deviation from individual regression	81	2.151	0.027	
Difference between regression	1	0.082	0.082	3.04 P >.05

Table 37. Statistics on the length –weight relationship of intermoult and premoult females of _Scylla serrata_ in Cochin waters (July 1980 to June 1981)

Type	N	SX	SY	SX^2	SY^2	SXY
Intermoult	57	121.032	144.414	257.406	369.413	307.832
Premoult	45	96.232	113.453	113.037	237.966	243.296

N = Number of crabs

SX, SY = Sum of logarithmic values of length and weight respectively

SX^2, SY^2, SXY = Sum of squares and products

Table 38. Regression data for the length-weight relationship of intermoult and premoult females of S. serrata.

Type	D.F.	Sum of squares and products			b	Errors of estimate	
		x^2	XY	Y^2		D.F.	S.S.
Intermoult	56	0.410	1.187	3.529	2.899	55	.092
Premoult	44	0.244	0.679	1.933	2.779	43	.043
	100	0.554	1.866	5.462		98	.0135

D.F. = Degrees of freedom; b = regression coefficient; S.S. sum of squares

Table 39. Analysis of covariance

Source of variation	D.F.	Sum of squares	Mean square	Observed F
Deviation from individual regression	98	0.135	0.00138	
Difference between regression	1	0.003	0.003	2.1739 P>.05

Table 40. Statistics on the length-weight relationship of males and females of
Scylla serrata serrata. in Cochin waters (July 1980 to June 1981)

Sex	N	SX	SY	SX^2	SY^2	SXY
Male	40	79.112	87.115	156.340	194.151	173.567
Female	35	69.357	73.581	137.654	158.447	146.424

N = Number of crabs

SX, SY = Sum of logarithmic values of length and weight respectively

SX^2, SY^2, SXY = Sum of squares and products.

Table 41. Regression data for the length-weight relationship of males and females of S. serrata serrata

Sex	D.F.	Sum of squares and products			b	Errors of estimate	
		X^2	XY	Y^2		D.F.	S.S.
Male	39	0.370	1.270	4.425	3.431	38	0.066
Female	34	0.214	0.614	3.753	2.374	33	1.996
		0.584	1.884	8.183		71	2.062

D.F. = Degrees of freedom; b = regression coefficient; S.S = sum of squares

Table 42. Analysis of covariance

Source of variation	D.F.	Sum of square	Mean square	Observed F
Deviation from individual regression	71	2.062	0.029	
Difference between regression	1	0.043	0.043	1.483 P > .05

Table 43. Statistics on the length-weight relationship of males and females of *Podopthalmus vigil* in Porto Novo waters (September 1978 to August 1979)

Sex	N	SX	SY	SX^2	SY^2	SXY
Male	45	86.526	73.926	166.751	124.438	143.196
Female	38	72.195	61.079	137.390	100.420	116.757

N = Number of crabs

SX, SY = Sum of logarithmic values of length and weight respectively

SX^2, SY^2, SXY = Sum of squares and products

Table 44. Regression data for length-weight relationship of males and females of P. vigil

Sex	D.F.	Sum of squares and products				Errors of estimate	
		X^2	XY	Y^2	b	D.F.	S.S.
Male	44	0.377	1.050	2.991	2.738	43	.067
Female	37	0.231	0.714	2.244	3.097	36	.037
		0.698	1.764	5.235		79	.104

D.F. = Degrees of freedom; b = regression coefficient; S.S. = Sum of squares

Table 45. Analysis of covariance

Source of variation	D.F.	Sum of squares	Mean square	Observed F
Deviation from individual regression	79	0.104	0.0013	
Difference between regression	1	0.013	0.013	10 $P < .005$

Table 46. Statistics on the length weight relationship of males and females of
Thalamita crenata in Porto Novo waters (September 1978 to August 1979)

Sex	N	SX	SY	SX^2	SY^2	SXY
Male	30	49.277	38.087	81.425	52.302	64.015
Female	30	48.239	34.436	73.065	43.381	56.825

N = Number of crabs

SX, SY = Sum of logarithmic values of length and weight respectively

SX^2, SY^2, SXY = Sum of squares and products

Table 47. Regression data for the length-weight relationship of males and females of M. grenata

Sex	D.F.	Sum of squares and products				Errors of estimate	
		X^2	XY	Y^2	b	D.F.	S.S.
Male	29	.435	1.448	4.448	3.002	28	0.083
Female	29	.498	1.453	4.353	2.916	28	0.114

D.F. = Degrees of freedom; b = regression coefficient; S.S. = Sum of squares

Table 48. Analysis of covariance

Source of variation	D.F.	Sum of squares	Mean square	Observed F
Deviation from individual regression	56	0.197	.0035	
Difference between regression	1	0.001	.001	.2857 P >.05

Fig 24. Length - weight relationship in

    a - _Portunus pelagicus_ male

    b - _P. pelagicus_ female

    c - _P. sanguinolentus_ male

    d - _P. sanguinolentus_ female

Fig 25. Length – weight relationship in

a – _Scylla serrata_ male

b – _S_. _serrata_ female

c – _S_. _serrata_ combined

d – _S_. _serrata serrata_ male

e – _S_. _serrata serrata_ female

f – _S_. _serrata serrata_ combined

Fig 26. Length-weight relationship in

     a - _Podopthalmus vigil_ male

     b - _P. vigil_ female

     c - _Thalamita crenata_ male

     d - _T. crenata_ female

     e - _T. crenata_ combined

LENGTH - WEIGHT RELATIONSHIP

FIG.24
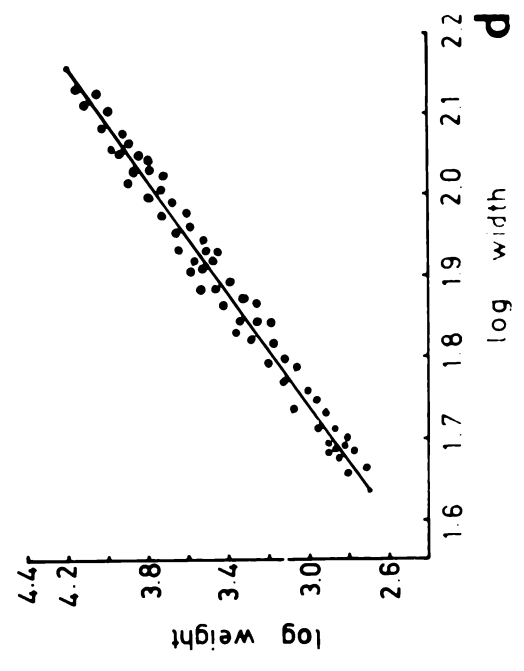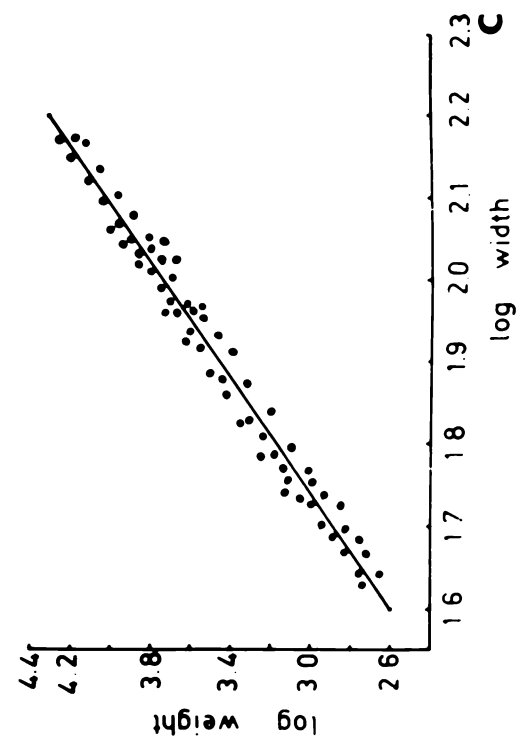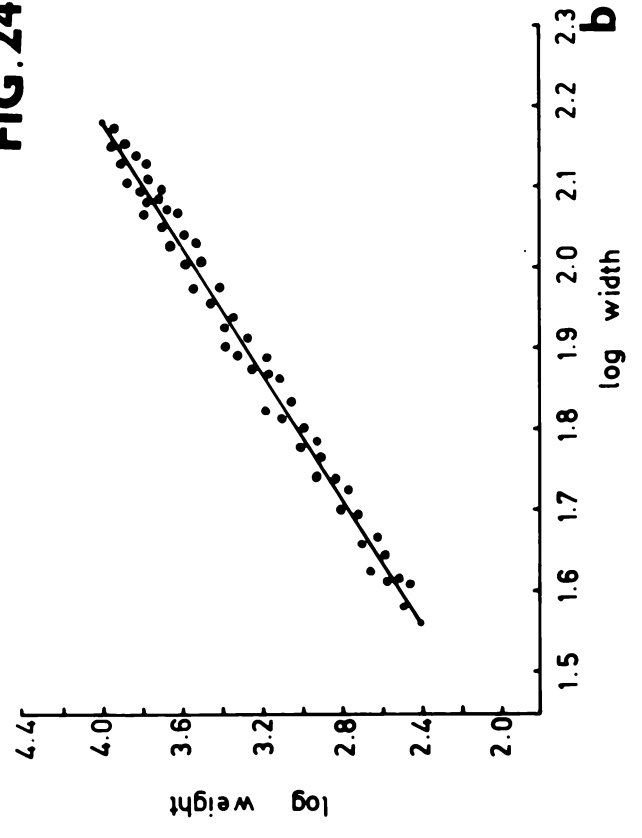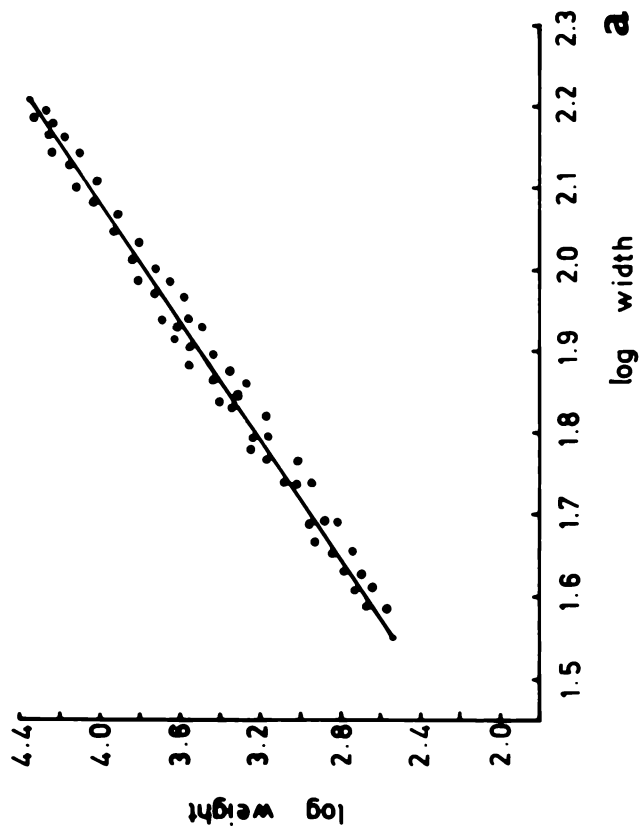
FIG.25
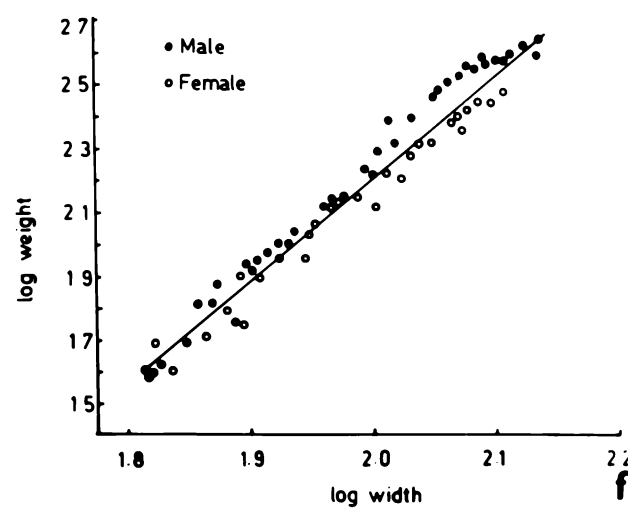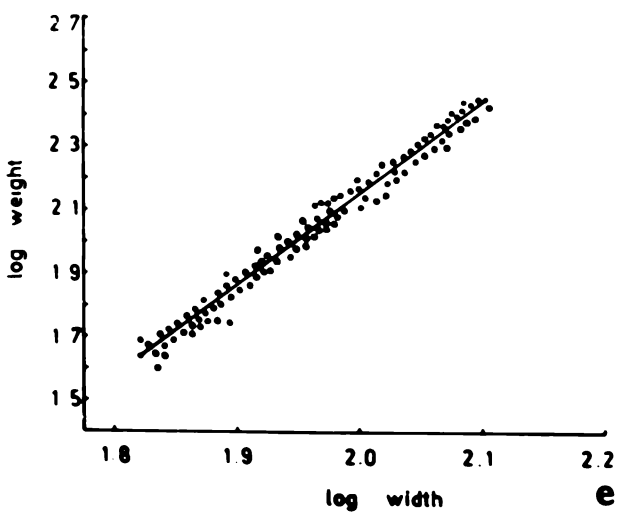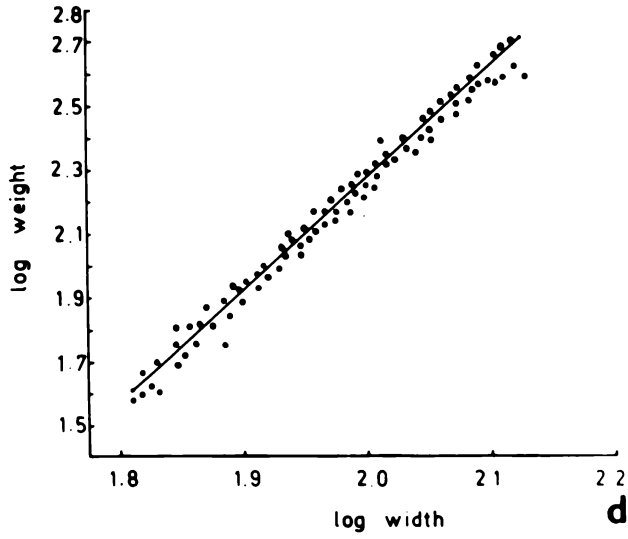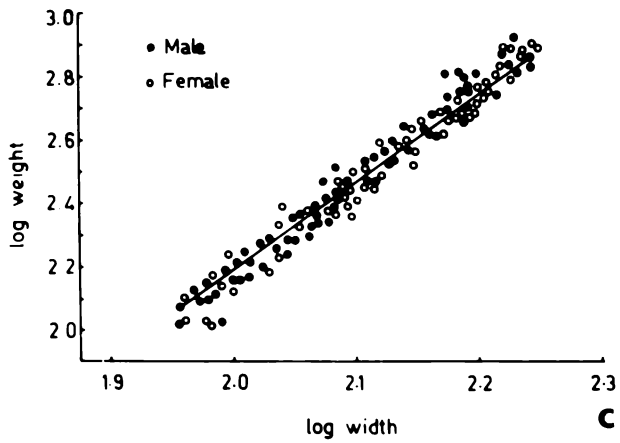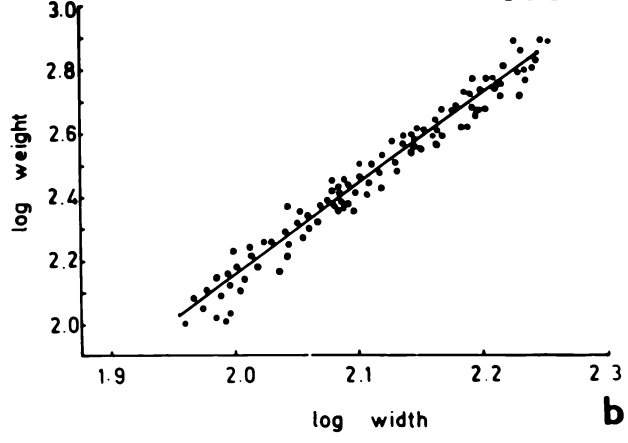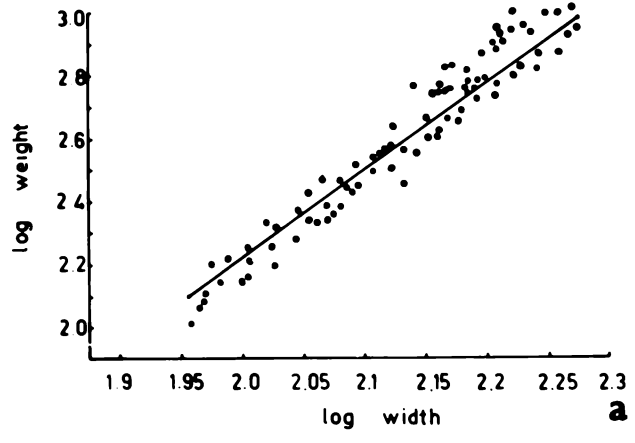
FIG.26
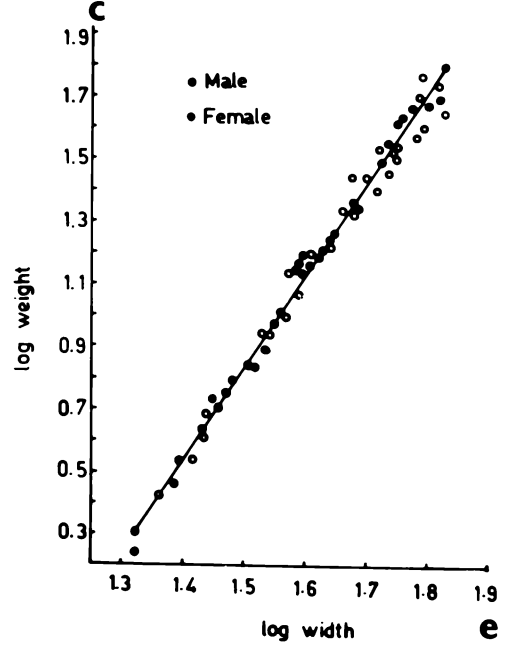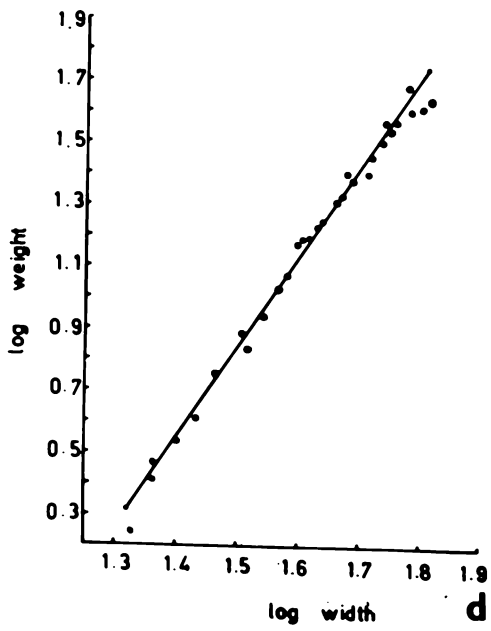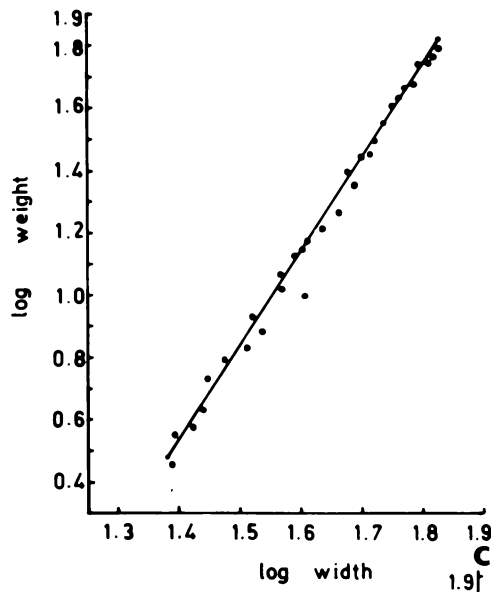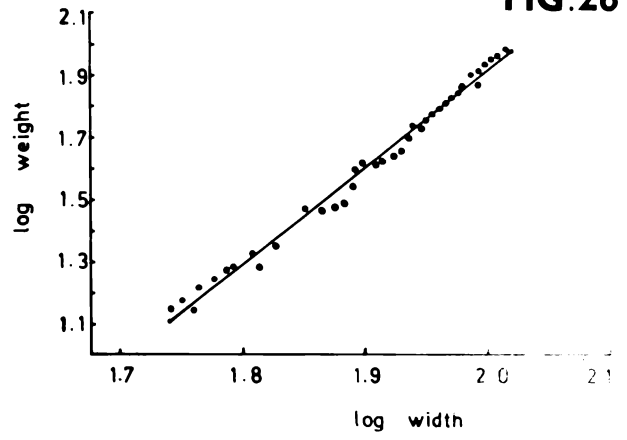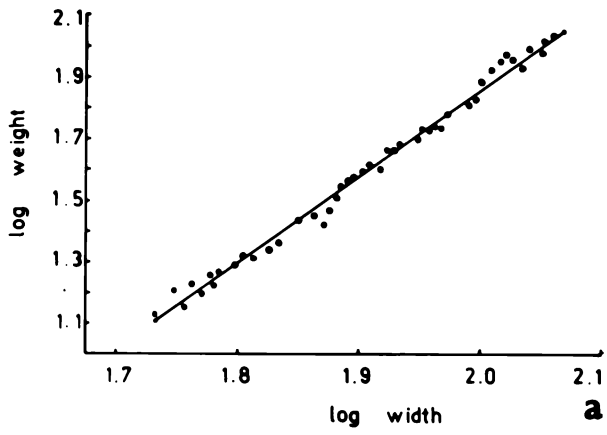
LARVAL DEVELOPMENT

