LARVAL BIOLOGY OF THE SPINY LOBSTERS OF THE GENUS *PANULIRUS*

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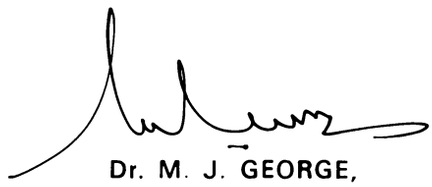
Certificate

This is to Certify that the thesis entitled "LARVAL BIOLOGY OF THE SPINY LOBSTERS OF THE GENUS *PANULIRUS*" is the bonafide record of the work carried out by Miss. SARASU T. N. under my guidance and supervision and that no part thereof has been presented for the award of any other Degree.



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Declaration

I hereby declare that this thesis entitled "LARVAL BIOLOGY OF THE SPINY LOBSTERS OF THE GENUS *PANULIRUS*" has not previously formed the basis for the award of any degree, diploma, associateship, fellowship, or other similar titles or recognition.

Cochin - 682 031,
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P R E F A C E

Mariculture has gained considerable importance all over the world and India also has made rapid progress in developing mariculture technologies in respect of cultivable species of crustaceans, molluscs, fin fishes and seaweeds. With a view to provide baseline studies for the applied aspects of mariculture the Central Marine Fisheries Research Institute (CMFRI) has taken up multidisciplinary programmes under the Centre of Advanced studies (CAS) in Mariculture of CMFRI funded by ICAR/UNDP/ FAO project.

The candidate after getting M.Sc degree in Zoology from the Kerala University in 1982 joined the CAS in Mariculture as a Senior Research Fellow in the Ph.D. programme in March 1983. During the 1st semester the candidate underwent a course work in Mariculture with a curriculam including detailed studies of the biology, ecology and fishery of commercially important marine organisms, Mariculture practices in the world, resource potential of valuable marine organisms, techniques for culture of crustaceans molluscs, fin fishes, seaweeds,

live food organisms etc. The course work also included practicals and study tours to different Mariculture field centres of CMFRI. During the 2nd semester a detailed study of the special subject of biology and fishery of Crustacea was taken up and the scholar has passed the Ph.D. qualifying examination of the Cochin University of Science and Technology.

By the end of the 2nd semester the candidate started work on the particular research project allotted to her on Larval biology of the spiny lobsters of the genus Panulirus. The topic was selected in view of the current importance of spiny lobsters as contributing to one of the most valuable commercial marine product. Compared to other commercially important crustaceans very little work has been done so far on the culture of the larvae of the spiny lobsters. With the increasing demand and consequent increase in exploitation of the spiny lobster resources resulting in the depletionary tendency of the existing resources, the only way to augment production is by artificial culture. For this, suitable culture technologies to rear the larvae in the laboratory needs

to be developed involving laboratory spawning, hatching of the eggs and rearing the larvae through all the stages. In order to develop suitable technology for their culture it is essential to get a thorough understanding of the basics of the biology, ecology, nutrition, physiology etc of the larvae. Therefore the topic of larval biology of the spiny lobsters involving larval rearing, ecological and physiological studies on the larvae was taken up. The results would defenitely have practical application in the development of a suitable technology for culture of spiny lobsters.

The availability of fully live berried specimens was highly necessary for successfully carrying out the larval rearing experiments of the project work. Live berried females of the chosen species of spiny lobster Panulirus homarus being available almost throughout the year along Tuticorin coast, all the experimental works were carried out at the Tuticorin Research Centre of CMFRI, where excellent hatchery and laboratory facilities exist. Inspite of repeated attempts with the excellent laboratory and rearing facilities at

hand it was not possible to successfully rear the larvae through all the stages. However, it should be mentioned to the credit of the candidate that some of the stages have been reared in the laboratory for the first time and a good deal of information has been obtained on the optimal levels of environmental parameters suited for rearing the larvae with maximum survival rate and moulting and also on the taxonomy of phyllosoma larvae collected from plankton samples. The results obtained in the project work would undoubtedly, be greatly helpful for developing techniques suited for the controlled culture of the spiny lobsters.

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With deep sense of indebtedness I wish to express my sincere thanks to Dr.M.J.George, former Joint Director of CMFRI and my supervising teacher, for his untiring guidance, help and affectionate treatment during the course of this investigation, without whose help this piece of work would not have materialised. My sincere gratitude is recorded to Dr.P.S.B.R.James, Director CMFRI and sub project co-ordinator. CAS in mariculture, for providing excellent facilities for the laboratory studies. I express my sincere thanks to Dr.E.G.Silas, former Director of CMFRI, who took keen interest in my work and gave valuable advice and suggestions.

I wish to offer my sincere gratitude to Shri.K.Nagappan Nair, Officer-in-charge, Tuticorin Research Centre of CMFRI for providing me with hatchery and laboratory facilities to carryout all my experimental works in connection with rearing of the larvae. I wish to recall with gratitude all the help encouragements and affectionate treatment given by Dr.K.Satya Narayana

Rao, Senior Scientist, Tuticorin Research Centre of CMFRI.

I am grateful to Shri.Pon Seraimeetan, Dr.H.Mohammed Kasim, Shri.R.Marichamy, Dr.M.Rajamani, Shri.D.Kandasami, Shri. A.Chellam, Shri.T.S.Velayudhan, Shri.M.E.Rajapandian, Scientists, of the Tuticorin Research Centre of CMFRI for all their help and encouragement given during the course of my work. My thanks are also due to all the other staff of CMFRI, Tuticorin for their timely help.

I record my sincere thanks to Shri.M.Srinath Scientist, CMFRI Cochin, who helped me in the statistical analysis of the data.

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I am thankful to the ICAR/UNDP/FAO for providing me this opportunity to carry out the investigation and a fellowship during the course of this study.

Sarasu T.N. 10.3.87

Cochin - 682 031 (SARASU.T.N.)

March 1987.

LARVAL BIOLOGY OF THE SPINY LOBSTERS OF THE GENUS *PANULIRUS*.

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CHAPTER 1

Introduction

Lobsters are renowned the world over as tasty delicacies and are in great demand for Epicurian gourmets. As a result these animals found in different parts of the world form valuable seafood product and from countries like India they are mostly frozen and exported thus earning considerable foreign exchange for the country. Importance of this crustacean is thus well known and whatever harvested from nature are utilised to the maximum extent. The demand being much more than what is being produced, the need for artificial culture becomes evident. In this context a complete knowledge of the life cycle and larval biology and their culture is very essential. Thus with the object of studying the life history of the commercially important lobsters fished from Indian waters the larval biology of *Panulirus homarus* has been taken up as the project for the present study.

The lobsters are classified under class Crustacea, sub class Malacostraca, super order Eucarida, order Decapoda, suborder Reptantia and section Macrura.

Under section Macrura the super family Scyllaridea and super family Nephropsidea include the lobsters. Thus lobster is a common term applied to members of both the superfamilies. Superfamily Nephropsidea comprises the clawed or true lobsters. The American lobster Homarus americanus, (H. emilne Edwards 1837) the European lobster H. gammarus (Linnaeus 1758), the Norvigian lobster Nephrops norvigicus (Linnaeus 1758) etc comes under this family. These are distinguished from the other lobsters by the presence of the large first pair of walking legs with the crushing claws. These lobsters do not have a phyllosoma larval stage in their life cycle. Under super family Scyllaridea, the family Scyllaridae (slipper lobsters) includes seventy four species, family Synaxidae (coral lobsters) 2 species and family Palinuridae ~~xxx~~ known as spiny lobsters dus to the presence of spines on the carapace and basal segments of antenna, and are also referred to as rock lobsters, include 49 species.

The genus Panulirus (White 1847) under family Palinuridae are the most important from a commercial point of view as these constitute major fisheries in many parts of the world. The spiny lobsters enjoy a world wide distribution. Various

species of spiny lobsters are found throughout the tropical, sub tropical and temperate regions of the world (Chace et al. 1949)

The following species have been reported in the commercial fishery of India in various parts of the coast. Panulirus homarus (Linnaeus 1758) enjoys a wide range of distribution in the Indopacific extending from S. Africa through south coast of Arabia and Indian seas to East Indies and Japan. (Holthuis 1946, Sheard 1949, Barnard 1950). The species was formerly, recorded in the name of Panulirus burgeri and P. dasypus and later synonimised with P. homarus as suggested by Holthuis (1946) and George (1973). This species contributes to a commercial fishery in the east and west coast of South India (Miyamoto and Sharif, 1961, George 1967, 1973).

Panulirus ornatus (Fabricius 1798) is distributed in the Indo pacific from East Africa through the Indian seas and Malaysia to North Australia. (George 1973) It is found on both the coasts of North and South India in the fishery.

Panulirus polyphagus (Herbst 1796) is found throughout the Indopacific from Natal to the Great barrier reef. It provides a fishery in the East and West coasts of India especially in the Northern region (Balasubramanyan 1967)

Panulirus longipes (A.Milne Edwards 1868) distributed in the Indowest pacific extending from East Africa to Malaysia, Japan and Polynesia. (George & Holthuis 1965) From the South west coast of India also it has been recorded (George and Rao 1965)

Panulirus penicillatus (Olivier 1791)

The species is found throughout the Indian and South pacific oceans recorded from S. Africa, Indian seas, North Australia, New guinea and Hawaiian Islands. It has been recorded from Kerala coast off Quilon, the south west coast of India (Satyanarayana 1961)

Panulirus versicolor (Latreille 1804)

A common species found throughout the Indopacific distributed from East Africa to Malaysia and Australia. It forms a good fishery in the Lakshadweep seas and south West coast of India.

Though the deep sea lobster Puerulus sewelli (Ramadan 1938) (Alcock 1901), Palinustus mossambicus (Barnard 1926) (George and George 1965) and several species of the Scyllarid lobsters are also recorded from the Indian coasts they do not contribute to a fishery except Thenus orientalis which is coming into the fishery in some places (Bombay area) in recent years.