5.1   INTRODUCTION

In the marine realm, the larvae are considered
to be the neglected link among the biological resources
and remained unexplored since quite long time (Costlow,
1963; Costlow and Bookhout, 1970). There was a time
when the crab larvae were considered as separate entity
by themselves and generic names such as Zoea and Megalopa
were assigned to them. Only when the eggs from berried
females were hatched in the laboratory, it was understood
that they were the free swimming stages called as larva
of those crabs. These larval stages represent the weakest
phase in the process of perpetuation of the species. They
are virtually found in all estuaries, backwaters and marine
environments and during certain seasons of the year they
constitute a major part of zooplankton. Their distribution,
abundance and seasonal variations are base-line studies and
cannot be pursued without keys for correct identification
of the larval stages. Keys are also necessary for assess-
ing the seed resources. Lack of information on the larval
stages often leads to misidentification of the larvae which
inturn leads to erroneous interpretation of field data
(Costlow, 1963).

Initially, the first larval stage was hatched
in the laboratory from berried females and the larval

life history was constructed by collecting further stages from planktonic materials. The validity and authenticity of such constructed life histories became questionable since there were chances of one species of larvae being mistaken for another. So techniques for the development of crabs from eggs to juvenile instar through different larval stages thus became imperative. Through laboratory culture, field guides for the identification of individual larval stages can be prepared which will help in conducting field studies with reasonable assurance. Laboratory culture in addition to providing positive identification and accurate description, also provides basic information regarding number of larval stages, their moulting frequencies, food habits etc. So techniques for rearing the larvae from hatching to post larvae in the laboratory were developed and many life histories worked out.

Information on the larval development of portunids crabs in India is restricted to very few reports and in these reports too, only the first larval stage has been described. Rajabai (1955) described the first zoeal stage in two portunid crabs namely Scylla serrata and Portunus sanguinolentus. Prasad and Tampi (1953) described the first zoeal stage of Portunus pelagicus. Chhapgar (1956) while studying the breeding habits of some crabs of Bombay coast described the first zoea of

Thalamita crenata. Srinivasagam and Natarajan (1976) in their study on the early development and fishery of _Podopthalmus vigil_ described the first zoea of this crab. Except the above, there is no other work on portunid crabs. The present study describes the complete development stages of the portunid crab _Thalamita crenata_ from Indian waters.

5.2   MATERIALS AND METHOD

An ovigerous female crab was collected from Vellar estuary by cast net operation during July, 1979. The crab was maintained in a rectangular glass trough full of sea water with sandy substratum until hatching occurred. The water was changed daily. As soon as the larvae were hatched, they were separated and reared in groups of 5 in small plastic trays each containing 100 ml of filtered sea water. No bactericides were used and the water was changed daily. The presence of the moult or exuviae was carefully checked in each container before changing water. The larvae were fed daily with freshly hatched _Artemia_ nauplii. The larvae and moult were preserved as suggested by Thakur (1960). Dissections were made with the help of entomological needles under a binocular microscope in glycerine and drawings were made with the aid of camera lucida.

The salinity of the sea water used in the present study was 5±1‰. Temperature of the water during the larval rearing period was 29±1°C. Duration of stage was considered to be the time spent in a given instar by larvae which successfully completed the moult to enter the next instar. The following measurements were taken in fresh zoeal stages and megalopa:

Zoea:

1. Rostral spine : from tip of rostrum to its base

2. Dorsal spine : from terminal outer edge of spine to its base

3. Carapace length : from the anterior edge of eye-stalk to the posterior edge of carapace

4. Abdominal length : from first somite to tip of telson fork

Megalopa:

1. Carapace length : from tip of rostrum to posterior margin along middorsal line

2. Abdomen length : from first abdominal somite to hind end of telson

3. Total length : from tip of rostrum to hind end of telson

The telson processes were numbered following Kurata (1975).

5.3   RESULTS

There were 3 zoeal stages and a megalopa under laboratory conditions, The shortest intermoult duration of each zoeal stage (in days) is given below:

Shortest intermoult duration (in days) of zoeal stages in Thalamita crenata

Zoeal Stages		
I	II	III
6	4	5

Description of larval stages:

I Zoea

Rostral spine length	=	0.18 mm;
Dorsal spine length	=	0.22 mm;
Carapace length	=	0.38 mm;
Abdomen length	=	0.86 mm.

Carapace typical of portunid crabs with dorsal, rostral and a pair of lateral spines, all spines smooth, dorsal spine curves backwards, longer than rostral spine but shorter than carapace, rostral spine almost straight, lateral spines short, inconspicuous anterior dorsal knob present, eyes large and sessile (Fig. 27a,b).

Antennule (Fig. 27c):

Uniramous with 4 long aesthetascs.

Antenna (Fig. 27d):

Exopod less than half the length of protopodite, with 2 terminal setae, 1 long and 1 short, protopodite serrated on both margins, slightly longer than rostrum, no endopod.

Mandible (Fig. 27e):

Without palp and with well developed incisor process.

Maxillule (Fig. 27f):

Coxal and basal endites with 6 and 5 setae respectively, endopod 2 - segmented, distal segment with 4 terminal and 2 subterminal setae, proximal segment with 1 seta.

Maxilla (Fig. 27g):

Coxal and basal endites bilobed, coxa with 3 and 4 setae on proximal and distal segments respectively, basis with 6 and 5 setae, endopod with 2 setae terminally and 2 setae subterminally, scaphognathite with 5 setae.

First maxilliped (Fig. 27h):

Basis with 6 setae, endopod 5-segmented, with 2,2,2,2, 4+1 setae from proximal to distal segments, exopod 2-segmented with 4 natatory setae.

Second maxilliped (Fig. 27j):

Basis with 4 setae, endopod 3 - segmented, segments 1 and 2 with a setae each and segment 3 with 4 setae, 3 terminally and 1 subterminally, exopod unsegmented with 4 natatory setae.

Abdomen (Fig. 27q):

5-segmented, segments 1 and 2 smooth, segments 2 and 3 with a pair of dorsolateral protruberances, segments 3-5 with posterolateral spines, spines on segment 3 almost as long as that of segment 4.

Telson (Fig. 27t):

Longer than wide, forked with a median notch on posterior margin, outer spine 1 visible only under high magnification, spine 2 hair-like, spine 3 bending inwards distally, place of insertion of outer seta 3 about ¼ the length of fork, inner process formula 3+3, inner setae 1, more than half the length of fork.

II Zoea

Rostral spine length	=	0.55 mm;
Dorsal spine length	=	0.54 mm;
Carapace length	=	0.70 mm;
Abdomen length	=	1.33 mm.

Eyes stalked, rostral spine as long as or

slightly longer than dorsal spine, ventral margin of carapace denticulated with few setae, 5 pairs of pereiopod buds developed, first pair shows chelate nature (Fig. 28a,b).

Antennule (Fig. 28c):

No change.

Antenna (Fig. 28d):

Protopodite of antenna longer than rostral spine, endopod developed as a bud.

Mandible (Fig. 28e):

Molar process developed.

Maxillule (Fig. 23f):

Coxa with 7 setae, basis with 11 setae, no change in endopod.

Maxilla (Fig. 28g):

No change except increase in the number of setae on scaphognathite.

First maxilliped (Fig. 28h):

Except increase in the number of natatory setae from 4 to 9, no other change.

Third maxilliped:

Developed as a bud.

Abdomen (Fig. 28q)

Posterolateral spines in somite 3 slightly longer than those of somite 4 and about 3/4 the length of somite 4, pleopod buds quite evident from segments 2-5.

Telson (Fig. 28t):

Outer spines 1 and 2 disappear, a median pair of process added and the inner process formula becomes 4+4, median notch shallowed, telson about 2 times longer than wide, outer spine hardly visible.

III Zoea

Rostral spine length   = 0.63 mm;

Dorsal spine length   = 0.63 mm;

Carapace length   = 1.10 mm;

Abdomen length   = 2.35 mm.

Rostral spine as loij as dorsal spine, periopod buds enlarged, rostral spine shorter than protopodite of antenna (Fig. 20a,b).

Antennule (Fig. 29c):

Biramous, inner ramus developed as a bud, outer ramus with 9 aesthetascs, 4 terminal and 5 subterminal.

Antenna (Fig. 29d):

Endopod bud enlarged, more than half the length

of protopodite.

Mandible (Fig. 29e):

Increased in size, palp not yet developed.

Maxillule (Fig. 29f):

No change in distal segment setation, basis and coxa with 14 and 7 setae respectively.

Maxilla (Fig. 29g):

Setae on scaphognathite 35-37, setae on endopod increased to 6, 4 terminal and 2 subterminal, basis with 6 and 8 setae on distal and proximal segments respectively, coxa with 5 and 3 setae on proximal and distal segments.

First maxilliped (Fig. 29h):

Enlarged in size, exopod with 12 natatory setae.

Second maxilliped (Fig. 29j):

Enlarged in size, exopod with 12 natatory setae.

Third maxilliped:

Bud enlarged.

Abdomen (Fig. 29q):

With 6 somites, somite 6 being separated from telson, 4 pairs of uniramous pleopod buds developed from somites 2-5, uropod bud (Fig. 29r) seen at the end of somite 6,

posterolateral spine on somite 3 almost touches the base of
spine on somite 4.

Telson (Fig. 29t):

About 1½ times longer than broad, all spines intact,
a median process added and inner process formula becomes
4+1+4, first process of inner setae more than half the length
of fork.

Megalopa

Carapace length	=	1.52 mm;
Abdomen length	=	1.02 mm;
Total length	=	2.50 mm.

Carapace with a square rostrum, the centre produced
into a long spine sticking out forward almost horizontally,
about half as long as rest of rostrum, rostrum bears few
setae, carapace smooth without any protruberances or dorsal
spines, eyes large (Fig. 30b).

Antennule (Fig. 30c):

Biramous, peduncle 3-segmented, inner ramus
unsegmented with 5 setae, 3 terminal, 1 subterminal and 1 in
the middle, outer ramus 5-segmented, segments 2-4 bear 12
long aesthetascs, terminal segment with 2 terminal and
2 middle setae.

Antenna (Fig. 30d):

Flagellum exceeds tip of rostrum by 4 flagellar segments; peduncle 4-segmented, flagellum 8-segmented, segment 5 of flagellum with a pair of long setae at its distal end, last segment of flagellum with 3 setae terminally.

Mandible (Fig. 30e):

Mandible spoon shaped, 2-segmented palp, proximal segment without seta and distal segment with 7 setae, palp bends inside the cutting edge.

Maxillule (Fig. 30f):

Basal endite with 20 terminal setae, 3 setae on lower margin, coxal endite with 13 setae, endopod unsegmented and bears 5 setae.

Maxilla (Fig. 30g):

Shows somewhat degenerated features compared to that in the last zoea in the setation of endites and in endopod being without setae, scaphognathite greatly enlarged and fringed with numerous setae.

First maxilliped (Fig. 30h):

Bilobed, protopod with 12 and 27 setae respectively on proximal and distal lobes, endopod short, flattened, unsegmented and with 4 setae, exopod 2-segmented with 4

plumose setae distally, epipod comparatively shorter than other maxillipeds and with 4 setae at its distal end.

Second maxilliped (Fig. 30j):

With 5-segmented endopod, with 1,2,0,8,8 setae from proximal to distal segments, exopod 2-segmented with 5 apical setae on its distal segment, epipod long and bears 7 setae distally and 2 setae proximally.

Third maxilliped (Fig. 30k):

Endopod 5-segmented, ischium longest segment, ischium, merus, carpus, propodus and dactylus with 15,12,6, 7,9 setae respectively, excpod 2-segmented, 4-5 terminal setae on distal segment, no seta on proximal segment, epipod long and bears 3 setae proximally, 1 in middle and 11 setae terminally.

Pereiopods (Fig. 30 l-p):

First pair of pereiopods equal, chelate, fingers with 4 teeth each along cutting edges, ischial and carpal spines absent, finger tips cross each other in closed condition of chela, leg 2 with spine on ventral edge of coxa, dactyli of legs 2-4 longer than propodi with several prickly spines along ventral edge, last segment of leg 5 paddle shaped ending in a spine, with setae and a few feelers along ventral edge, sternal spine at base of leg 4 larger than

spine on coxal endite of leg 2 but smaller than the sternal spine of closely related genera, it touches about ¼ the length of abdominal somite 2.

Abdomen:

6-segmented, shorter than carapace, posterolateral border of first 4 segments smooth and without spines, posterolateral spine on somite 5 extends to about ¼ the length of telson, 4 pairs of biramous pleopods (Fig. 30r) on somites 2-5, no seta on protopod, exopod with 15 setae, endopod small, non-setose, with 3 microscopic hooks.

Telson (Fig. 30t):

Telson as long as wide and tapers slightly behind.

Uropod (Fig. 30s):

Uniramous, exopod with 14 setae and protopod with a single seta.

Chromatophore:

All the 3 zoeal stages and megalopa appear diffused yellowish, black chromatophores consistent over vicera extending along intestine as far back as abdominal somite 2. Diffused yellow chromatophores are present in all the abdominal somites and on the upper part of telson consistently in all the 3 zoeal stages.

5.4   DISCUSSION

Alcock (1899) recorded 21 species of Thalamita from the Indian waters, but information on the larval stages is available for only one species (T. crenata)(Prasad and Tampi, 1953; Chhapgar, 1956). In this species too, only the first zoeal stage has been described from Indian waters. Presently the whole life history stages have been worked out for this species. Certain differences between the first zoeal stage of earlier studies and the present study have been observed and they are summarised in Table 49.

The impracticability of using the number of larval stages as an inter-or intra-generic character within the potuninae has been well established (Fielder and Greenwood, 1979). The known range of zoeal stages for portunids is 4-7 (Rice and Ingle, 1975). But it was subsequently changed by Fielder and Greenwood (1979) as 3-7. Therefore meaningful comparisons can only be made between the larvae of many species at the first, last zoeae and megalopa stages because different degrees of development obviously occur at inter-mediate points depending upon the number of zoeal stages. Presently in T. crenata only three zoeal stages were found. The same species was also reared by Greenwood and Fielder (1979) in Australian waters but they came across 7 zoeal stages. They have not described all the larval stages. As

there is variation in the number of zoeal stages at the intraspecific level also, comparisons are made for the first and last zoeal stages only (Table 50). This suggests that differing environmental conditions during development could yield different means and variance in dimensions not only at the interspecific level, but also in intraspecific level too.

In some decapod crustaceans, larval characteristics are sufficiently distinctive to be of value in establishing specific distinctness of adult populations previously regarded as conspecific (Gore, 1972). In Thalamita, the reverse seems almost the case (Greenwood and Fielder, 1979).

Kurata (1975) devised a key to the known zoeal and megalopa of Japanese genera of portuninae. The present study supports the criterion or larval characteristics he used to distinguish the larval stages of Thalamita (both zoeae and megalopa) from those of Portunus and Charybdis.

Identification of larvae of Thalamita upto species level is difficult as it had been the case with various authors who faced similar difficulties with different portunid genera (Yatsuzuka, 1957; Kurata, 1975) because larvae are so similar and it is very difficult to tell species apart other than by examination of minute characteristics. Kurata (1975) also suggested that identification of species is almost impossible without referring to every available

minor difference. But in the case of Thalamita even minor differences are of limited use. Greenwood and Fielder (1979) were able to find larval features of value in distinguishing at least four species of Thalamita they worked with. But the present study on one among the four species showed overlapping in characters they used to distinguish the species (e.g. percentage of abdominal segment 4 overlapped by abdomen 3 post-lateral spines - vide Table50). So, the present study agrees with the sentiments of those who encountered difficulties to find out species even after examination of minute characteristics.