The spiny lobsters constitute major fisheries along both the coasts of India. In the south west coast of India the fishing ground extends from Cape Comarin to Quilon in the southern region and the northern region includes north of Calicut the Tikkoti and Cannanore region. George (1973) made detailed study of the lobster fishery resources of India. Throughout the South west coast of India, the dominant species is P. homarus P. ornatus and P. versicolor are also fished from this coast to a certain extent. Though P. homarus is the major species contributing to the fishery in the Tikkoti region P. polyphagus also is equally abundant.

The fishing season of the southern region of the South west coast commences by November and ends

by April. Miyamoto and Shariff (1961) studied in detail the fishery, fishing methods and chief gears employed in these regions. The anchor hooks, lobster traps, scoop nets and gill nets are the main fishing gears operated from this area. In the Tikkoti Cannanore region the fishing season is only for two three months somewhere in the July - October period. A special type of cast net and bottom set gill net are the main types of gear used in these areas. The total lobster landing from the Kerala coast for 1985 was 96 tonnes.

In the south east coast of India from Cape comarin to Madras coast major fisheries exist in different areas along the coast line. The major landing centres are Tiruchendur, Tuticorin, Mandapam and Madras. P. homarus and P. ornatus contribute to the major fishery throughout this area. P.versicolor and P. polyphagus are also fished occassionally. The fishery exist throughout the year but the peak season is January-March and July-September. Bottom set gill net is the main gear operated for collection. Total lobster landings from Tamil Nadu for 1985 was 520 tonnes.

The Malpe and Karwar coast of Karnataka, and Bombay, Ratnagiri and Veraval area of the North west coast constitute major fishery of P. polyphagus and P. ornatus. The fishing season is during October to March. In the Bombay water P. polyphagus constitute a major portion of the fishery. (Chapgar and Deshmukh 1964) P. homarus and P.versicolor are also reported. Wall siene nets and lobster pots are the chief gears used in these areas. Total catch from Maharashtra coast was 1529 tonnes and 1062 tonnes from Gujarat coast for the year 1984-85. In the northern region of the east coast P.polyphagus and P. ornatus are mainly fished. Along the Bengal coast P. polyphagus is the dominant species. The total production of lobsters in India was 3250 tonnes in 1985. One third of this quantity would form the exported quantity.

The spiny lobster fishery in India contributes to an important seafood industry and at present the industry wholly depends on the commercial exploitation of lobsters from the various resources mentioned. An examination of the landings of lobster in India in recent years show a declining trend. This not only affects the industry but also the

fisherman engaged in the fishery. In the context of declining trend in production in the fishery and side by side increase in demand for the products, one method for increasing production is to develop artificial culture techniques for lobsters as in the case of prawns, in which case the possibility has already been reported and being adopted. The commercial production of palinurid lobsters by culture is possible only if reliable techniques for phyllosoma culture are developed. The development of culture techniques would help in raising crops artifidally and then increase production. The artificially raised larvae could also be used to restock areas where population depletion occurs. However the long duration of the metamorphosis of the phyllosoma larval stage of the spiny lobster makes it very difficult to rear the larvae from the eggs to juvenile stages. So far no one has succeeded in rearing in the laboratory the phyllosoma through all the stages up to the post larval stages on a commercial scale. Therefore it is a great necessity to develop an adequate method for culturing of the lobsters from the egg to the juvenile stages in the laboratory.

When we go through the literature it is clear that investigations on the phyllosoma larvae are very limited. Most of the studies are based on material from plankton collection. Attempts to rear phyllosoma larvae started quite early and some of the authors succeeded in hatching the eggs in the laboratory and keeping the phyllosoma larvae for few days and months. Alikunhi (1948) observed the metamorphosis of phyllosoma larvae from the Plankton. Prasad and Tampi (1959) studied the first phyllosoma larvae of P. burgeri = (P.homarus) by hatching eggs from a berried specimen in the laboratory. Inoue and Nonaka (1962) obtained 7th stage phyllosoma of P.japonicus in the laboratory in 40-48 days. They gave Artemia nauplii and adult Artemia as the larval feed. Saisho (1962) reared larvae of P. japonicus in the laboratory using Artemia as their food. He observed the metamorphosis of Ibacus ciliatus to the reptant larvae. Successful rearing through all the stages has been achieved with scyllarid lobster. Robertson (1968) observed the complete larval stages of S.americanus in 32-40 days. Dexter (1972) reared P.interruptus larvae upto the 6th stage through 8 moults in 114 days. Artemia nauplii provided the

main food source during her study. Chaetognaths, Ctenophores and fish larvae also proved to be best food item by her studies. Inoue (1978) successfully reared P. japonicus probably up to the last stage of 29.6 cm within 253 days. Nauplii and adult of Artemia, adults of Sagitta, fish fry of several species were used for feeding of the larvae. Takahashi and Saisho (1979) reared the scyllarid species Ibacus ciliatus and I. novemdentatus through all the phyllosoma stages.