Summary of changes during the larval development of Thalamita crenata

Stage	Feature	Particulars
I Zoea	Rostral spine length	0.18 mm
	Dorsal spine length	0.22 mm
	Carapace length	0.38 mm
	Abdomen length	0.86 mm
	Eyes	Sessile
	Antennule	Uniramous with 4 aesthetascs
	Antenna	Without endopod
	Mandible	With incisor process only
	Maxillule	Coxal and basal endites with 6 and 5 setae respectively

Stage	Feature	Particulars
I Zoea	Maxilla	Scaphognathite with 5 setae
	I & II maxilliped	4 natatory setae on exopod
	III maxilliped	Not developed
	Abdomen	5-segmented
	Telson	Inner process formula 3+3. Outer spine 1 visible only under high magnification
II Zoea	Rostral spine length	0.55 mm
	Dorsal spine length	0.54 mm
	Carapace length	0.70 mm
	Abdomen length	1.33 mm
	Eyes	Stalked
	Antennule	Uniramous
	Antenna	Endopod developed as bud
	Mandible	Molar process developed
	Maxillule	Coxa with 7 setae basis with 11 setae
	Maxilla	Scaphognathite with more than 20 setae
	I & II maxilliped	9 natatory setae on exopod
	III maxilliped	Developed as a bud
	Abdomen	Pleopod buds quite evident from segments 2-5

Stage	Feature	Particulars
II Zoea	Telson	Outer spines 1 and 2 disappear. Inner process formula 4+4
III Zoea	Rostral spine length	0.63 mm
	Dorsal spine length	0.63 mm
	Carapace length	1.10 mm
	Abdomen length	2.35 mm
	Antennule	Biramous, inner ramus developed, outer ramus with 4 terminal and 5 sub-terminal aesthetascs
	Antenna	Endopod more than half the length of protopodite
	Maxillule	Coxa with 7 setae Basis with 14 setae
	Maxilla	Scaphognathite with 35-37 setae
	I & II maxillipea	Exopod with 12 natatory setae
	Abdomen	With 6 segments. 4 pair of uniramous pleopods on segments 2-5
	Uropod	Developed as bud
	Telson	Inner process formula 4+1+4
Megalopa	Carapace length	1.52 mm
	Abdomen length	1.02 mm
	Total length	2.50 mm

Stage	Feature	Particulars
Megalopa	Antennule	Biramous
	Antenna	Uniramous
	Mandible	2-segmented, palp developed
	Maxillule	Coxa with 13 setae Basis with 20 setae
	Maxilla	Endopodite setae reduced completely
	I maxilliped	Radical change occurs in the appendage and differs sharply from other two maxillipeds 5-segmented endopod becomes single segmented Epipod developed
	II maxilliped	3-segmented endopod of III zoea becomes 5-segmented, epipodite developed
	III maxilliped	Becomes a typical appendage from the bud of III zoea Epipodite developed
	Pereiopods	First pair chelate Dactylus of fifth leg paddle shaped
	Abdomen	6-segmented with 4 pairs of biramous pleopods, exopod of pleopod with 15 setae endopod of pleopod with 3 microscopic hooks
	Telson	Broad base with distal end rounded
	Uropod	Uniramous Exopod with 14 setae Endopod absent

Table 49. Comparison of the first zoeal stage of
Thalamita crenata

Feature	Prasad and Tampi (1953)	Chhapgar (1956)	Present study
Rostral spine length (mm)	0.23	0.188	0.18
Dorsal spine length (mm)	0.275	0.238	0.22
Antennal aesthetascs	3	1	4
Setae on coxa of maxillule	5	–	7
Setae on basis of maxillule	8	–	12
Setae on basis of I maxilliped	5	–	–
Setal formula in endopod of I maxilliped	2,2,0,2,5	–	2,2,2,2,5
Setae on basis of II maxilliped	3	–	4
Median abdominal spines	Absent	Present	Absent
No. of outer spines in telson	2 + 2	1 + 1	3 + 3

Table 50. Comparison of I and last zoeal stages of
Thalamita crenata from different localities

I Zoea	Feature	Greenwood and Fielder (1979)	Present study
	Length of carapace (A)	0.48 mm	0.38 mm
	Length of dorsal spine (B)	0.34 mm	0.22 mm
	Length of rostum (C)	0.35 mm	0.18 mm
	Ratio B/A	0.71	0.58
	Ratio B/C	0.97	1.22
	% abd.segment 4 overlapped by abd. 3 post-lat. spine	50	100
	Maxilliped I, Basis	With 10 setae	With 6 setae
	Maxilliped II, endopod distal segment	With 5 setae	With 6 setae
Last zoea	Length of carapace (A)	1.19	1.10 mm
	Length of dorsal spine (B)	1.05	0.63 mm
	Length of rostral spine (C)	1.00	0.63 mm
	Ratio B/A	0.64	0.57
	Ratio B/C	0.72	1.00
	Antennule terminally Subterminally	With 5 setae With 10 setae	With 4 setae With 5 setae
	Maxillule basal endite	With 18 setae	With 14 setae
	Scaphognathite	With 33-35 plumose setae	With 35-37 plumose setae
	Maxilliped II exopod	With 14 setae	With 12 natatory setae

Fig 27. I zoea of _Thalamita crenata_

        a - Entire larva (lateral view)

        b - Entire larva (dorsal view)

        c - Antennule

        d - Antenna

        e - Mandible

        f - Maxillule

        g - Maxilla

        h - First maxilliped

        j - Second maxilliped

        q - Abdomen

        t - Telson

Fig 28. II zoea of _Thalamita crenata_

      a - Entire larva (lateral view)

      b - Entire larva (dorsal view)

      c - Antennule

      d - Antenna

      e - Mandible

      f - Maxillule

      g - Maxilla

      h - First maxilliped

      j - Second maxilliped

      q - Abdomen

      t - Telson

Fig 29. III zoea of _Thalamita crenata_

    a - Entire larva (lateral view)

    b - Entire larva (dorsal view)

    c - Antennule

    d - Antenna

    e - Mandible

    f - Maxillule

    g - Maxilla

    h - First maxilliped

    j - Second maxilliped

    q - Abdomen

    r - Pleopod

    t - Telson

Fig 30. Megalopa of *Thalamita crenata*

b - Entire larva (dorsal view)

c - Antennule

d - Antenna

e - Mandible

f - Maxillule

g - Maxilla

h - First maxilliped

j - Second maxilliped

k - Third maxilliped

l - Cheliped

m - Second leg

n - Third leg

o - Fourth leg

p - Fifth leg

r - Pleopod

s - Uropod

t - Telson

LARVAL DEVELOPMENT

FIG.27

a

b

c

d

e

f

g

h

j

q

t

a,b,d,h,j,t
0.1mm

c,e,f,g
0.25mm

q
0 25mm

FIG.28

a , b
0.2 mm

c , e , f , g
0.25 mm

d,h,j,t
0.1mm

q
1mm

FIG.29

a

_{a,b}
0.2mm

e

b

d

c,e,f,g,r
0.25mm

j

c

r

d,h,j,t
0.1mm

h

q
1mm

q

g

f

t

FIG.30

b

d

c

e

f

g

b,l,m - p
0.2 mm

h

l

m

d
1mm

j

c,e-h, r,s,t
0.25 mm

o

n

p

j,k
0.25mm

s

k

t

r

EFFECT OF SALINITY ON LARVAL DEVELOPMENT

6   EFFECT OF SALINITY ON THE LARVAL DEVELOPMENT OF
                THALAMITA CRENATA IN THE LABORATORY
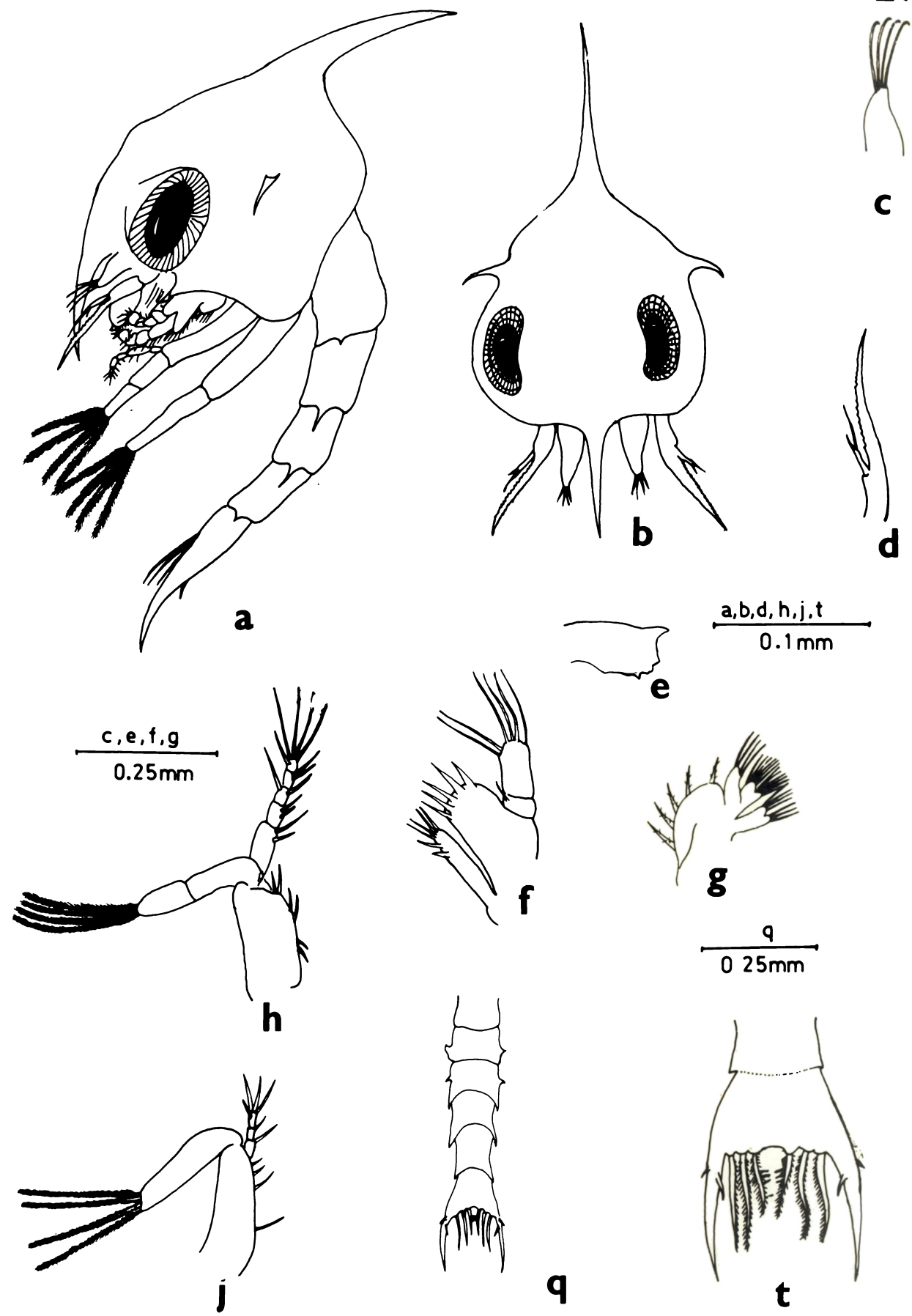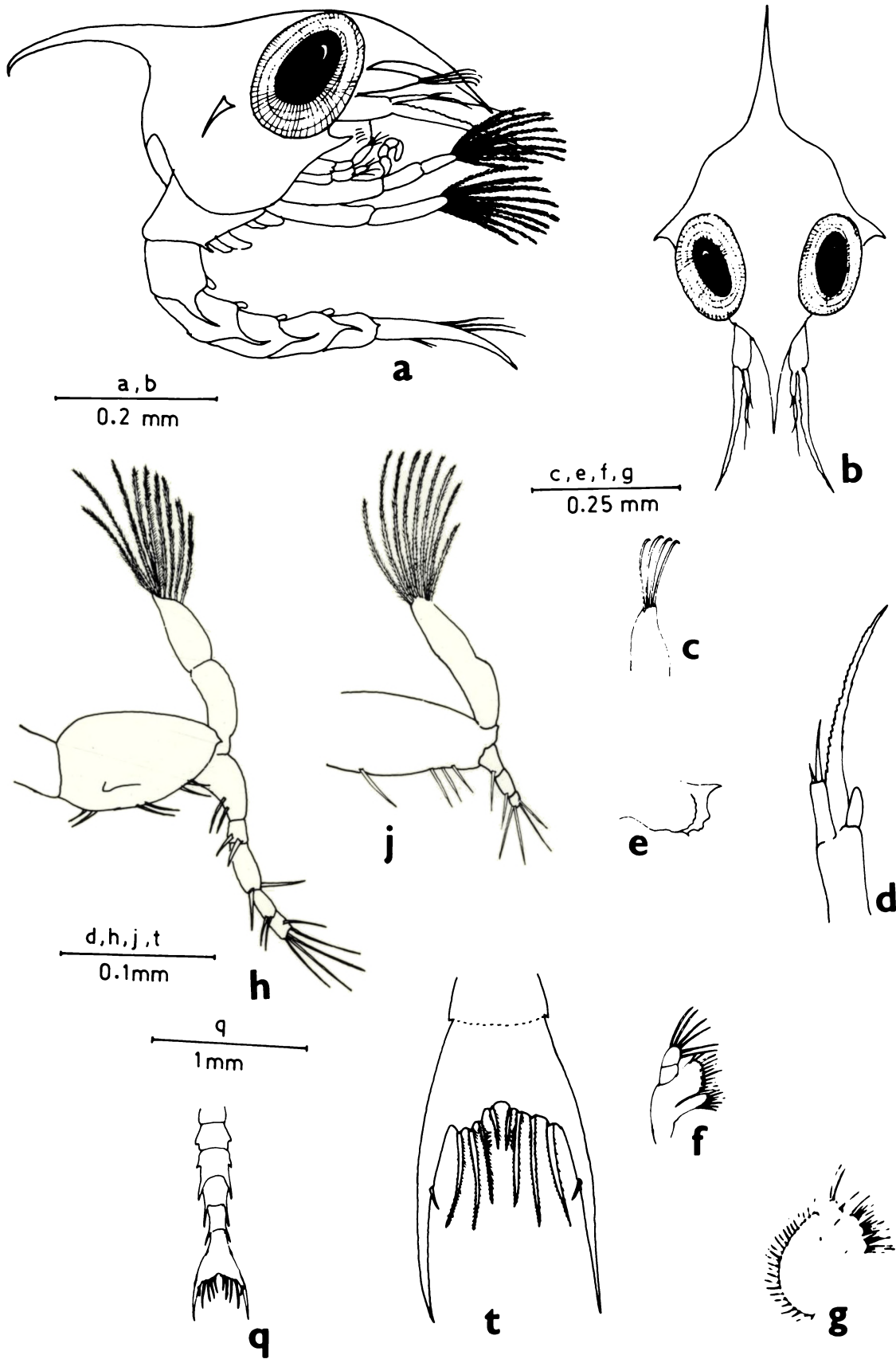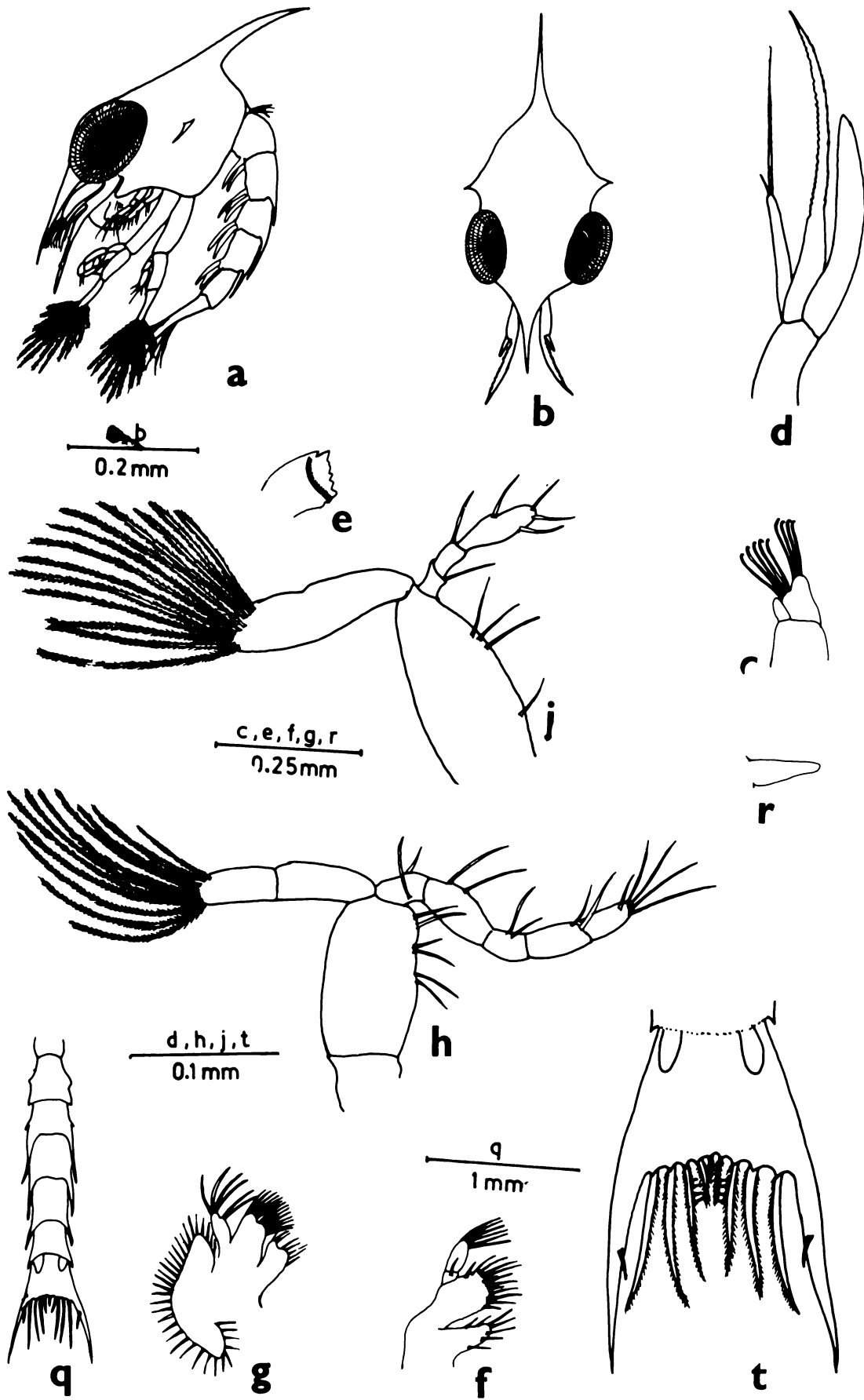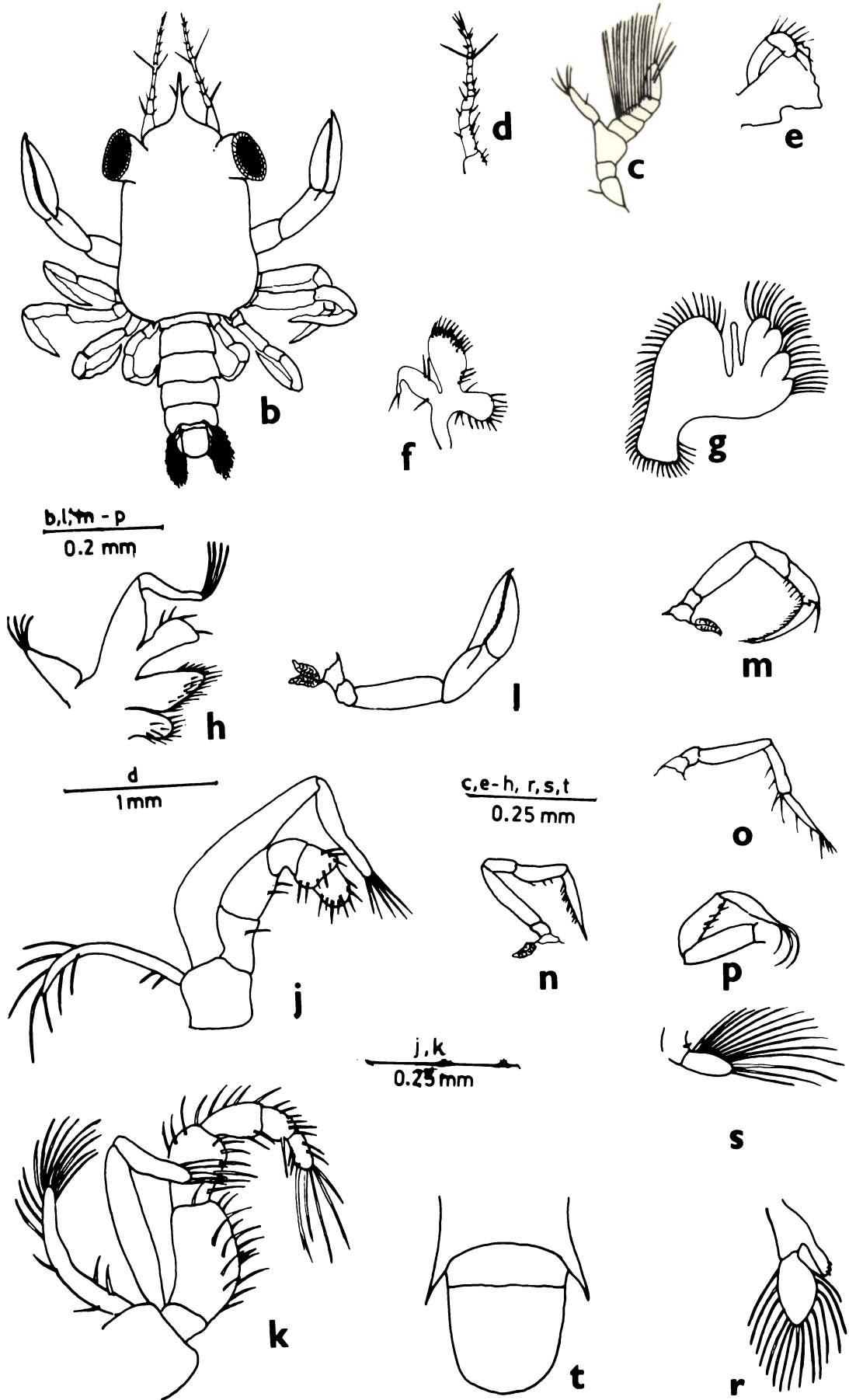
6.1   INTRODUCTION