Though researchers in different parts of the world, spent several years for developing techniques for culturing phyllosoma larvae through all the stages in order to develop commercial cultures, the problem still remains unsolved. The main factors inhibiting the development of a proper technique for culture is the long duration of the larval stages and the poor knowledge about the biology, ecology, food preferences and other related aspects of the phyllosoma larvae through this long period. The prolonged planktonic life of the larvae and the delicate nature of the body make it difficult to maintain in the laboratory. One of the major constraints in the culture of the phyllosoma larvae is the scanty information available about the natural food of the animal. Although various

researchers fed the larvae with Artemia nauplii and it was found the best food in the laboratory culture, it cannot be taken as the natural food of the larvae since the development takes place in the sea. Thomas (1963) and Shojima (1963) reported phyllosoma of Ibacus attached to scyphozoan medusae. Williamson (1963) observed feeding of phyllosoma of Jasus on hydromedusae. Mitchel (1971), Dexter (1972) showed that Chaetognaths, Ctenophores, fish larvae, Tubifex, Mytilus gonad, lytechinus eggs were preferred by larvae of P.interruptus. Hernkind (1976) observed phyllosoma larvae clinging to scyphozoan medusae. Simsand Brown (1968) analysed the gut content of several phyllosoma and found nematocyst in the gut. Provenzano (1968) emphasised the supply of natural or artificial food of soft texture, larger than Artemia with suitable chemical combination of nutritive value. Maintanance of high water quality for rearing is one of the major consideration in laboratory culture. Salinity, pH, Oxygen concentration and temperature should remain as those of the natural condition. Sea water free of organisms that are harmful to the larvae is highly necessary.

Mortality of phyllosoma larvae in large numbers is a constant observation in the culture system. All these points to the fact that more studies on the biology of the larvae is absolutely essential in order to develop large scale culture of the organisms. From the studies so far made it may be seen that phyllosoma is highly sensitive to water quality. Detailed studies to find out the optimum levels of the different environmental parameters that play a vital role in the growth and moulting of the larvae is very important. Experiments supplying different food materials so as to get a better knowledge about the favourable food items of the larvae for better growth also have considerable importance in rearing of the larvae.

In order to understand the larval biology by rearing of the larvae in the laboratory and determine the optimum water conditions necessary for proper growth of the larvae the species of spiny lobster easily available in Indian waters namely P.homarus was selected and experiments conducted in the present study. Berried P. homarus, were collected for the experiments and reared in the laboratory tanks. Larvae hatched out successfully were reared through subsequent stages. It

may be mentioned here that inspite of several repeated attempts only 5 moults of the larvae were obtained and these are reported here. Tracing of complete larval history by rearing was not possible. However results of experiments conducted with the different stages of larvae for determining the optimal water conditions for successful growth and moulting are also reported here. Experiments were made with different environmental parameters like salinity, pH, temperature and dissolved Oxygen to determine the optimum levels of these factors required for successful moulting of the larvae in the culture systems.

In order to supplement the studies on culture, phyllosoma larval samples collected through plankton collection during a particular period from the coastal water were analysed for the species and stages. Earlier works by Tampi and George (1975) and Prasad et al.(1980) on phyllosoma collections from Indian water were used in this study. Different stages of the commercially important species of Indian water, namely, P.homarus, P. versicolor, P. polyphagus, P. ornatus, P.penicillatus, and P. longipes have been identified and reported.

CHAPTER 2

Historic resume

Considerable work has been done on the taxonomy and some of the aspects of fishery biology of the spiny lobsters. A review of the available literature on these works has been made, especially with reference to larval history and the records of phyllosoma larvae. A resume of this review is attempted here and it reveals the conspicuous lack of sufficient work on successful rearing of phyllosoma larvae through all the stages, most of the available work on these larvae being based on plankton collection. The references in the literature may be treated in two sections, the first section dealing with literature in general about spiny lobster fishery, taxonomy and other biological aspects and the second consisting of references on phyllosoma larvae, larval biology, larval rearing and culture.

1. General biology, taxonomy and other features

Holthuis (1946) gave a systematic account of the Palinuridae of Snellius Expedition. Chace et al. (1949) studied the biology, identification and world distribution of the spiny lobster. Sheard (1949) made

a detailed study of the spiny lobsters and their fishery in W. Australia. A descriptive catalogue of the South African species of the spiny lobsters was given by Barnard (1950) Bachus (1960) observed growth rate of spiny lobster. From Cylon De Bruin (1960 and 1962) studied the spiny lobster fishery, their biology and ecology. George (1962) compared the new species P. cygnus of Western Australia with P. longipus and P. japonicus. Sheard (1962) investigated in detail the Western Australian cray fishery. George (1964) recorded variations and the possible geographic population of P. homarus. The extra ordinary pattern of file chain formed by the migrating lobster P.argus. was studied by Hernkind and Hummings (1964) Inoue (1964) found out the amount of food required by Japanese spiny lobster P. japonicus kept in cage, in relation to size and temperature. The growth of captive lobster and the reproductive cycle of the female lobster was studied in detail by Fielder (1964). Fielder (1965) observed the food, feeding and locomotor activity of J. lalandii in S. Australia. George and Holthuis (1965) reviewed the Indopacific spiny lobster of P. japonicus group

and found striking difference between 5 species previously included under *P. japonicus*. Sims (1965) proposed to refer members of family Palinuridae as spiny lobster and to leave the term crayfish or crawfish to members of family Astacidae. Bowen and Chittleborough (1966) estimated the stock size, recruitment and exploitation rates of *P. cygnus*. Sims (1966) gave an annotated bibliography of the spiny lobsters of family Palinuridae and Scyllaridae. Moulting behaviour of the *P. cygnus* was studied by Thomas (1966). George (1967a) found ecological separation of *Panulirus* species of Australia while studying the distribution of them in Western Australia. He and Main (1967 b) studied the evolution of spiny lobster and according to them speciation with in the genus *Panulirus* occurred during the plestocene. Kensler (1967 a) recorded the size at first maturity of *Jasus verreauxi* and (1968 b) determined the fecundity of the same species. Berry (1969) reported the occurrance of an external spermatophoric mass in *P. gilchristi*. Hernkind (1969) studied the queueing behaviour of spiny lobster. Mitchel and others (1969) worked on the biology and behaviour of the California spiny lobster *P. interruptus*. The mating behaviour, oviposition and fertilization of *P. homarus*

were studied by Berry (1970). Chittleborough (1970) reported that the density independent factors operating upon planktonic larvae and density dependent factors limiting survival of juveniles play, complementary roles in determining the level of recruitment to the adult life of the Western rock lobster P. longipes cygnus. Berry (1971) gave an account of the biology of P.homarus. Newman and Pollock (1971) studied the biology and migration of J. lalandii at Elands bay of South Africa. On proposal of FAO George (1972) reviewed the resources of spiny lobster in south and South west pacific to establish and operate a South pacific Islands Fisheries Development Agency. Hickman (1972) observed captive J.edwardsii opening and eating the oyster Ostrea species by breaking away the shell with mandibles and walking legs. Morgan (1972) determined the fecundity of P. longipes cygnus. Berry (1973) made a review on the spiny lobsters of genus Panulirus in the South western Indian ocean. Stead (1973) conducted experiments to assess the tolerance of sudden changes in salinity of J.edwardsii. Tazaki and Tanino (1973) suggested that the setal organs on the antenna of P.japonicus is an osmoreceptor. Berry (1974) reviewed the P. homarus group of spiny lobster and found difference between S. African

and Indian ocean forms. The ecology of rock lobster in relation to coral reefs in the Indowest Pacific region have been studied by George (1974). Newman and Pollock(1974) observed the growth of *J.lalandii* in relation to benthos.

Chittleborough (1975) determined the effect of environmental factors such as temperature, photo-period, oxygen, food supply, crowding, autotomy of limbs etc on growth and survival of juvenile *P.longipes* under controlled conditions. Berril (1976) gave an account of Homarid and Palinurid life styles. Ansell and Robb (1977) made observation on the biology of spiny lobster *P.elephas* from the W.Coast of Scotland. Ford (1977) determined the effect of thermal effluent on survival growth, moulting and reproductive condition of the California spiny lobster, *P. interruptus*. George (1978) gave an illustration of Hongkong lobster *P.stimpsoni*. The oxygen consumption of *P. cygnus* and *P.guttatus* were found out by Bussa (1979) and concluded that there is no important physiological difference between spiny lobster and true lobster. George and others (1979) reviewed the general biology, environment, population biology and management of the fishery of *P.cygnus*. Grey (1979) estimated the size at first

maturity of P.cygnus using the secondary sexual characters. Pollock (1979) conducted studies to identify the major environmental factors responsible for limiting growth rate and distribution of J.lalandii.

Berry and Smale (1980) estimated production and consumption rate of food in a population of P.homarus off the Natal coast. Kanciruk (1980) made a review of the ecology of adult and jevenile Palinuridae. The available data on identity, distribution, life history, population dynamics, exploitation, production management and artificial culture of P.cygnus George, have been reviewed by Philips et al.(1980). Philips, Cobb and George (1980) reviewed the general biology of lobsters. Tamm (1980) proposed that spiny lobster culture is an alternative to the natural stock assessment. Gregory and Labinsky (1981) evaluated eggs, spermatophores and ovigerous setae as 3 external indicators of reproductive maturity of P.cygnus from Florida Keys. Joll (1982) examined the foregut evacuation of four foods by P.cygnus by serial slaughter techniques. Kanciruk, Herrnkind, Philips and Arnaud (1982) gave an indexed bibliography of spiny lobsters, Palinuridae. Brito et al.(1983) observed the feeding rate and its effect on growth of juvenile P.cygnus. Brown and Caputi (1983) conducted