By rearing the larvae in controlled conditions of

temperature, salinity diet and light it is possible to

determine the extent to which individual stages are affected

by such environmental factors, the way in which the duration

of the larval stages is affected and the way in which the

environmental factors could be manipulated suitably to maximize

survival rate and production (Costlow and Bookout, 1970).

Studies on annual reproductive cycle show that in

marine invertebrates the breeding is timed so as to provide

maximum larval survival and the larvae are produced at a

time ecologically favourable to them (Giese, 1959). In

temperate waters, breeding can be correlated with changes

in temperature and larvae of Organisms are liberated at a

time when the temperature of the environment is suitable

for their metamorphosis (Giese, 1959). Many studies have been

carried out there on the effects of temperature and salinity

on larval development of decapod crustaceans (Costlow and

Bookhout, 1962,'71; Bookhout, 1964,'72; Ong and Costlow,

1970; Regnault and Costlow, 1970; Roberts, 1970; Christiansen

and Costlow, 1975). These studies show that temperature is

an important factor affecting the development and survival

of larvae. It was also found to regulate the time of

metamorphosis of larvae and to restrict the distribution
(Costlow and Bookhout, 1969). In tropics, due to stenothermal
conditions, salinity more than temperature was found to play
a major role in timing the reproduction in marine invertebrates
especially in nearshore and estuarine animals (Pillay and
Nair, 1971). But experimental studies in support of the above
fact are not many (Ajmalkhan and Natarajan, 1981).

Presently estuarine portunid crab *Thalamita crenata*
was found to breed for an extended period except during
monsoon (vide Chapter 2). The reason for this may perhaps
lie in its larval life history. So the present study was
attempted to elucidate the role of salinity on the larval
development of this estuarine portunid crab.

6.2   MATERIALS AND METHOD

Ovigerous females were collected from Vellar
estuary and kept in water obtained from the same general area
as the ovigerous females. Sea water was diluted with
distilled water to obtain desired lower salinities and
salinity was determined by standard argentimetric method
with necessary corrections (Harvey, 1955). The larvae
hatched in water of 20‰ salinity were reared in 6 test
salinities of 10,15,20,25,30 and 35‰. The temperature

was 20+1°C during the study period. The larvae were

segregated in groups of 5 and kept in plastic trays contain-

ing 100 ml of filtered water. The larvae were fed daily

with freshly hatched Artemia nauplii. Water was changed

daily. Each tray was examined daily for exuviae, and number

and stage of dead and living larvae recorded before the

larvae were transferred to clean dishes of sea water of the

desired salinity with freshly hatched Artemia nauplii.

Evidence of moulting was determined by the presence of an

exuvium. Duration of a stage was determined from the time

of hatching to the first moult and in later stages from one

moult to the next. The criterion of a successful moult was

to find to complete exuvium with no remnant on the larvae.

The effect of salinity was studied only in the three zoeal

stages of this species. In each test salinity 100 larvae

were reared. No separate control was maintained as the

present test salinity range covered the normal salinity

existing in the estuarine environment (35‰).

Percentage of moulting here does not represent

percentage of the original hundred larvae, but rather the

percent of the number in each stage to moult to the next

stage. The percentage of moulting was calculated in the

following way:

$$\text{Percentage of moulting} = \frac{\text{No. of larvae completing particular moult} \times 100}{\text{No. of larvae completed previous moult}}$$

Presently it could be seen that even in the most favourable test salinity, some of the larvae did not moult for quite a long time, and the above formula did not take them into consideration which may otherwise impair the results.

6.3   RESULTS

Among the six test salinities, in 10 and 15%o salinities, total larval mortality was encountered in the same day and the following day of transfer respectively and complete metamorphosis took place only in four test salinities from 20 to 35%o .

Mortality:

The mortality rate of the three zoeal stages of T. crenata in different test salinities is given in Fig. 31a. At 35%o salinity, the larval development was most satisfactory among all the test salinities and 84 out of the 100 larvae moulted to the II zoeal stage. The mortality rate in II zoeal stage was slightly less than the previous stage and 73 larvae moulted to the next stage. Out of these 73 larvae, 62 larvae moulted to the megalopa stage. Thus the cumulative survival rate in this test salinity was 62% . Stage wise, the cumulative survival rate was 84,73 and 62% and cumulative mortality rate 16,27 and 38% respectively in the I, II and III zoeal

stages. Larvae died just prior to moulting or soon after moulting to the subsequent stage. The mortality rate at 30%₀ salinity was more than that of 35%₀ salinity and the overall survival rate was 51% . There was 30% mortality in stage I and the cumulative mortality rate in II and III stages rose to 41 and 49% respectively. Stage wise mortality rate to cumulative mortality rate was more in the I zoeal stage and it decreased as development progressed (11% in II stage and 8% in III stage). Larvae died both prior to and just after moulting.

As salinity decreased, the overall survival rate also decreased and it was 37% in the 25%₀ salinity. The cumulative mortality rate in II stage rose to 46% from the 35% in the I stage and it was 63% in stage III. Stagewise mortality rate to cumulative rate was 35,11 and 17% respectively in the I, II and III zoeal stages.

The mortality rate was highest at 20%₀ salinity and the overall survival rate amounted to only 19%. The cumulative mortality rate rose to 73% in II stage from the 61% in stage I and it further rose to 81% in the III stage. Stagewise mortality rate to the cumulative mortality rate was 61, 12 and 8% respectively in the I, II and III zoeal stages.

The ability to tolerate low salinity was remarkable

in the II and III zoeal stages than in the I zoeal stage
which was more vulnerable to lower salinity. Larvae dying
prior to moulting showed anlagen of structures of the succeed-
ing stage beneath the cuticle and also separation of hypodermis
from exuvium. These larvae were probably weak and could not
free themselves from the exuviae and so died. In lower
salinities, some larvae also died during the process of
moulting. They shed part of the integument, either the head
exuviae or abdominal exuviae, and this part alone swelled
in size, but they could not free themselves from the rest of
the old integument. Larvae which died after completing the
moult probably might have succumbed due to the struggle for
completing the moult.

Intermoult duration:

Most ofthe 'larvae moulted during night time but
few larvae moulted in the morning immediately after change
of water. The mean time after hatching or moulting of each
zoeal stage till the next moult, in days, was calculated in
all the test salinities. The mean intermoult duration of
each zoeal stage in four test salinities is given in Table 51.

I Zoea:

The mean intermoult duration of 7.57 days for this
zoeal stage at 35‰ salinity was the shortest and increased

gradually as salinity decreased and it was 11.33 days at 20‰ salinity. There was significant statistical difference between the mean intermoult duration of all the four test salinities in which complete development took place. In 35‰ salinity larvae started moulting after the 6th day and the majority moulted after the 7 and 8 day. As salinity decreased, the day of moult shifted gradually and in 20‰ salinity moulting started only after the 9th day (Fig. 31b).

II Zoea:

In all the 4 test salinities, the II zoea had the shortest intermoult duration than the other two zoeal stages (I and III). Here also the mean intermoult duration increased as salinity decreased. The difference between the mean intermoult duration of 35 (4.83) and 30‰ (5.05) salinities was not statistically significant. But the mean intermoult duration of 25‰ salinity differed significantly from that of 30‰ salinity and that of 20‰ salinity differed significantly from that of 25‰ salinity. Larvae in 35‰ salinity started moulting first and the day of second moult shifted gradually as salinity decreased (Fig.31c).

III Zoea:

The mean intermoult duration of this stage is more than that of the previous stage (II zoea), but less than that of the I zoeal stage. It was 5.33 days at 35‰

salinity and increased gradually as salinity decreased. The 't' values for the differences in mean intermoult duration between all the four test salinities were statistically significant. As seen in the previous two zoeal stages the day of third moult also shifted gradually as salinity decreased (Fig. 31d).

Whole zoeal development:

The effect of salinity on the intermoult duration of all the three zoeal stages was quite apparent. At 35‰ salinity, the mean development time of all the 3 zoeae was short (17.73 days). As salinity decreased, the mean development time increased and it was 19.16, 22.30 and 27.79 days respectively in 30, 25 and 20‰ salinities. The **t values** for the differences in mean development time between all the four test salinities were statistically significant (Table 52).

6.4   DISCUSSION

It is clear from the present study that, the duration of the zoeal stages, the overall time required for zoeal development and the mortality rate of larvae in T. crenata increased as the salinity was lowered. Below 20‰ salinity, larval development did not take place and as the salinity increased above 20‰, the rate of development and survival rate improved.

The notion that larval stages are subject to limita-
tion by abiotic environmental factors such as **salinity,**
temperature etc. was mooted by Shelford (1915). Later works
on the influence of these environmental factors on larvae
proved the above fact. The best documented example in this
line is among the brachyurans. The adults of blue crab
Callinectes sapidus, have the ability to live in fresh to
oceanic water. But to hatch off their eggs, the females
have to return to water with a salinity of more than 15‰.
The complete larval development in this species was found to
occur only at 20‰ salinity and above (Sandoz and Rogers, 1944;
Costlow and Bookhout, 1959; Costlow, 1957). In _Rhithropanopeus_
harrisii also larval development took place between 15 and
30‰ salinities (Costlow _et al._, 1966). Still in another
brachyuran crab _Hepatus epheliticus_ the larval development
was completed only within a narrow range of 30-35‰ salinity
(Costlow and Bookhout, **1962**). In contrast to the above the
range within which the whole larval development could take
place was broader (15-45‰) in the terrestrial brachyuran
crab _Cardisoma guanhumi_ (Costlow and Bookhout, 1968).

In adult decapod crustaceans, the osmoregulatory
mechanism is well developed and this mechanism enables them
to thrive in places where extreme variations are noted in
salinity. But in larval stages, as this mechanism is not

well developed, they are adapted only to higher salinities
and so they die in low salinities. Presently, larvae of
T. crenata were found to die prior to, during or just after
ecdysis:. During ecdysis, major changes take place in the
cuticle structure and they lower the defence of the larvae.
As the larval stages do not possess that good osmoregulatory
mechanism found in adults, they succumb in lower salinities.

Present study partly explains why T. crenata is
not breeding during monsoon. Further studies suggested on
the lines in Chapter 2 will enable us to understand fully
the reproductive strategy of this portunid crab.

Table 51. Duration of zoeal stages and total time of zoeal development of _Thalamita_ _crenata_ in four test salinities

Salinity	I				II				III				Whole development			
	N	Mean in days	S.D.	t value for diff. in means	N	Mean in days	S.D.	t value for diff. in means	N	Mean in days	S.D.	t value for diff. in means	N	Mean in days	S.D.	t value for diff. in means
35‰	84	7.57	.78	6.25***	73	4.83	1.02	1.33	62	5.33	0.69	2.10*	62	17.73	0.69	8.58***
30‰	70	8.43	.93	2.76**	59	5.05	0.84	2.02*	51	5.68	1.07	9.46***	51	19.16	1.07	12.80***
25‰	65	8.92	1.12	10.07***	54	5.38	0.90	6.04***	37	8.00	1.22	4.39***	37	22.30	1.22	17.48***
20‰	39	11.33	1.28		27	7.08	1.39		19	9.38	0.86		19	27.79	0.86	

*** P <.001

** P <.01

* P <.05

Fig 31. a - Mortality rate of _Thalamita crenata_
           zoeal stages in different test
           salinities

         b - Intermoult duration of I zoea of _T. cre_
             in different test salinities

         c - Intermoult duration of II zoea of
             T. crenata in different test
             salinities

         d - Intermoult duration of III zoea of
             T. crenata in different test salinities

EFFECT OF SALINITY ON LARVAL DEVELOPMENT

FIG.31
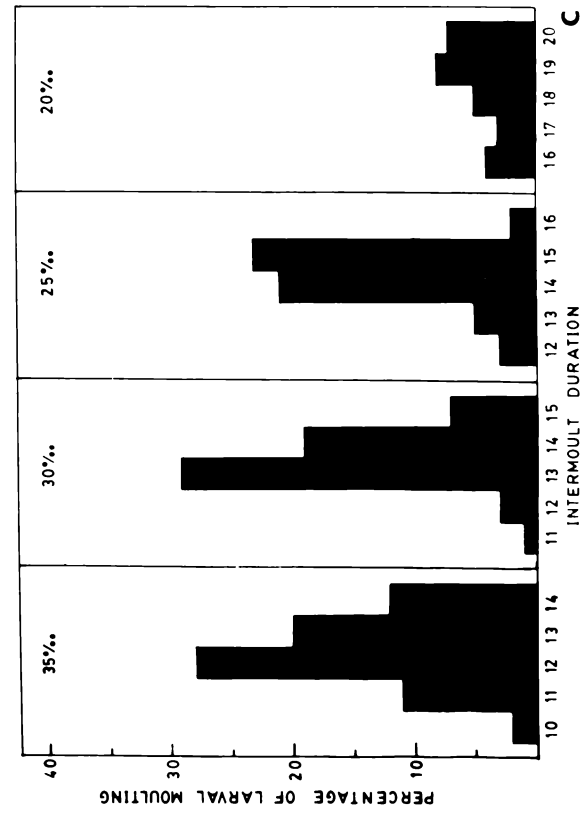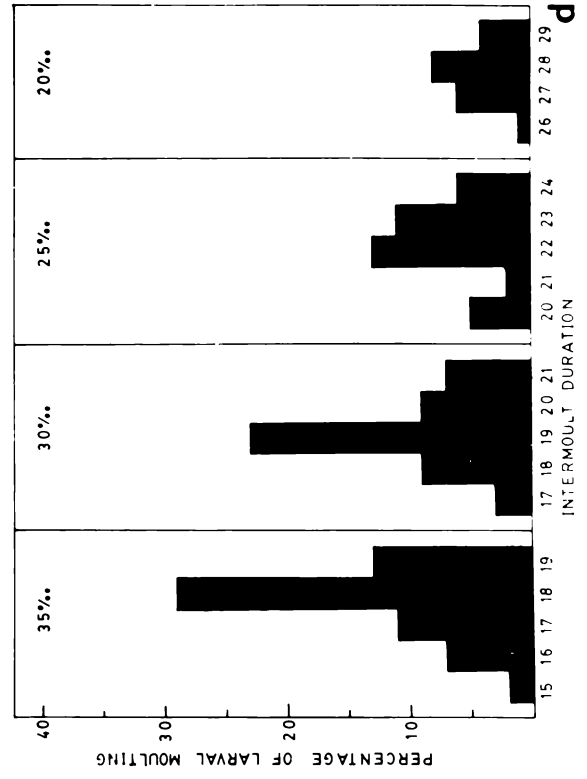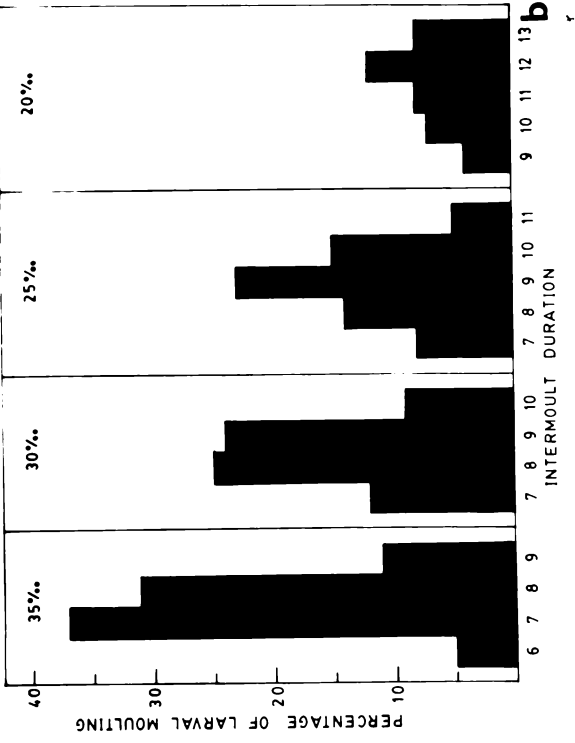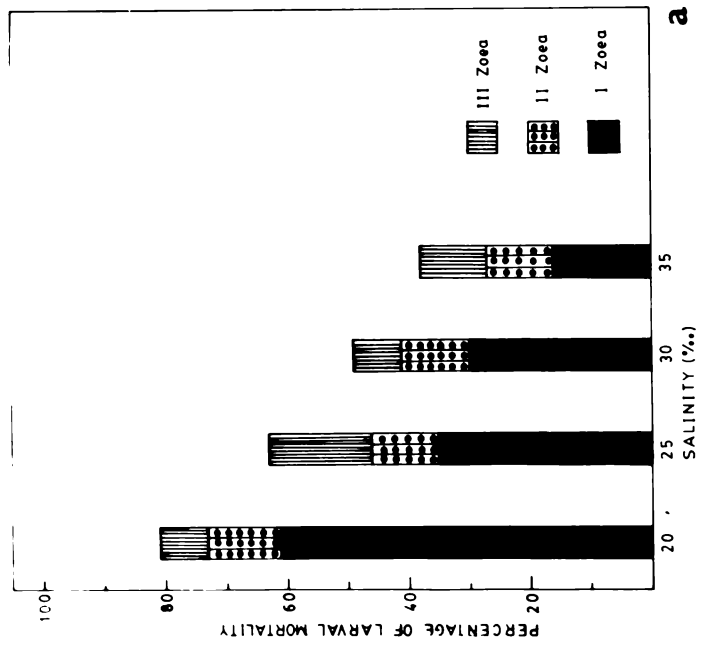
PROXIMATE
COMPOSITION