studies to ascertain whether the capture and release experience of undersized P.cygnus by fishermen caused mortality. Glen and MacDonald (1983) determined the moult stages of the Hawaiian lobster P. marginatus. The age at first maturity of P.elephas was found out by Marin (1983). Philips (1983) observed migration of pre adult P.cygnus by tagging experiments. The longivity, reproductive condition and growth of P.cygnus was studied by Philips et al.(1983) by rearing them in the laboratory for 13 years. Tegner and Levin (1983) found that P. interruptus strongly prefer sea urchin S.purpuratus over S.franciscanus. Moore and Mac Farlane (1984) studied the migration of P.ornatus in Papua New Ginea. Annala and Bycroft (1985) estimated the growth rate of juvenile J.edwardsi after puerulus settlement. Faust and others (1985) conducted experiments to determine the mechanisms of aggregation by P.interruptus. Gooding (1985) found that predation on released berried spiny lobster Panulirus marginatus by large carnivores such as Caranx ignobitis was very high. A revision of the family scyllaridae was done by Holthuis (1985). James and Herrnkind (1985) measured the emigration of early benthic P. argus from different types of algal clamps to assess the relative importances of food and shelter. Growth, moult frequency,

moulting season of J.edwardsii were estimated by Mckoy (1985) by tagging the lobsters in Stewart Islands of New Zealand. The recruitment of Jasus verreauxii in New Zealand,Booth (1986) studied. Brown & Caputi (1986) opined that conservation of recruitment of P.cygnus can be obtained by improving survival and growth of under sized lobster captured and returned by the fisherman. The relationship between juvenile abundance and recuritment in P.cygnus fishery was studied by Caputi and Brown (1986) Gregory & Labinsky (1986) studied the movement of P.argus in South Florida. Hunt & Lyons (1986) determined the factors affecting the growth and maturation of P.argus in Florida Keys. Mac Donald (1986) found that settlement of puerulus of P.marginatus occurred irregularly throughout the year, while studying the recruitment of it in Hawaii. MacFarlane and Moore (1986) studied the reproductive biology of P.ornatus in the gulf of Papua New Giunea. The ecology and intraspecific variations in the spiny lobster P.echinatus was studied by Marcio (1986) from Brazil. Settlement of P.argus puerili in south Florida, Marx (1986) evaluated. The fishery and biology of Jasus lalandii was reviewed by Pollock (1986). Richard and Ann (1986) reported the occurrance of Palinurellus waineckii from Hawaian Islands. Thomas & Ford (1986) studied the population ecology and fishery potential of P.penicillatus

from Marshal Islands.

Among Indian authors, Balasubramanyan Satyanarayanam and Sadanandan (1960) gave an account of the experiments conducted for the introduction of a new fishing gear for the rock lobster. Balasubramanyan (1961) conducted a series of tests to study the working of the lobster fishing gear, the bottom set gill net, in the South west coast of India. Chapgar and Deshmukh (1961) reported P. dasypus in Bombay waters and gave a note on the systematics of Bombay lobsters. A detailed study of the lobster fishery of the South West coast of India was made by Miyamoto and Shariff(1961). Satyanarayan (1961) reported P. penicillatus from the inshore waters of Kerala coast off Quilon. Chapgar & Deshmukh (1964)recorded P. ornatus, P.homarus, S. sordidus and Thenus orientalis from the Bombay waters. Deshmukh (1964) estimated the epizoic associates of P.polyphagus and described the interrelationships between the epizoa and the host. George (1965) studied the biology and fishery of P. homarus along the South West coast of India.

P.mossambicus, a rare spiny lobster was reported from the Kerala Coast off Calicut by George and George(1965) Kurian (1965) reported the possibility of fishery for Puerulus sewelli off Kerala coast. A detailed account of the taxonomy, biology and fishery of J. lalandii frontalis from the St.Paul and Amsterdam Islands in the Southern Indian ocean was given by Silas (1965). Balasubramaniyan (1967) gave an account of the spiny lobsters of India and their fishery. Scyllarid lobster S.batei batei (Holthuis) and S.rubens (Alcock and Anderson) were reported from the Arabian sea by George (1967). He (1967) gave a detailed account of the Indian spiny lobster P. homarus. George and Rao (1967) obtained one specimen of P.longipes off Muttam in the S.west coast of India. Prasad and Tampi (1967) obtained 6 nistos of scyllarus tuberculatus (Bate) from the Laccadive and one nisto of S.sordidus from the gulf of Mannar off Mandapam. Allometric growth of peraopod 2 and 3 in P. ornatus P.versicolor and P.homarus were observed by Adolph (1968). Prasad and Tampi (1968) investigated in detail the distribution of Palinurid and Scyllarid lobster in Indian waters. Balasubramanyan reported (1969) the occurrance of P.polyphagus in the Cochin back water. Mohammed and George (1971) conducted tagging experiments to study the movement and growth of P.homarus. Rao and