7.1   INTRODUCTION

Importance of knowing the proximate composition in edible organisms was emphasized by Stansby (1954) and knowledge on the protein, lipid and carbohydrate contents of the meat do certainly help in assessing the nutritional qualities of organisms in question. Nutritive values of crabs can be helpful in the selection and utilisation of a particularly advantageous species as also to know which size groups will be adequate and advantageous for consumption from a nutritive view point. Proximate composition in fresh condition and after processing has been studied in many fishes. Studies in this direction on crabs are available but they are lesser in number compared to the quantum of work done on fishes. Some earlier works are by Fellers (1936) and Fellers and Harris (1940) on canned crab meat; by Dassow (1950) on the freezing and canning of king crab meat; by Littleford (1957) on pasteurization of crab meat; by Tanakawa (1959) on canned crab meat; by Gangal and Mahar (1963) on the freezing of crab meat; by Grominger and Dassow (1964) on the blueing of king crab meat; by Burnett (1965) on the ammonia content as index of decomposition of crab meat; by Collins and Brown (1965) and Early (1967) on the spoilage of crab meat; by Barnett <u>et al.</u> (1967) on the

spoilage of dungeness crab meat; by Dewar et al. (1969) on postmortem spoilage of queen crab meat; by Varga et al. (1970) on frozen and heat processed red crab meat; by Chinnamma et al. (1970) and Chinnamma (1973a,b) on the preservation of the meat of Scylla serrata.

All the works listed above by and large pertain to the post-harvest technology rather than to the chemical composition of crab meat and regarding this aspect few studies are available. They are by Heath (1970) on Carcinus maenas, by Badawi (1971) on Portunus pelagicus; by Chinnamma (1973a) on Scylla serrata, by Addison et al. (1972) on the queen crab Chionoecetes opilio; by Pillay and Nair (1973a) on Uca annulipes and Portunus pelagicus, by Radhakrishnan (1979) on Portunus pelagicus, P. sanguinolentus and Scylla serrata. Works done by Adiyodi (1968,'69), Rahaman (1967), Chandran (1968), Martin (1971) and Diwan and Nagabhushanam (1974) mainly deal with storage and mobilisation of organic resources in crabs during moult or reproductive cycle.

Thalamita crenata is being taken as food by poor people in Porto Novo region when the regular commercial fishery is lean and the present study deals with the meat content and chemical composition of this crab in relation to sex and size.

7.2   MATERIALS AND METHOD

Random samples of live specimens of T. crenata were collected from Vellar estuary at Porto Novo and the sexes were separated (berried females were not used in the analyses). Based on the carapace width they were grouped into six size groups as shown below:

20 mm and below

21 - 30 mm

31 - 40 mm

41 - 50 mm

51 - 60 mm

61 - 70 mm

Each specimen was cleaned and carapace width measured. Then the total body weight was weighed accurately to the nearest 0.1 mg. The carapace was then removed, the meat was separated and transferred to a petri dish, carefully from all parts of the body including the chelate legs. The separated meat content was weighed and the meat content was then calculated in percentage. The methods of estimation of dry weight, water content, protein, fat and carbohydrate are given below:

Dry Weight:

The body tissues as a whole were dried in an electric oven at 60°C till a constant weight was obtained

and then weighed in an electric balance to the nearest
0.1 mg.

The equation

$$\frac{Dry\ weight\ of\ the\ body\ tissue}{Wet\ weight\ of\ the\ body\ tissue} \times 100$$

gave the percentage of dry matter in the body of the animals.

Water content:

Difference in weight between wet and dried tissues
gave the weight of water present in the body tissues. So
the equation

$$\frac{Weight\ of\ water\ in\ the\ body\ tissues}{Wet\ weight\ of\ the\ body\ tissue} \times 100$$

gave the percentage of moisture content in the meat of the
animal.

Protein:

It was estimated employing Biuret method modified
by Raymont et al. (1964).

Fat:

Total fat extracted using, chloroform-methanol
mixture was estimated gravimetricaly, following the method
of Folch et al. (1956).

Carbohydrate:

Carbohydrate was estimated following the method

of Dubois et al. (1956) using phenol and concentrated
sulphuric acid. Percentage of protein, carbohydrate and
fat is given on dry weight basis.

7.3   RESULTS

Meat content:

Mean percentage in different size groups of males
and females is given in Table 52. In the males the maximum
meat content was 26.3% and the minimum 20.7%. In the females,
the maximum meat content was 23.2% and the minimum 16.4%.
Thus generally males were found to have more meat content
than females. The maximum meat content in both the sexes
were noticed in the lowest size group (11-20 mm). In males,
meat content decreased gradually as the animal grew and the
lowest value was found in the 51-60 mm size group. However
in the highest size group (61-70 mm), the meat content
slightly increased. In females, eventhough the highest
value was found in the lowest size group, the next size
group (21-30 mm) was found to have the lowest meat content.
However the meat content increased gradually as the animals
grew and once again there was a fall in the highest size
group.

Water content and dry weight:

    Mean percentage of water content and dry weight of both males and females are plotted in Fig. 32a. Water content shows fluctuations in different size groups. In males, the lowest water percentage (68.4%) was found in the lowest size group viz. 11-20 mm. Then it started increasing gradually in other size groups and the maximum (82%) was found in the 51-60 mm size group. Then it fell to 76.3% in the highest size group (61-70 mm). The mean dry weight percentage exhibited an inverse relationship with the mean percentage of water. The maximum dry weight percentage (31-67%) was encountered in the group which showed the minimum water content (11-20 mm size group). As the animal grew the dry weight percentage decreased and the lowest dry weight percentage (18%) was recorded in the 51-60 mm size group which showed the highest water content. However in the highest size group, dry weight increased to 23.7%.

    In females, as in the case of males, the lowest water content (69.6%) was encountered in the lowest size group and the highest water content (83.5%) in the next size group (21-30 mm). It decreased in subsequent stages and in the last size group again it rose. The dry weight percentage as in the case of males showed inverse relationship with water content and it behaved exactly in the opposite direction

of water content.

The protein content in different size groups of
T. crenata sex wise is plotted in Fig. 32b,c. It could be
seen that males were more proteinaceous than females in all
the size groups. In males, the maximum values of protein
(75.2%) was found in the smallest crabs (11-20 mm size group).
As the animals grew the protein content decreased gradually
and the lowest value (64.9%) was noted in the highest size
group (61-70 mm).

In females the protein content varied from 65.4%
to 53.9% in different size groups. As observed in the case
of males, here also the highest value was encountered in the
lowest size group (11-20 mm). After a decline, in the next
size group (21-30 mm), it started increasing in the subsequent
two higher size groups and then declined again in the highest
two size groups and the lowest value (53.9%) as found in the
case of males was encountered in the highest size group
(61-70 mm).

Carbohydrate:

The carbohydrate content in different size groups
- sex wise is presented in Fig. 32b,c. In males the values
varied from 1.4 to 9.8%. Initially i.e. in the lower two
size groups (11-20 and 21-30 mm) it was high and touched
the lowest level in the 31-40 mm size group. From 41-50 mm

size group it started increasing and the highest value (9.8%) was found in the 61-70 mm size group animals.

In females also, the trend was more or less the same, smallest animals had high carbohydrate content (9.6% for 11-20 mm size group). It declined as the animal grew and the lowest value 0.4% was recorded for the 41-50 mm size group. It increased again and the highest value was noted in the highest size group animals (61-70 mm).

Fat:

Fat values (plotted sexwise for different size group animals in Fig.32b,c) were generally low in the smaller crabs and more in the bigger crabs. In males fat values fluctuated from 5.4 to 15.6% and behaved erratically in inbetween groups. Initially (in 11-20 mm size group) it was 6.2%. After a drop in 21-30 mm group, it rose to 6.2% in the 31-40 mm size group and declined again in the 41-50 mm size group. Then the values increased and the highest value (15.6%) was recorded in the 61-70 mm size group animals.

In females, there was decline in only one size group and in other size groups it showed a progressive trend. In the lowest size group animals (11-20 mm), it was 6.1%. It declined in the next size group (21-30 mm) to 5.9%. Then it started increasing and the highest value (17.5%) was recorded in the highest size group animals (61-70 mm).

7.4   DISCUSSION

Through the present study, it could be discerned that meat content, water content, dry weight, protein, carbohydrate and fat vary in relation to size and sex. Meat content was more in the lowest size group animals and generally less in the higher size group animals. In males the fall in meat content was gradual. But in females there was a sudden drop in the 21-30 mm size group. Incidentally this happens to be the size group at which the females attain their first sexual maturity. Generally in younger animals, the orientation is towards building up of body parts and this involves lot of synthesis and mobilisation of organic nutrients. But in the case of adults, gonadial development largely influences the body components (Shulman, 1972). In addition to gonadial development, ecdysis, diurnal changes, lunar periodicity, food availability, salinity stress and parasitic associations are generally considered as the factors which influence and alter the basic body components. Presently biochemical analyses were conducted only in animals of intermoult condition. So the question of ecdysis influencing and altering the basic chemical components does not arise. The present study was also conducted during the dry season, in only healthy non-parasitised animals. During dry season variation in salinity is not pronounced and food

availability is also more and it becomes scarce only during the monsoon season. The above facts rule out the possibility of salinity stress, food availability and parasitization changing the chemical make up of organisms. Among the other factors (gonad development, diurnal changes and lunar periodicity), gonad development, is the most important factor. Generally, males spend less energy on reproduction than females and it is quite evident in the present study where in a size group at which the females attain first sexual maturity (21-30 mm size group) the drop in meat content was quite marked. Similar results have been reported by Radhakrishnan (1979) in *Portunus pelagicus*, *P. sanguinolentus* and *Scylla serrata* from Porto Novo waters from where the present study was also done.

Water content and dry weight showed perfectly inverse relationship in the present study. Generally in marine invertebrates, when organic nutrients are more, dry weight percent is more and water content less. When nutrient reserves are used for one or other purpose (gametogenesis, ecdysis, or altered by other factors enumerated above), energy is utilised and this leads to reduced organic nutrients, so less dry weight percentage and more water content. Presently gametogenesis is the most probable factor that accounts for the variations in water content and dry

weight percentage as has been found also by Adiyodi (1968,'69), Rahaman (1967), Chandran (1968) and Diwan and Nagabhushanam (1974) in various brachyuran crabs.

Protein content was more in younger animals than in adult crabs presently. High protein content in the younger forms may be attributed to increased protein synthesis during the active growth phase, as has been observed elsewhere in brachyuran crabs (Radhakrishnan, 1979). The fall in protein content which is very well pronounced in females suggests that the protein in the muscle may be mobilised for the gonadial development.

Carbohydrate content was more in the highest size group and lowest size group animals presently. This may be due to rapid utilisation of carbohydrate in the other size group organisms. Various factors as gonad development in addition to rest, exercise, feeding, starvation and other physiological state change the carbohydrate content. The fluctuation in glycogen content and the various intrinsic factors associated with it have been extensively reviewed by Fraser et al. (1965). Presently the higher values in small and bigger crabs may be due to storage and due to the juvenile phase in smaller organisms (no expenditure due to reproduction) and to senility in bigger sized crabs as found by Radhakrishnan (1979) in three species of brachyuran crabs.

Presently fat content was found to be more in bigger crabs and generally lower in younger forms. Thus, there was found to be an inverse relationship between fat and protein. Such an inverse relationship between fat and protein content has also been reported by George and Patel (1956), Barnes et al. (1963), Pillay and Nair (1973a) and Radhakrishnan (1979). The fat values were generally lower in smaller crabs of T. crenata where more of protein was noticeable. Conversely in larger forms, where minimum protein was observable, the lipid was high. The high fat content in older forms indicates fat storage in their meat. The inverse relationship between fat and protein is well pronounced in smaller and larger crabs than in medium sized crabs. This is largely due to gonadial cycles in them which is quite active. Thus maturation of gonads exert direct influence on them and so the inverse relationship is obliterated.

Considering the above results from the nutritive view point, it could be seen that the meat of younger crabs of T. crenata which has higher protein and less fat is most suitable for feeding purposes. By maintaining a brood stock quite a large number of nutritious younger crabs can be produced and marketed successfully.

Table 52. Meat content in different size groups and sexes of _Thalamita crenata_

Size groups (carapace width in mm)	Average total wt. (gm)	Average meat content	Mean %
Male			
11-20	1.6	0.42	26.3
21-30	4.5	1.04	23.1
31-40	10.8	2.43	22.5
41-50	20.5	4.39	21.4
51-60	39.0	8.07	20.7
61-70	57.5	12.59	21.9
Female			
11-20	1.4	0.33	23.2
21-30	3.7	0.61	16.4
31-40	11.1	1.89	17.0
41-50	20.0	3.74	18.7
51-60	33.8	6.49	19.2
61-70	42.6	7.11	16.7

Fig 32. a – Percentage of water content and
            dry weight in different   size
            groups of Thalamita crenata
            (values denote means ± standard
            errors)

         b – Proximate composition in different
            size groups of T. crenata male
            (values denote means ± standard
            errors)

         c – Proximate composition in different
            size groups of T. crenata female
            (values denote means ± standard
            errors)

PROXIMATE
COMPOSITION

FIG.32
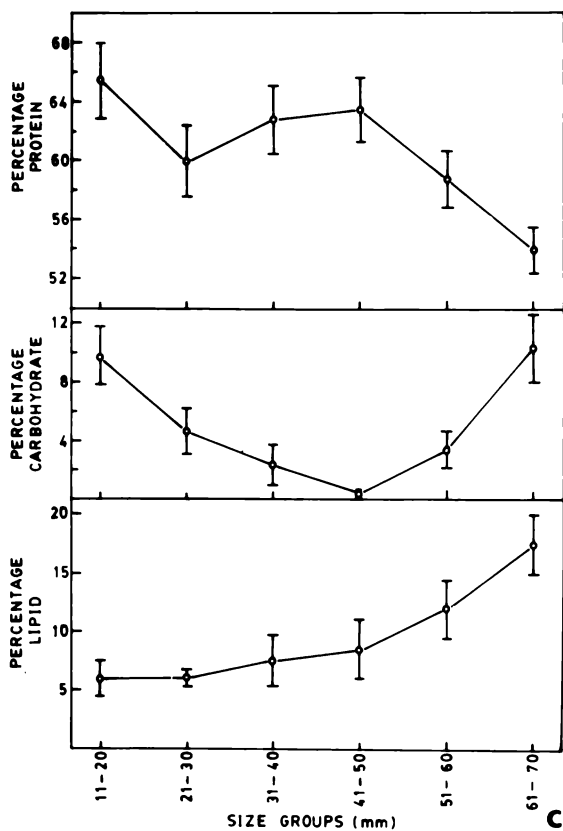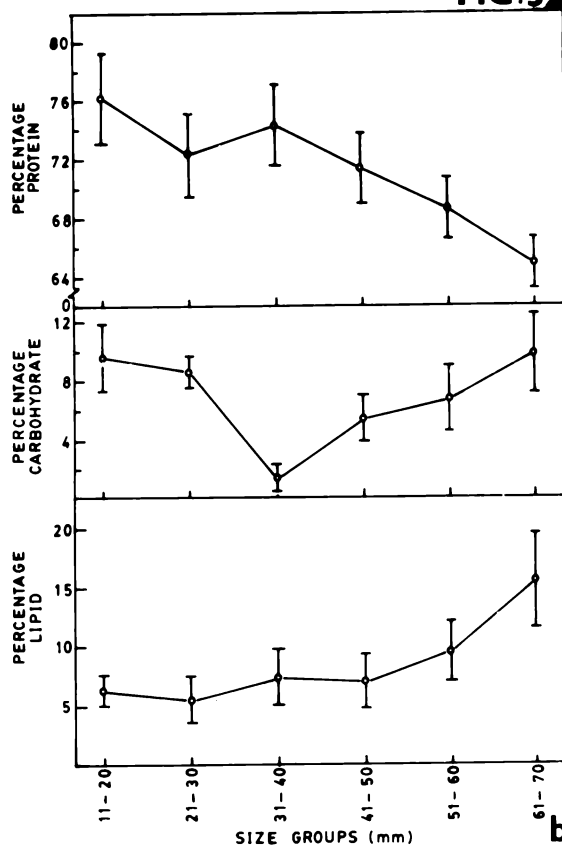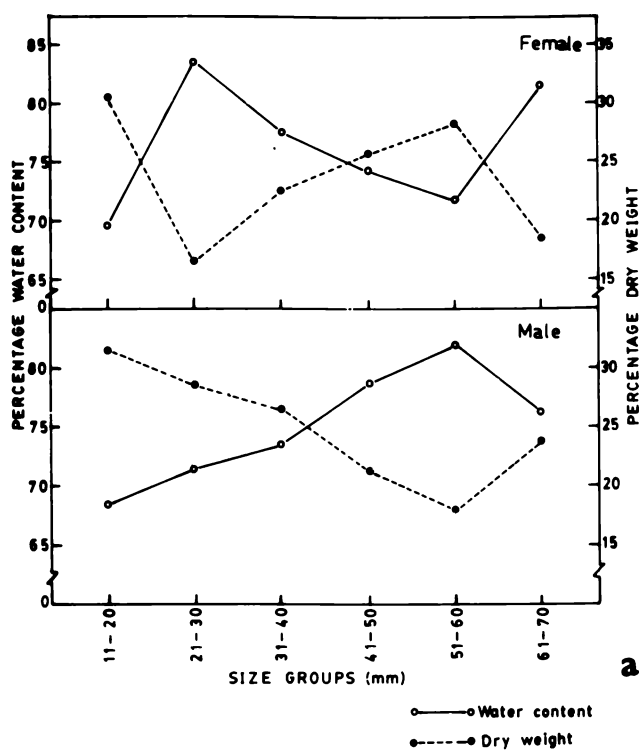
SUMMARY

SUMMARY

This thesis contains seven chapters. The first
chapter deals with the general introduction (a preface,
description of study area, review of literature and research
approach). Second chapter pertains to the reproductive
biology in five species and one subspecies of crabs, three
species and one subspecies (Portunus pelagicus, P. sanguino-
lentus, Scylla serrata, S. serrata serrata) from Cochin area
(lat. 9°58' N; long.76°15' E) and two species (Podopthalmus
vigil and Thalamita crenata) from Porto Novo region (lat.11°
29' N; long.79°46' E). Third chapter relates to the age and
growth and fourth chapter length-weight relationship in the
crabs listed above. In the fifth chapter larval life history
of T. crenata is described and illustrated. Sixth chapter
presents the influence of salinity on the larval life history
of T. crenata. Seventh chapter covers the proximate composi-
tion of the crab T. crenata in relation to size and sex.
Findings of the present study is given below in the order
described above.