Kathirvel (1971) observed the presence of P.polyphagus in the estuarine waters of Cochin. The growth of P.homarus in captivity in relation to moulting was studied by Thomas (1972). George (1973) made a detailed investigation on the lobster fishery resources of India. Kathirvel (1973) worked on the growth of P.polyphagus in captivity and observed the regeneration of right antennal flagellum and the effect of regeneration on growth. Nair et al. (1973) reported P. polyphagus P.longipes and P.penicillatus in the south east coast in the gulf of Mannar and the lobster fishery around Mandapam. The commercial potential of the deep sea lobster P.sewelli was investigated by Rao and George (1973). Kathirvel (1975) found pueruli of P.homarus in Cochin back water and observed their metamorphosis to post puerulus. The distribution pattern of spiny lobsters of India contributed to the fishery was studied in detail by Premkumar and Daniel (1980). The occurrance of pueruli of P.polyphagus was reported by Thomas (1975) from the estuarine waters of Goa. Girijavallabhan and Devaraj (1978) were able to collect pueruli of P.polyphagus from Madras Coast. From Lakshadweep Meiyappan and Kathirvel (1978) recorded P.antarcticus and P.homarus. Kuthalingam et al. (1980) reared juveniles of P.versicolor of carapace length 9-21 mm size in the laboraty collected from the Vizhinjam Bay.

Nair and others (1981) studied the growth and moulting of P.homarus P.Ornatus and P.penicillatus in captivity. From the Kakinada Bay Lalitha devi (1982) reported the occurrance of puerulus, juveniles and adults of P.homarus and P.polyphagus. Sharmugham and Kathirvel(1983) gave an account of the lobster resources and culture potetital in the Andamans and Nicobar Islands. Radhakrishnan and Vijayakumaran (1984)a) found that bilateral ablation of eyestalk accelerated the moulting frequency and weight gain in juvenile, maturing and matured P.homarus. Induced gonadal growth in males and females of P.homarus was reported by Radhakrishnan and Vijayakumaran (1984 b) by eyestalk ablation. Vijayakumaran and Radhakrishnan (1984) conducted experiments on eyestalk ablation on P.homarus and found that this induced hyperphagia and food consumption was increased 50-75% and at low feeding rate also conversion efficiency was maximum. Kasim (1986) estimated the lethal Oxygen levels, time to death, total Oxygen consumed and metabolic rates of P.polyphagus at different saturated temperature and Oxygen partial pressures.

2. Larval biology, phyllosoma larvae and culture

Saisho and Nakahara (1960) succeeded in raising the phyllosoma of Ibacus ciliatus and P. longipes upto the 4th stage in glass jars. George (1962) prepared notes

on the investigation on the phyllosoma of P.longipes. Upto 90 days Saisho (1962) kept larvae of P.japonicus hatched in the laboratory and these underwent ecdysis 10 times during the period. Saisho (1962) got three stages of P.antarcticus reared in the laboratory. Inoue and Nonaka (1963) obtained 7 stages of phyllosoma of P.japonicus by rearing from the 1st stage hatched in the laboratory. A comparative study was made by Saisho (1963) on the first phyllosoma of spiny lobster of genus, Panulirus. Inoue (1965) found out the relation of amount of food taken to the density of size of food in Phyllosoma of P.japonicus. From the Yucatan Straits Sims (1965) obtained 17 specimens of prenaupliosoma stage of P.argus . Dotsu and others (1966) were able to raise phyllosoma of I.ciliatus and I. novemdentatus collected from plankton to the reptant larvae and the mechanism of metamorphosis described. From the coast of California Johnson and Knight (1966) collected ten stages of phyllosoma of P.inflatus. Saisho (1966) gave a brief account of the phyllosoma stages and the duration of larval life of P.argus, P.interruptus P.penicillatus, P. longipes, P.cygnus and P.japonicus. He (1966) made a detailed study of the phyllosoma larvae in connection with oceanographic condition that sorrounds them. Sims (1966) described larvae of Palinurid and Scyllarid lobsters. He (1966) collected 8 stages of the

phyllosoma of Palinurellus gundalachi from Florida and Yucatan straits. The 1st phyllosoma of S.americanus obtained by Sims (1966) hatched in the laboratory. Murano (1967) studied the ecology, life history and habitat of phyllosoma larvae and compared the natural and cultured larvae. Scarratt and Raine (1967) observed that newly hatched lobster larvae avoided low salinity. From the Hawaiian Archipelago Johnson (1968) obtained phyllosoma of P.penicillatus, P.marginatus and unidentified larvae of other Palinurid species. Two phyllamphion larvae were collected by Johnson from the Hawaiian Islands and South China sea. Provenzano (1968) published a paper on the experiments on the laboratory rearing of lobster larvae reviewing the early culture experiments and gave suggestions for further rearing works. A giant scyllarid phyllosoma was recorded from the Carribean by Robertson (1968). Ingle and Witham (1968) gave an account of the biological consideration on spiny lobster culture. Chittleborough and Thomas (1969) worked on the ecology of the larvae of W.Australian cray fish and other Palinurid larvae from the eastern Indian Ocean. From the Western Atlantic Robertson (1969) collected 10 stages of Justitia longimana from the plankton. Johnson (1970) gave an account of the phyllosoma of genus Scyllarides