Reproduction in five species and one subspecies
of crabs presently studied covers length frequency distribu-
tion, size at first maturity, sex ratio, fecundity and
annual reproductive cycle. Length frequency distribution
in samples collected from the commercial catches and from

the field revealed that the matured forms and older groups contributed to the fishery than immature group forms. The minimum size at first maturity was found to be 92, 62.5, 114.5, 85, 65 and 27 mm respectively for P. pelagicus, P. sanguinolentus, S. serrata, S. serrata serrata, P. vigil and T. crenata. They attained maturity either during latter part of I year of their life or in the early II year. Sex ratio conformed to the 1:1 ratio in P. pelagicus monthwise, sizewise and for the whole year. In P. sanguinolentus,
and
S. serrata /S. serrata serrata, the ratio was 1:1 monthwise and for the whole year, but sizewise it deviated significantly in the highest size group. In P. vigil the ratio conformed to the 1:1 ratio monthwise and for the whole year. Sizewise, in the highest two size groups, it deviated significantly from 1:1 ratio. In T. crenata the ratio conformed to the 1:1 ratio monthwise, for the whole year and in smaller size groups. In larger size group, it deviated significantly from the 1:1 ratio. The deviation in higher size groups proves sex ratio as a function of size. Fecundity studies done in five crabs except T. crenata revealed the following results:

Name of species	Fecundity (range)
P. pelagicus	67,540 - 10,41,600
P. sanquinolentus	45,792 - 7,98,340
S. serrata	2,35,250 - 6,14,575
S. serrata serrata	1,52,140 - 3,36,250
P. vigil	37,817 - 8,15,336

There was a good linear relationship between fecundity and carapace width of crabs presently studied. P. pelagicus, S. serrata and T. crenata were found to breed for an extended period but breeding was not continuous year round. P. sanquinolentus and S. serrata serrata were found to be continuous breeders. In P. vigil eventhough the breeding was continuous, it was intense just prior to and during monsoon.

As hard parts of crab cannot be used for growth studies, indirect methods (statistical methods) were used to find out the age and growth in five species and one subspecies of crabs. Length frequency method of Petersen (1891) was helpful in estimating the age and growth in three species and one subspecies of crabs. In P. pelagicus only a single mode could be traced, for 12 months and from this the annual growth for the I year was calculated to be 90 mm. In P. sanquinolentus similarly the earliest mode was traced for 12 months and the growth for the I year could be calculated

as 80 mm. In $\underline{S}$. $\underline{serrata}$ $\underline{serrata}$ modes were traced for a period of two years, the growth was found to be 90 and 125 mm for I and II year respectively. In $\underline{T}$. $\underline{crenata}$, modes traced for an year gave the growth for the I year and it was found to be 36 mm. Growth determined by months mode curve indicated that $\underline{P}$. $\underline{pelagicus}$ can grow upto 72, 108 and 150 mm; $\underline{P}$. $\underline{sanguinolentus}$ upto 65, 105 and 141 mm; $\underline{S}$. $\underline{serrata}$ upto 112, 151.5 and 187.5 mm; $\underline{S}$. $\underline{serrata}$ $\underline{serrata}$ upto 88.5, 110.0 and 130 mm; $\underline{P}$. $\underline{vigil}$ upto 73, 89, and 104 mm and $\underline{T}$. $\underline{crenata}$ upto 34, 51 and 64 mm in the I, II and III year respectively. Growth assessed by probability plot for $\underline{P}$. $\underline{pelagicus}$ was found to be upto 44, 82, 123.5 and 152.5 mm, for $\underline{P}$. $\underline{sanguinolentus}$ 42.5, 74, 90.5 and 133 mm, for $\underline{S}$. $\underline{serrata}$ 81.5, 117, 157 mm and 182 mm, for $\underline{S}$. $\underline{serrata}$ $\underline{serrata}$ 71, 95.5, 112.0 and 126 mm, for $\underline{P}$. $\underline{vigil}$ 59.5, 79, 95 and 108 mm and for $\underline{T}$. $\underline{crenata}$ 24, 35.2, 52 and 62.2 mm in the O, I, II and III year respectively. Employing von Bertalanffy's growth equation it was found that $\underline{P}$. $\underline{pelagicus}$ can grow upto 72, 130 and 154 mm, $\underline{P}$. $\underline{sanguinolentus}$ upto 77, 107 and 133 mm, $\underline{S}$. $\underline{serrata}$ to 118, 162 and 180 mm, $\underline{S}$. $\underline{serrata}$ $\underline{serrata}$ to 96, 114 and 126 mm, $\underline{P}$. $\underline{vigil}$ to 75, 92 and 105 mm and $\underline{T}$. $\underline{crenata}$ to 35.3, 52.2 and 62.6 mm respectively in the I, II and III year of life. The empirical lengths at different ages found by von Bertalanffy's growth equation showed general agreement

with growth estimated by other methods. This shows that, in the length ranges studied, the theoretical growth equation can be taken as adequate to indicate actual growth. The asymptotic length (L∞) calculated by Ford - Walford method is 395, 318, 360, 160, 160 and 78 mm respectively for P. pelagicus, P. sanguinolentus, S. serrata, S. serrata serrata, P. vigil and T. crenata.

Length-weight relationship studied in five species and one subspecies of these commercially important crabs showed that cube law is obeyed. Males and females in two species and one subspecies namely S. serrata, T. crenata and S. serrata serrata did not show significant variations but in other three species namely P. pelagicus, P. sanguinolentus and P. vigil the difference was significant.

In the larval development studied presently in T. crenata by rearing the larvae, 3 zoeal stages and a megalopa were noticed under laboratory condition. The shortest duration of all zoeal development was found to be 15 days. The characters by which it can be separated from the larvae of other two important portunid genera Portunus and Charybdis are given. There was difficulty in establishing identity at the species level.

Larvae of T. crenata were reared in the laboratory from hatching to megalopa stage in six different test

salinities (10, 15, 20, 25, 30 and 35%o) to find out the
effect of salinity on larval development. In 10 and 15%o
salinities total mortality was encountered in the I zoea
itself and complete development took place only in 4 test
salinities (20, 25, 30 and 35%o).

Mortality rate was heavy in the I zoeal stage. The
day of each moult and mean intermoult duration increased as
the salinity decreased. There was significant variation in
the total period required for completing the whole zoeal
development between all the four test salinities in which
development was complete as shown below:

Salinity	I Zoea	II Zoea	III Zoea	Whole development
		Mean days		
35%o	7.57	4.83	5.33	17.73
30%o	8.43	5.05	5.68	19.16
25%o	8.92	5.38	8.00	22.30
20%o	11.33	7.08	9.38	27.79

Proximate composition was also studied in T. crenata.
Though the total meat content increased progressively in
higher size groups, the percentage of meat was more in
lowest size group crabs (10-20 mm). In males the percentage
of meat varied from 26.3 to 20.7%. In females the range

was 23.3-16.4%. Thus males were found to have more meat

content than females. Water content in males varied from

82 to 68.4% and in females from 69.6 to 83.5%. The low

values were found in the smaller crabs, conversely highest

values of dry weight percentage were encountered in this

group. Males were found to have more protein than females.

In males, the protein content varied from 64.9 to 76.2%, in

females from 53.9 to 65.4%. Both in males and females,

smaller size groups upto 11-50 mm were found to have more

protein while the still higher size groups showed lesser

protein content. Carbohydrate content in both sexes

(males - 1.4 to 9.8% and females - 0.4 to 10.3%) was

initially high (11-20 mm size group) and as the animal grew

it declined for a while upto 41-50 mm size group and was

once again higher in the higher size groups. Fat values

were generally low in the smaller crabs and high in the

bigger crabs. In males it varied from 5.4 to 15.6% and in

females from 5.9 to 17.5%. Thus proximate composition varied

in relation to size and sex and from the nutritive point of

view, small animals which have high protein and less fat

were found to be advantageous.

Based on the present study the following conclusions

may be drawn:

1)   Size frequency distribution has been studied

presently in all the five species and one subspecies of crabs. By incorporating the findings on reproduction and age and growth, it could be seen that the fishery is constituted by matured and older group forms by and large. So as such, no regulatory measure is necessary at present in the areas covered presently.

2) Since crabs lack any reliable hard parts like fishes, indirect methods have to be used to find out age and growth studies. These indirect methods when more than one method is used, more or less give reliable results. Still direct growth observation will be very much helpful.

3) Length-weight equations calculated presently can be used in fields reliably for converting the catches in weight basis.

4) Since the present study indicates the presence of high protein content in *T. crenata* meat, it can be utilized as a cheap protein source. Baseline information collected on *T. crenata* in the present study can be used with advantage for culture practices of this crab to bring out a major break through in the production of cheap animal protein. The present study shows that *T. crenata* breeds for an extended period in an year. There are only three zoeal stages and the larval development itself is completed in a short period of 15 days. As indicated further in the study on

effect of salinity on the larval development of this species,
the salinity of water in larval culture tanks should be kept
preferably between 30 and 35%$_o$. Age and growth study reveals
that this crab $\underline{T}$. $\underline{crenata}$ can grow faster, reaching maturity
within an year. Therefore, it is suggested that this crab
can profitably be grown to the required size within an year.
Biochemical studies showed that crabs of lowest size group
(21-30 mm) are more suitable for consumption from the nutri-
tive point of view (more protein less fat). Commercial
culture of this crab can be undertaken meaningfully, by
maintaining a brood stock and growing the crabs for a period
of less than one year when the crabs reach a size of 24-30 mm
which is the appropriate size nutritively and by this time,
they may also breed once (size at first maturity 27.5 mm)
thus providing another batch of larvae to be grown upto
required size. Thus the cycle can be repeated again and
again and in addition a brood stock can also be maintained.
So commercial culture of this crab is technologically
feasible. But ethinic food preferences still persist.

REFERENCES

REFERENCES

Addison, R.F., R.G. Ackman and J. Hingley, 1972.
Lipid composition of the queen crab
Chionoecetes opilio. J. Fish. Res. Bd.
Canada, 29 (4) : 407-411.

Adiyodi, R.G., 1968. Protein metabolism in relation
to reproduction and moulting in the crab
Paratelphusa hydrodromus (Herbst). Part
II - Fate of conjugated proteins during
vitellogenesis. Indian J. exp. biol., 6 :
200-203.

Adiyodi, R.G., 1969. On storage and mobilisation of
organic resources in the hepatopancreas of
a crab Paratelphusa hydrodromus. Experientia,
25 : 43-44.

Adiyodi, R.G. and K.G. Adiyodi, 1970. Lipid metabolism
in relation to reproduction and moulting in
the crab Paratelphusa hydrodromus (Herbst) :
Phospholipids and reproduction. Indian J.
exp. biol., 8 : 22-223

Ajmalkhan, S. and R. Natarajan, 1977. Annual reproductive
cycle of the hermit crab Clibanarius longitarsus
(De Haan) and factors influencing breeding.
Indian J. mar. Sci., 6 : 102-104.

Ajmalkhan, S. and R. Natarajan, 1981. Effect of salinity
on the larval development of the estuarine
hermit crab, Clibanarius longitarsus (De Haan).
Indian J. mar. Sci., 10 : 132-135.

Akumfi, C.A., 1975. The breeding biology of two sympatric
species of tropical intertidal hermit crabs
Clibanarius chapini and C. senegalensis.
Mar. Biol., 29 : 15-28.

Alcock, A., 1895, '96, '98, '99, 1900. Materials for
a carcinological fauna of India. Reprint
1968. Wheldon and Wesley Ltd., Stechert-Hafner
Service Agency Inc., New York.

Allen, K.R., 1938. Some observations on the biology of the trout (Salmo trutta) in Windermere. J. Anim. Ecol., 7 : 333-349.

Ameerhamsa, K.M.S., 1978a. On the meat content of Portunus pelagicus with some observations on lunar periodicity in relation to abundance, weight and moulting. Indian J. Fish., 25 : 165-170.

Ameerhamsa, K.M.S., 1978b. Fishery of the swimming crab Portunus pelagicus Linnaeus from Palk Bay and Gulf of Mannar. Indian J. Fish., 25 : 229-232.

Aravindakshan, M., 1980. On the unusual catch of portunid crab Charybdis (Charybdis) lucifera Fabricius at Sassoon Dock, Bombday. Indian J. Fish., 27 : 263-265.

Arriola, F.J., 1940. A preliminary study of the life history of Scylla serrata (Forskal). Philipp. J. Sci., 73 (4) : 437-454.

Badawi, H.K., 1971. On the chemical composition of the red crab Portunus pelagicus. Mar. Biol., 11 (3) : 198-200.

Balakrishnan, A., 1957. Variation of salinity and temperature in Ernakulam channel. Bull. cent. Res. Univ. Kerala, 5 : 7-9.

Barnes, H., M. Barnes and D.M. Finlayson, 1963. The seasonal changes in body weight, biochemical composition and oxygen uptake of two common borneo arctic cirripedes Balanus balanoides and B. balanus. J. mar. biol. Ass. U.K., 43 : 185-211.

Barnett, H.J., R.W. Nelson and J.A. Dassow, 1967. Technical studies of dungeness crab processing. Part 3 - Laboratory experiments in the control of drain time. U.S. Fish. Wildl. Serv. Fish. Ind. Res., 3 (4) : 11-17.

Bennet, D.B., 1974. Growth of the edible crab (Cancer pagurus L.) off South-west England. J. mar. biol. Ass. U.K., 54 : 803-823.

Beverton, R.J.H., 1954. Notes on the use of theoretical models in the study of dynamics of exploited fish populations. U.S. Fish. Lab., Misc. contribs., 2 : 181.

Beverton, R.J.H. and S.H. Holt, 1957. On the dynamics of exploited fish populations. Fish. Invest., London, Ser., 2, 19 : 533.

Bookhout, C.G., 1964. Salinity effects on the larval development of Pagurus bernhardus (L) reared in the laboratory. Ophelia, 1 : 275-294.

Bookhout, C.G., 1972. The effect of salinity on molting and larval development of Pagurus alatus Fabricius reared in the laboratory. Fifth European Marine Biology Symposium, 173-184.

Bookhout, C.G. and J.D. Costlow, Jr., 1974. Crab development and effects of pollutants. Thalassia Jugoslavica, 10 : 77-87.

Boolootian, R.A., A.C. Giese, A. Farmanfarmaian and J. Tucker, 1959. Reproductive cycles of five west coast crabs. Physiol. Zool., 32 : 213-220.

Brick, R.W., 1974. Effects of water quality, antibiotics, phytoplankton and food on survival and development of larvae of Scylla serrata (Crustacea : Portunidae). Aquaculture, 3 (3) : 231-244.

Broekhuysen, G.J., 1936. On the development, growth and distribution of Carcinus maenas (L). Arch. Neerl. Zool., 2 (2,3) : 257-399.

Broekhuysen, G.J., 1941. The life history of Cyclograpsus punctatus M. Edw. : breeding and growth. Trans. R. Soc. S. Afr., 28 : 331-366.

Burnett, J.L., 1965. Ammonia as an index of decomposition in crab meat. J. Ass. Office Agr. Chem., 48 : 624-627.

Butter, T.H., 1961. Growth and age determination of the Pacific edible crab Cancer magister Dana. J. Fish. Res. Bd. Canada, 18 : 873-889.

Cassie. R.M., 1954. Some uses of probability paper in the analysis of size frequency distributions. Aust. J. mar. Freshw. Res., 5 (3) : 515-522.

Chacko, P.I. and E. Palani, 1952. An unusual crab fishery in the sea off Ennur near Madras. J. Bombay Nat. Hist. Soc., 52 : 946-947.

Chandran, M.R., 1968. Studies on the marine crab, Charybdis variegata I. Reproductive and nutritional cycle in relation to breeding periodicities. Proc. Indian Acad. Sci., 67B : 215-223.

Cherian, P.V., 1967. Hydrological studies in and around Cochin harbour. Bull. Dept. Mar. Biol. and Oceanogr., Univ. Kerala, 3 : 9-17.

Chhapgar, B.F., 1956. On the breeding habits and larval stages of some crabs of Bombay. Rec. Indian Mus., 53 : 1-45.

Chhapgar, B.F., 1958. On the life history of Philyra globosa (Fabricius) Decapoda : Brachyura. Rec. Indian Mus., 53 : 1-45.

Chinnamma George, 1973a. Technological aspects of preservation and processing of edible shell fishes. III. Factors influencing the keeping quality of crab (Scylla serrata) during freezing and frozen storage. Fish. Technol., 10(1) : 15-20.

Chinnamma George, 1973b. Technological aspects of preservation and processing of edible shell fishes. IV. Comparative efficiency of different glazes in the preservation of frozen crab meat. Fish. Technol., 10(2) : 166-167.

Chinnamma George and M.A. James, 1971. Technological aspects of preservation and processing of edible shell fishes. II. Influence of season on the chemical composition of crab (Scylla serrata). Fish. Technol., 8 (1) : 83-88.

Chinnamma George, D.R. Choudhary and V.K. Pillai, 1970. Technological aspects of processing of edible mussels, clams and crabs. I. Spoilageduring ice storage. Fish. Technol., 8(1) : 33.

Chopra, B., 1936. The cape crawfish industry of S. India with some observation on the prawns and crab fisheries in India. Curr. Sci., 4 (7) : 529-538.

Chopra, B., 1939. Some food prawns and crabs of India and their fisheries. J. Bombay Nat. Hist. Soc., 41 (2) : 221-234.

Christiansen, M.E. and J.D. Costlow, Jr., 1975. The effect of salinity and cyclic temperature on larval development of the mud crab Rhithropanopeus harrisii (Brachyura : Xanthidae) reared in the laboratory. Mar. Biol., 32 : 215-221.

Churchill, E.P., 1919. Life history of the blue crab. J. Bombay Nat. Hist. Soc., 41 (2) : 221-234.

Collins, J. and R.L. Brown, 1965. Frozen king crab (Paralithodes camtschatica) meat : Effect of processing conditions on fluids freed upon thawing. U.S. Fish. Wildl. Serv. Fish. Ind. Res., 2 (4) : 45-53.

Costlow, J.D. Jr., 1963. Larval development. AIBS Bulletin, 13: 63-65.

Costlow, J.D. Jr., 1967. The effect of salinity and temperature on survival and metamorphosis of magalopa of the blue crab Callinectes sapidus Rathbun. Helgolander Wiss. Meeresunters, 15 : 84-97.

Costlow, J.D. Jr. and C.G. Bookhout, 1959. The larval development of Callinectes sapidus Rathbun reared in the laboratory. Biol. Bull., 116 : 373-396.

Costlow, J.D. Jr. and C.G. Bookhout, 1962. The larval development of Hepatus epheliticus (L.) under laboratory conditions. J. Elisha Mitchell Sci. Soc., 78 : 113-125.

Costlow, J.D. Jr. and C.G. Bookhout, 1968. The effect
of environmental factors on the development
of the land crab Cardisoma quanhumi Latreille.
Amer. Zool., 8 : 397-410.

Costlow, J.D. Jr. and C.G. Bookhout, 1969. Temperature
and meroplankton. Chesapeake Sci., 10 :
252-257.

Costlow, J.D. Jr. and C.G. Bookhout, 1970. Marine larvae-
the neglected link in biological resources.
Proc. Symp. Hydrobiol., 8 : 228-239.

Costlow, J.D. Jr. and C.G. Bookhout, 1971. The effect
of cyclic temperature on larval development
in the mud crab Rhithropanopeus harrissi.
Fourth European Marine Biology Symposium,
210-220.

Costlow, J.D. Jr., C.G. Bookhout and R. Monroe, 1966.
Studies on the larval development of the
crab Rhithropanopeus harrissi (Gould). I.
The effect of salinity and temperature on
larval development. Physiol. Zool., 35 : 79-93.

Crothers, J.H., 1967. The biology of the shore crab,
Carcinus maenas (L).Fld. Stud., 2 : 407-434.

Darnell, R.M., 1962. Sex ratios : Aquatic animals,
439-442. In : Growth. Eds. P.L. Altman and
D.S. Dittmer. Federation of American
Societies for Experimental Biology, Washington,
D.C., 608 pp.

Dassow, J.A., 1950. Freezing and canning of king crab.
U.S. Fish. Wildl. Serv. Fish. Leafl., 374, 9p.

Devaraj, M., 1977. The biology and fishery of the
seerfishes of India. Ph.D. Thesis, Madurai
University.

Dewar, A.B., S. Varga and W.E. Anderson, 1969. Effect
of post mortem spoilage on the quality of pro-
cessed queen crab meat. Presented at meeting
on Atlantic Crab Fishery Development,
Frederiction, N.B., March, 4-5.

Dhawan, R.M., S.N. Dwivedi and G. Victor Rajamanickam, 1976. Ecology of the blue crab *Portunus pelagicus* (Linnaeus) and its potential fishery in Zuari estuary. Indian J. Fish., 23 : 57-64.

Diwan, A.D. and R. Nagabhushanam, 1974. Reproductive cycle and biochemical changes in the gonads of the fresh water crab *Barytelphusa cunicularis* (Westwood). Indian J. Fish., 21 : 164-176.

Dubois, M., K.A. Gilles, J.K. Hamilton, R.A. Rebers and F. Smith, 1956. Colorimetric method for determination of sugars and related substances. Analyt. Chem., 28 : 350-356.

Durve, V.S., 1964. Preliminary observations on the seasonal gonadal changes and spawning in the clam *Meretrix casta* from the marine fish farm. J. mar. biol. Ass. India, 6 : 241-248.

Early, J.C., 1967. Spoilage of crab meat. M.Sc. Thesis, University of Nottingham, England.

Escritor, G.L., 1972. Observations on the culture of the mud crab *Scylla serrata*, 355-361. In: *Coastal Aquaculture in Indo-Pacific Region*. Ed. T.V.R. Pillay.

Ezhilarasi, S., 1982. Biochemical investigations on the vitellogenesis of an edible crab *Scylla serrata* (Forskal). Ph.D. Thesis, University of Madras.

Farooqui, U.M., 1980. Reproductive physiology of the marine crab *Scylla serrata*. Ph.D. Thesis, Marathwada University.

Fellers, C.R., 1936. Canning of the crab meat. U.S. Patent, 2, 27, 270.

Fellers, C. R. and S.G. Harris, 1940. Canned Atlantic crab meat. Ind. Eng. Chem., 32 : 592-594.

Fielder, D.R. and J.G. Greenwood, 1979. Larval development of the swimming crab *Thalamita danae* Stimpson (Decapoda, Portunidae) reared in the laboratory. Proc. R. Soc. Qd., 90 : 13-20.

Fisher, R.A. (Ed.), 1930. The Genetical theory of
    natural selection. 291 pp. 2ndrev. ed., Dover,
    New York, 1958.

Folch, J., M. Lees and G.H. Sloane Stanley, 1950. A
    simple method for the isolation and purifi-
    cation of total lipids from animal tissues.
    J. Biol. Chem., 226 : 497-509.

Ford, E., 1933. An account of the herring investigations
    conducted at Plymouth during the years 1924-
    1933. J. mar. biol. Ass. U.K., 19 : 305-384.

Forsels, F.A., 1892. Le Leman Monographic limnologique,
    Lausanne.

Fraser, D.I., H.M. Weinstein and W.J. Dyer, 1965.
    Postmortem glycolytic and associated changes
    in the muscle of trap and trawl caught cod.
    J. Fish. Res. Bd. Canada, 22 : 83-100.

Galtsoff, P.S., 1934. Factors governing the propagation
    of oysters and other marine invertebrates.
    Proc. Pacif. Sci. Congr., 5 : 4213-4220.

Gangal, S.V. and N.G. Magar, 1963. Freezing of crab
    meat. Food Technol., 17 (12) : 101-106.

George, J.C. and B.S. Patel, 1956. The seasonal varia-
    tion in the fat content of the liver and
    gonads in a marine and freshwater decapod.
    J. Anim. Morph. Physiol., 3 : 49-55.

George, M.J., 1958. Observation on the plankton of
    Cochin backwaters. Indian J. Fish., 5 (2) :
    375-401.

George, P.C. and K.R. Nayak, 1961. Observation on the
    crab fishery of Mangalore coast. Indian
    J. Fish., 8 : 44-53.

George, P.C. and P.V. Rao, 1967. An annotated biblio-
    graphy of the biology and fishery of the
    edible crabs of India. Symp. Crustacea, 5 :
    1548-1555.

Giese, A.C., 1959. Comparative physiology : Annual
reproductive cycles in marine invertebrates.
A. Rev. Physiol., 21 : 547-576.

Greenwood, J.G. and D.R. Fielder, 1979. A comparative
study of the first and final zoeal stages of
four species of Thalamita (Crustacea :
Portunidae). Micronesica, 15 : 309-314.

Grominger, H.S. and J.A. Dassow, 1964. Observation of
the blueing of king crab (Paralithodes
camtschatica). U.S. Fish. Wildl. Serv. Fish.
Ind. Res., 2 (3) : 47-52.

Gore, R.H., 1972. Larval characters and adult systematics
in trans-panamanian porcellanid crabs
(Crustacea : Anomura). Amer. Zool., 12 (4):
628.

Harding, J.P., 1949. The use of probability paper for
the graphical analysis of polymodal frequency
distributions. J. mar. biol. Ass. U.K., 25 :
141-153.

Haridas, P.M., Madhupratap and T.S.S. Rao, 1973. Salinity,
temperature and zooplankton biomass of back-
waters from Cochin to Alleppey. Indian J.
mar. Sci., 2 : 94-102.

Hartnoll, R.G., 1965. Notes on the marine grapsid crabs
of Jamaica. Proc. Linn. Soc. Lond., 176 :
113-147.

Harvey, H.W. (Ed.), 1955. The Chemistry and Fertility
of seawater. Cambridge University Press
(Second Edition), 240 pp.

Heath, J.R., 1970. Some changes in the biochemical
composition with season and during the moult
cycle of the common crab Carcinus maenas.
J. exp. mar. Biol. Ecol., 5 : 199-233.

Hiatt, R.W., 1948. The biology of the lined shore crab,
Pachygrapsus crassipes Randall. Pacif.
Sci., 2 : 135-213.

Hill, B.J., 1975. Abundance, breeding and growth of the crab _Scylla serrata_ in two South African estuaries. Mar. Biol., 32 (2) : 119-126.

Hile, R., 1936. Age and growth of the ciso _Leucickthys artedi_ (Le Sucur) in the lakes of the north eastern highlands, Wisconsin. Bull. U.S. Bur. Fish., 48 : 211-317.

Hoda, S.M.S., 1976. Reproductive biology and length-weight relationships of _Thryssa dussumieri_ (Val.) of the Pakistan coast. J. mar. biol. Ass. India, 18 : 272-287.

Hoopes, D.T. and J.F. Karinen, 1972. Longevity and growth of tagged king crabs in the eastern Bering Sea. Fish. Bull. Nat. Oceanic Atmos. Admin., 70 : 225-226.

Hora, S.L., 1935. Crab fishery at Utter-Bhag, lower Bengal. Curr. Sci., 3 (11) : 543-546.

Hornell, J., 1910. Note on an attempt to ascertain the principal determining factor in oyster spawning in Madras backwaters. Madras Fish. Bull., 4 : 1-14.

James, P.S.B.R., 1967. The ribbon fishes of the family Trichiuridae of India. Mem., I : 1-169 (M.B.A.I.).

Joel, D.R. and P.J. Sanjeeva Raj, 1982. The breeding of three edible portunid crabs of Pulicat Lake, 135-140. In : _Progress in Invertebrate Reproduction and Aquaculture_. Eds. T. Subramoniam and Sudha Varadarajan. New Century Printers, Madras.

Jones, S. and K.H. Sujansingani, 1952. Notes on the crab fishery of Chilka Lake. J. Bombay Nat. Hist. Soc., 51 : 128-134.

Josanto, V., 1971. The bottom salinity characteristics and the factors that influence the salt water penetration in the Vembanad Lake. Bull. Dept. Mar. Biol. Oceanogr., 5 : 1-16.

Kakati, V.S., 1977. Larval development of the crab
    Menippe rumphii (Fabricius) as observed
    in the laboratory (Crustacea : Brachyura).
    Proc. Symp. Warm Water Zoopl., Sp. Publ./
    NIO, 634-641.

Kakati, V.S. and V.N. Nayak, 1977. Larval development
    of the xanthid crab Ozius ruqulosus ruqulosus
    Stimpson (Decapoda : Brachyura) under
    laboratory conditions. Indian J. mar. Sci.,
    6(1) : 26-30.

Kakati, V.S. and K.N. Sankolli, 1975a. Larval culture
    of an estuarine crab Sesarma lanatum (Alcock)
    in the laboratory (Brachyura : Grapsidae).
    Bull. Dept. Mar. Sci., Univ. Cochin, 7(2):
    389-402.

Kakati, V.S. and K.N. Sankolli, 1975b. Larval develop-
    ment of the pea crab Pinnotheres gracilis
    Burger under laboratory conditions (Decapoda :
    Brachyura). Bull. Dept. Mar. Sci.,Univ.
    Cochin, 8(4) : 965-980.

Kakati, V.S. and K.N. Sankolli, 1975c. Laboratory culture
    of the spider crab Acheus lacertosus Stimpson
    (Brachyura : Majidae). Indian. J. mar.
    Sci., 4 : 185-188.

Kannaiah, N., 1981. Fecundity studies in crabs. M.Sc.
    Dissertation, Annamalai University.

Kannupandi, T., S. Ajmalkhan, Mercy Thomas, S. Sundaramoorthy
    and R. Natarajan, 1980. Larvae of the land
    crab Cardisoma carnifex (Herb st) (Brachyura :
    Gecarcinidae) reared in the laboratory.
    Indian J. mar. Sci., 9 : 271-277.

Kircher, A.B., 1967. The larval development of
    Clibanarius vittatus and Hypoconcha arcuata
    in six salinities. M.S. Thesis, Duke University,
    Durham, U.S.A.

Kolman, W.A., 1960. The mechanism of natural selection
    for the sex ratio. Amer. Natur., 95 : 373-377.

Krishnakumari, L. and K.V. Rao, 1974. Life cycle of the pea crab *Pinnotheres vicaiii* Chhapgar infesting the clam *Paphia malabarica*. Indian J. mar. Sci., 3 : 165-172.

Krishnaswamy, S., 1967. Reproduction and nutritional cycles in a few invertebrates from the east coast of India. International Indian Ocean Expedition, News letter, 4 (4) : 18.

Krishnaswamy, S. and S. Krishnan, 1967. A report on the reproductive cycle of the holothurian *Holothuria scabra*. Curr. Sci., 36 : 155-156.

Kurata, H., 1975. Larvae of decapod brachyura of Arasaki, Sagami Bay. V-the swimming crabs of subfamily Portuninae. Bull. Nansei Reg. Fish. Res. Lab., 8 : 39-65.

Kurup, B.M., 1982. Studies on the systematics and biology of the fishes of the Vembanad lake. Ph.D. Thesis, Cochin University.

Le Cren, C.P., 1951. The length-weight relationship and seasonal cycle in gonad weights and condition of the perch (*Perca fluviatilis*) J. Anim. Ecol., 16 : 189-204.

Leigh, E.G. Jr., 1970. Sex ratio and differential mortality between the sexes. Amer. Natur., 104 : 205-210.

Lewis, J.B., 1960. The fauna of rocky shore of Barbados, West Indies. Can. J. Zool., 38 : 391-435.

Littleford, R.A., 1957. Studies on pasteurization of crab meat. Univ. Maryland, Seafood Processing Lab., Chrisfield, Maryland, Bull., 2 : 14 p.

Lucas, J.S. and E.P. Hodgekin, 1970. Growth and reproduction of *Halicarcinus australis* (Haswell) (Crustacea, Brachyura) in the Swan estuary, Western Australia. Aust. J. mar. Freshw. Res., 21 : 149-162.

Mac Arthur, R.H., 1961. Population effects of natural selection. Amer. Natur., 95 : 195-199.

Malpas, A.H., 1933. Further observations on the age and growth rate of the ceylon pearl oyster Margaritifera vulgaris with special reference to oysters of Donnan's Mutturarattu Paar. Ceylon J. Sci., 5 : 21-48.

Martin, W.R., 1949. The mechanism of environmental control of body form in fish. Univ. Toronto Stud. Biol., 58, Publ. Ont. Fish. Res. Lab., 70 : 1-91.

Martin, L.M., 1971. Development of protein in the ovary of female Carcinus maenas L. during oogenesis. Tethys, 3 : 251-254.

Menon, C.A., 1913. Cochin State Manual-Mangalodayam Company, Trichur, pp 1-688.

Menon, M.K., 1933. The life histories of decapod crustacea from Madras. Bull. Madras. Mus. New Series-Nat. Hist. Section, 2 (3).

Menon, M.K., 1937. Decapod larvae from the Madras plankton. Bull. Madras Mus. New Series-Nat. Hist. Section, 3 (5).

Menon, M.K., 1940. Decapod larvae from Madras plankton II. Bull. Madras Mus. New Series-Nat. Hist. Section, 3 (6).

Menon, M.K., 1952. A note on the bionomics and fishery of the swimming crab Neptunus sanguinolentus (Herbst). J. Zool. Soc. India, 4 (2) : 177-184.

Moorehouse, F.W., 1933. Notes on Trochus niloticus. Rep. Gt. Barrier Reef Exped., 3 : 145-155.

Mortensen, T. (Ed.), 1921. Studies on the development and larval forms of echinoderms. G.E.C. Gad., Copenhagen.

Nagabhushanam, R. and U.M. Farooqui, 1981. Photoperiodic stimulation of ovary and testis maturation in the immature marine crab Scylla serrata Forskal. Indian J. mar. Sci., 10 : 396-398.

Nagabhushanam, R. and U.M. Farooqui, 1982a. Mobilisation
        of protein, glycogen and lipid during ovarian
        maturation in marine crab Scylla serrata
        Forskal. Indian J. mar. Sci., 11 : 184-186.

Nagabhushanam, R. and U.M. Farooqui, 1982b. Influence
        of photoperiod on ovarian maturation of the
        marine crab Scylla serrata. 141-148. In :
        Progress in Invertebrate Reproduction and
        Aquaculture. Eds. T. Subramoniam and Sudha
        Varadarajan, New Century Printers, Madras.

Nagabhushanam, R. and U.M. Mane, 1975a. Reproduction
        and breeding of the clam, Katelysia opima
        in the Kalbadevi estuary at Ratnagiri, West
        coast of India. Indian J. mar. Sci., 4 : 86-92.

Nagabhushanam, R. and U.M. Mane, 1975b. Reproduction
        in the mussel Mytilus viridis at Ratnagiri.
        Bull. Dept. Mar. Sci., Univ. Cochin, 7 :
        377-388.

Nair, N.B., 1965. Seasonal settlement of marine wood
        boring animals in Cochin backwaters, South
        west coast of India. Int. Revueges Hydrobiol.,
        50 : 411-420.

Narasimhan, K.A., 1970. On the length weight relation-
        ship and relative condition in Trichiurus
        lepturus L. Indian J. Fish., 17 : 90-91.

Nicholls, A.G., 1931. On the breeding and growth rate
        of the backlip pearl oyster Pinctada
        margaritifera. Rep. Gt. Barrier Reef Comn., 3.

Noble, A., 1974. On the eggs and early larval stages
        of Pinnotheres gracilis and P. modiolicolus.
        J. mar. biol. Ass. India, 16 (1) : 175-181.

Ong, K.S., 1966. Observations on the post-larval life
        history of Scylla serrata (Forskal) reared
        in the laboratory. Malay. Agric. J., 45 : 429-443.

Ong, K.S. and J.D. Costlow, Jr., 1970. The effect of
        salinity and temperature on the larval develop-
        ment of the stone crab Menippe mercenaria (Say)
        reared in the laboratory. Chesapeake Sci.,
        11 : 16-29.

Orton, J.H., 1920. Sea temperature, breeding and
distribution in marine animals. J. mar. biol.
Ass. U.K., 12 : 339-366.

Panikkar, N.K. and R.G. Aiyar, 1939. Observations on
breeding in brackish water animals of Madras.
Proc. Indian Acad. Sci., 9B : 343-364.

Pantulu, V.R., 1963. Studies on the age, growth,
fecundity and spawning of Osteogeneiosus
militaris. J. Cons. perm. inst. Explor.
Mer., 28 : 295-315.

Patel, M.I. and I.N. Mahyavanshi, 1974. Larva of
Callinassa tyrrhena (Petagna) (Crustacea :
Decapoda, Callianassidae) a new record from
the Gulf of Kutch. J. mar. biol. Ass. India,
16 : 308-309.

Paul, M.D., 1942. Studies on the growth and breeding
of certain sedentary organisms of the Madras
Harbour. Proc. Indian Acad. Sci., 15B : 1-42.

Petersen, C.G.J., 1891. Eine methode Zur Bessimmung
des alters andwruchses des fische. Mitth.
Deutsch. Seefis cheria Ver., 11:226-235.

Pillai, N.G.K., 1978. Macrobenthos of a tropical
estuary. Ph.D. Thesis, University of Cochin.

Pillai, V.K., K.J. Joseph and A.K.K. Nair, 1975. The
plankton production in the Vembanad lake and
adjacent waters in relation to the environ-
mental parameters. Bull. Dept. Mar. Sci.,
Univ. Cochin, 7 : 137-150.

Pillay, K.K. and N.B. Nair, 1968. Observation on the
reproductive cycle of some crabs from the
south west coast of India. J. mar. biol.
Ass. India, 10 : 384-388.

Pillay, K.K. and N.B. Nair, 1971. The annual reproduc-
tive cycles of Uca annulipes, Portunus
pelagicus and Metapenaeus affinis, during
reproductive cycles. Mar. Biol., 11 : 152-166.

Pillay, K.K. and N.B. Nair, 1973a. Observation on the biochemical changes in the gonads and other organs of Uca annulipes, Portunus pelagicus and Metapenaeus affinis during reproductive cycles. Mar. Biol., 18 : 167-198.

Pillay, K.K. and N.B. Nair, 1973b. Observation on the breeding biology of some crabs from southwest coast of India.J. mar. biol. Ass. India, 15(2): 754-770.

Prasad, R.R., 1954a. Observations on the distribution and fluctuations of planktonic larvae off Mandapam. Proc. Indo Pacific Fish. Council, 21-24.

Prasad, R.R., 1954b. Some aspects of relative growth in the blue swimming crab Neptunus pelagicus (Linnaeus). Proc. Natn. Inst. Sci., India, 20B (2) : 218-234.

Prasad, R.R., 1959. The characters of marine plankton at an inshore station in the Gulf of Mannar near Mandapam. Indian J. Fish., 1 : 1-36.

Prasad, R.R., 1967. Study of larval crustacea and its significance. Seafood Trade J., 2(1) : 127-132.

Prasad, R.R. and P.R.S. Tampi, 1953. A contribution to the biology of the blue swimming crab Neptunus pelagicus (Linnaeus) with a note on the zoeae of Thalamita crenata Latreille. J. Bombay Nat. Hist. Soc., 51 : 674-689.

Prasad, R.R. and P.R.S. Tampi, 1957. Notes on some decapod larvae. J. Zool. Soc. India, 9 : 22-39.

Pritchard, D.W., 1967. What is an estuary? - physical view point. In : Estuaries. Ed. G.H. Lauff. Publication No.83, Washington D.C., American Association for the Advancement of Science.

Provenzano, A.J. Jr., 1967. Recent advances in the laboratory culture of decapod larvae. Symp. Crustacea, 2 : 940-945.

Qasim, S.Z., S. Wellershaus, P.M.A. Bhattathiri and
S.A.H. Abdi, 1969. Organic production in a
tropical estuary. Proc. Indian Acad Sci.,
69 : 51-94.

Radhakrishnan, C.K., 1979. Studies on portunid crabs
of Porto Novo (Crustacea : Decapoda : Brachyura)
Ph.D. Thesis, Annamalai University.

Radhakrishnan, C.K. and R. Natarajan, 1979. Nutritive
value of the crab Podopthalmus vigil (Fabricius).
Fish. Technol., 16 : 37-38.

Radhakrishnan, C.K. and C.T. Samuel, 1982. Report on
the occurrence of one subspecies of Scylla
serrata (Forskal) in Cochin backwater. Fish.
Technol., 19 : 5-7.

Rahaman, A.A., 1967. Reproductive and nutritional
cycles of the crab Portunus pelagicus
(Decapoda : Brachyura) of the Madras coast.
Proc. Indian Acad. Sci., 65 B : 76-82.

Rai, H.S., 1933. Part II. Shell fisheries of Bombay
Presidency. J. Bombay Nat. Hist. Soc., 36 :
884-897.

Rajabai Naidu, K.G., 1950. Some aspects in the develop-
ment and bionomics of Ocypoda platytarsis.
Proc. Indian Acad. Sci., 33 : 33-40.

Rajabai Naidu, K.G., 1954. The post larval development
of the shore crab Ocypoda platytarsis and
O. cardiomona. Proc. Indian Acad. Sci., 11 (4):
89-102.

Rajabai Naidu, K.G., 1955. The early development of
Scylla serrata (Forsk.) and Neptunus
sanguinolentus (Herbst). Indian J. Fish.,
2 : 67-76.

Rajabai Naidu, K.G., 1959. Development of Calappa
lophos Herbst and Matuta lunaris Forskal
(Crustacea : Brachyura). J. Zool. Soc.
India, 11 : 65-72.

Rajabai Naidu, K.G., 1960a. Studies on the larval development of Brachyura I. The early and post larval development of Dotilla blanfordi Alcock. Ann. Mag. Nat. Hist., 13 : 129-135.

Rajabai Naidu, K.G., 1960b. Studies on the larval development of Brachyura II. Development of Philyra scabriuscula (Fabricius) and Ixa cylindricus of the family Leucosidae. Crustaceana, 1 : 1-8.

Rajabai Naidu, K.G., 1962. Studies on the larval development of Brachyura III Early development of Metapograpsus messor Forskal, Plagusia depressa squamos (Herbst), Metasessarma rousseauxii A.M.Edwards and Sesarma tetragonum (Fabricius) of the family Gras-pidae. J. Zool. Soc. India, 13(2) : 154-165.

Rajabai Naidu, K.G., 1972. Studies on the larval development of Brachyura IV. The early development of Leipoecen sordidulum Hemp. (Crustacea : Brachyura). Proc. Indian Sci. Congr.

Rajabai Naidu, K.G., 1974. The early development of Macropthalmus depressus and M. travancorensis (Crustacea : Brachyura). Proc. Indian Acad. Sci., 79 : 41-51.

Rajendran, A., 1974. Studies on the ecology of Vellar estuary; Chemistry and microbiology of regeneration of nutrients. Ph.D. Thesis, Annamalai University.

Ramamoorthi, K., 1954. A preliminary study of the hydrology and fauna of Vellar estuary (South Arcot). Proc. Indo-Pacific Fish. Council Symp., 9 : 25-28.

Ramamritham, C.P. and R. Jayaraman, 1963. Some aspects of the hydrographical condition of the backwaters around Willington Island (Cochin). J. mar. biol. Ass. India, 5 (2) : 170-177.

Rangarajan, K., 1973. Length weight relationship in the snapper *Lutjanus hasmira* (Forsk.). Indian J. Fish., 20 : 205-208.

Rao, K.S., 1965. Reproductive cycle of *Oreaster hedemanni* in relation to chemical composition of gonads. Curr. Sci., 34 : 87-88.

Rao, P.V., M.M. Thomas and G.S. Rao, 1973. The crab fishery resources of India. Proc. Symp. Living Resources Seas Around India, 581-591.

Rasalam, E.J. and M.J. Sebastian, 1976. The lime-shell fisheries of the Vembanad lake, Kerala. J.mar. biol. Ass. India, 18(2) : 323-335.

Raymont, J.E.G., A. Austin and E. Lingfond, 1964. Biochemical studies on marine zooplankton I. The biochemical composition of *Neomysis integer*. J. Cons. Perm. Explor. Mes., 28 : 354-363.

Reese, E.S., 1968. Annual breeding seasons of three sympatric species of tropical hermit crabs with a discussion on factors controlling breeding. J. exp. mar. Biol. Ecol., 2 : 308-318.

Regnault, M. et. J.D. Costlow, Jr., 1970. Influence de la temperature et de la salinite sur le development larvaire de *Crangon septemspinosa* Say (Decapoda, Caridea). Vie Milieu (Ser. A. Biol. mar.), 21 : 453-466.

Rice, A.L. and R.W. Ingle, 1975. A comparative study of the larval morphology of the portunid crabs *Macropipus puber* (L.) and M. *holsatus* (F.) with a discussion of generic and sub-familial larval characters within the Portunidae. Bull. Br. Mus. nat. Hist. (Zool.), 28 : 123-51.

Ricker, W.E., 1968. Methods for assessment of fish production in freshwaters. IBP Hand Book No.3: 197-203.

Roberts, M.H., 1970. Larval development of *Pagurus longicarpus* Say reared in the laboratory II. Effects of reduced salinity on larval development. Biol. Bull., 140 : 104-116.

Rochford, D.J., 1951. Studies in Australian estuarine hydrology. I. Introductory and comparative features. Aust. J. mar. Freshw. Res., 2 : 1-116.

Ryan, E.P., 1967. Structure and function of the reproductive system of the crab *Portunus sanguinolentus* (Herbst) (Brachyura : Portunidae) Part II. The female system. Proc. Symp. Crustacea, 522-544.

Sandoz, M. and R. Rogers, 1944. The effect of environmental factors on hatching, moulting and survival of the zoea larvae of the blue crab *Callinectes sapidus* Rathburn. Ecology, 25 : 216-228.

Sankaranarayanan, V.N. and S.Z. Qasim, 1969. Nutrients of the Cochin backwaters in relation to environmental characteristics. Mar. Biol., 2 : 236-247.

Sankolli, K.N., 1961. On the early larval stages of two leucosid crabs *Philyra corallicola* Alcock and *Arcania septemspinosa* (Fabricius). J. mar. biol. Ass. India, 3 : 87-91.

Sankolli, K.N. and Shakuntala Shenoy, 1967. Larval development of a dromid crab *Conchocetes artificiosus* (Fabr.) (Decapoda : Crustacea) in the laboratory. J. mar. biol. Ass. India, 9 : 96-110.

Sankolli, K.N. and Shakuntala Shenoy, 1975a. Larval development of the mud shrimp *Callianassa* (*Callichirus*) *kewalramanii* Sankolli, in the laboratory. Bull. Dept. Mar. Sci., Univ. Cochin, 7 : 705-720.

Sankolli, K.N. and Shakuntala Shenoy, 1975b. On a new record of a majid crab *Doclea hybrida* (Fabricius) from the Maharashtra waters and its life history. J. mar. biol. Ass. India, 17(1):126-137.

Sastry, A.N., 1973. Culture of brachyuran crab larvae using a recirculating sea water system in the laboratory. Proc. Inter. Helgoland Symp., 406-416.

Semper, K., 1881. Animal life. Inter. Sci. Ser., London.

Sethuramalingam, S., S. Ajmalkhan and R. Natarajan, 1982. Breeding biology of Thalamita chaptali Aud-et-Savign and Portunus spinipes Miers in Porto Novo coast (Decapoda : Brachyura). 162-175. In : Progress in Invertebrate Reproduction and Aquaculture. Eds. T. Subramoniam and Sudha Varadarajan, New Century Printers, Madras.

Shanmugam, S. and P. Bensam, 1980. On the fishery for the crab Scylla serrata (Forskal) at Tuticorin during 1974-75. Indian J. Fish., 27 : 102-110.

Shelford, V.E., 1915. Principles and problems of ecology as illustrated by animals. J. Ecol., 3 : 1-23.

Shulman, G.E. (Ed.), 1972. Life cycle of fish. Translation from Russian, John Wiley and Sons, New York.

Simon John and P. Sivadas, 1978. Morphological changes in the development of the ovary in the eyestalk ablated estuarine crab Scylla serrata (Forskal). Mahasagar-Bull. natn. Inst. Oceanogr., 11 : 57-62.

Simon John and P. Sivadas, 1979. Histological changes in the oocytes of the estuarine crab Scylla serrata (Forskal) after eyestalk ablation. Mahasagar-Bull. natn. Inst. Oceanogr., 12 : 11-16.

Srikrishnadhas, B. and K. Ramamoorthi, 1976. Reproductive behaviour and spawning in Philyra scabriuscula (Fabricius) Leucosidae : Decapoda). Indian J. mar. Sci., 5 : 145.

Srinivasagam, S. and R. Natarajan, 1976. Early development of Podopthalmus vigil (F.) in the laboratory and its fishery off Porto Novo. Indian J. mar. Sci., 5 : 137-140.

Sriraman, K., 1978. Biological and biochemical studies on the prawns of Porto Novo coast (Crustacea Decapoda : Macrura). Ph.D. Thesis, Annamalai University.

Stensby, M.E., 1954. Composition of certain species
of freshwater fish-I. Introduction. The
determination of the variations of composition
of fish. Food Research, 19 : 231-234.

Stephen, D. and H.P.C. Shetty, 1981. Induction of
spawning in four species of bivalves of the
Indian coastal waters. Aquaculture, 25 : 153-159.

Stephenson, A., 1934. The breeding of reef animals.
Part II. Invertebrates other than corals.
Scient. Rep. Gt. Barrier Reef Exped., 3 : 247-272.

Tagatz, M.E., 1968. Biology of the blue crab Callinectes
sapidus Rathbun in the St. Johns River, Florida.
Fishery Bull., Fish. Wildl. Serv., US, 67 :17-33.

Tanakawa, F., 1959. Studies on technical problem in
the processing of canned crab Paralithodes
camtschatica. Mem. Fac. Fisheries, Hokkaido
Univ., 7 : 95-155.

Thakur, M.K., 1960. A new technique for preserving
prawn larvae. Curr. Sci., 29 : 138.

Thomas, A.J., 1972. Crab fishery of the Pulicat Lake.
J. mar. biol. Ass. India, 13 : 278-280.

Thompson, J.M., 1951. Catch composition of sand crab
fishery in Moreton Bay. Aust. J. mar. Freshw.
Res., 2 : 237-244.

Turaboyski, K., 1973. Biology and ecology of the crab
Rithropanopeus harrisii ssp. tridentatus.
Mar. Biol., 23 : 303-313.

Varga, S., A.B. Dewar and W.E. Anderson, 1970. Effect
of postmortem spoilage in the quality of frozen
and heat processed red crab meat. Department
of Fisheries and Forestry, Halifax, N.S. Technial
Report No.3.

Varikul, V., S. Phomiphol and M.H.Promyart, 1972. Some
preliminary experiments in pond rearing and
some biological studies of Scylla serrata
(Forskal). 366-374. In : Coastal Aquaculture
in Indo Pacific Region. Ed. T.V.R. Pillay.

Vijayalakshmi Nair, R. and V.T. Paulinose, 1982. Decapod
        larvae from the nearshore waters of Karwar. ♀
        Mahasagar-Bull. natn. Inst. Oceanogr., 13(3):
        277-280.

von Bertalanffy, L., 1938. A quantitative theory of
        Organic growth (inquiries of growth laws). II.
        Hum Biol., 10(2) : 181-213.

von Bertalanffy, L., 1949. Problems of organic growth.
        Nature, Lond., 163 : 156-158.

von Bertalanffy, L., 1957. Quantitative laws in metabolism
        and growth. Quart. Rev. Biol., 32 : 217-231.

Walford, L.A., 1946. A new graphic method of describing
        the growth of animal. Biol. Bull., 90(2) :
        141-147.

Warner, G.F., 1967. The life history of the mangrove
        tree crab Aratus pisoni. J. Zool., Lond., 153:
        321-335.

Warner, G.F. (Ed.), 1977. The Biology of crabs. 202 pp.
        Elek Science, London.

Wenner, A.M., 1972. Sex Ratio as a function of size
        in marine crustaceans. Amer. Natur., 106 :
        321-350.

Williamson, D.I., 1967. Some recent advances and out-
        standing problems in the study of larval crustacea.
        Symp. Crustacea, 2 : 815-823.

Yatsuzuka, K., 1957. Study of brachyuran zoea, artificial
        rearing and development. Suisangaku Shusei,
        571-590.

PUBLICATIONS

PUBLICATIONS

1. Ajmalkhan, S., Mercy Thomas and R. Natarajan, 1980.
   Principal component analysis in shell selection
   behaviour of the land hermit crab *Coenobita*
   cavipes Stimpson. Indian J. mar. Sci., 9 :
   293-294.

2. Kannupandi, T., S. Ajmalkhan, Mercy Thomas,
   S. Sundaramoorthy and R. Natarajan, 1980.
   Larvae of the land crab *Cardisoma carnifex*
   (Herbst) (Brachyura : Gecarcinidae) reared
   in the laboratory. Indian J. mar. Sci., 9 :
   271-277.

3. Ajmalkhan, S., S. Sundaramoorthy, Mercy Thomas,
   T. Kannupandi and R. Natarajan, 1981.
   Laboratory reared larval stages of the marine
   hermit crab *Clibanarius clibanarius* (Herbst)
   (Decapoda : Anomura). Proc. Indian Acad. Sci.,
   90 : 225-236.