and described S.gatori collected from Cubo San Lucas, Baja California. From the Hawaiian Islands and adjacent seas Johnson (1971 a) collected 8 stages of the larvae of Scyllarus modestus, S.timidus Paribacous antarcticus Scyllarides squamosus and Arctides regalis. Johnson (1971 b) studied the distribution of Palinurid and Scyllarid lobster larvae in the South China sea. From the neighbouring water of Japan Murenao (1971) obtained 5 forms of Palinurid phyllosoma. Dexter (1972) reared the phyllosoma of P. interruptus upto the 6th stage in 114 days. Rits (1972) (1972) studied the behaviour of newly hatched phyllosoma of P.longipes cygnus in different light intensity. He (1972) worked out the factors affecting the distribution of rock lobster larvae with reference to variability of Plankton net catches. Uchida and Dotsu (1973) obtained the 1st phyllosoma of P.polyphagus from berried female hatched in the laboratory. A detailed description of Palinurid and Scyllarid lobster larvae of the Natal coast was given by Berry (1974). Chittleborough (1974) reared P.longipes cygnus from pueruluss to adulthood and later (1974) made a review of prospects for rearing. The seaward drift of phyllosoma occurring along the coast of eastern tropical pacific ocean was studied by Johnson (1974). Lesser (1974)

identified the palinurid and scyllarid lobster larvae from Newsealand waters. A comparison of growth and temperature tolerance of larvae of Homarus gammarus and H.americanus was made by Gruffydd and others (1975). Johnson (1975) collected puerulus of Scyllarides astori and Evibacus princeps from the water of the Eastern tropical pacific. Johnson and Knight (1975) obtained 1st phyllosoma of Scyllarides astori by laboratory hatching. A simple inexpensive modular system for raising juvenile lobsters was described by Lang (1975). Philips (1975) described a method of illuminating collectors composed of artificial seaweed and field experiments with them to collect the puerulus. Philips and Rimmer (1975) fabricated a net capable of catching the larval stages of P.longipes. In closed system aquaria Serfling and Ford (1975) cultured puerulus of P.interruptus through juvenile stage at constant temperature of 22 - 28°C. Berril (1976) observed post puerulus of P.longipes were aggressive in their contacts with each other competing for limited space and food and these were able to produce sounds. Chittleborough (1976) succeeded in breeding P.longipes cygnus in the aquaria. He (1976) compared the growth of juvenile P.longipes cygnus in the wild and those reared in the

laboratory under optimal conditions. A paired sampler (Griffith and Rimmer 1977) was formulated to measure the abundance and vertical distribution of early and late phyllosoma larvae of P.longipes cygnus. Philip et al. (1977) cultured juvenile of P.longipes cygnus in the laboratory. Rita (1977) described the 1st phyllosoma stage of S.dimani, S. sordidus and S.timidus obtained in the laboratory and S.demani collected from the plankton. Baisre and others (1978) studied the distribution and abundance of P.argus.in the Carribean and Bahamas. From the South China sea Johnson (1978) collected 4 phyllosoma of Scyllarus species. Phyllosoma of P.japonicus was successfully reared by Inoue (1978) from berried females hatched in the laboratory. The relationship between the puerulus catches and the natural settlement was determined by Philips and Hall (1978). The ecology of the late stage phyllosoma and puerulus of P.longipes cygnus was investigated by Philips, Rimmer and Reid (1978). Smale (1978) described the effect of temperature on growth of small rock lobsters in the laboratory. Brain, Rimmer and Philips (1979) presented an illustrated key for identification of phyllosoma stages of P.cygnus. Johnson (1979) described 5 developmental stages of a Scyllarus phyllosoma with forked telson. The distribution and dispersal of the phyllosomas of P.cygnus in the South

eastern Indian Ocean was studied by Philips and others.(1979). Rimmer and Phillips (1979) made an investigation on the diurnal migration and vertical distribution of phyllosoma of P.cygnus. Alvarez (1980) reported a project for semiculture of P.interruptus. The project comprises two parts, culture of individuals less than commercial size and culture of larvae by capturin from the wild. Phillips and Sastry (1980) made a review of the ecology & life history of the larvae of spiny lobsters. Rimmer (1980) studied the spatial and temporal distribution of early stage larvae of P.cygnus. The circulation of the South eastern Indian ocean and the phyllosoma and pueurulus larval life of P.cygnus was studied by Phillips (1981). Phillips and others (1981) worked on the distribution and abundance of late larval stages of Scyllarid lobster from the South eastern Indian ocean and gave a key for identification of first phyllosoma stages of genus Palinuridae Scyllaridae and synaxidae. Atkinson et al. (1982) described the larval development of I.altigrenatus obtained by hatching in the laboratory and specimen from plankton samples. From the Carribean sea Baisre (1982) obtained two phyllosoma of P.laevicauda stage 8 and 10 and described

the larval groups within the genus. Baez (1983) conducted a study in order to find out the morphological variations of P.gracilis larvae and their distribution in the eastern Pacific off costa Rica. Calinsky and Lyons (1983) studied the swimming behaviour of pueruliі of P.argus at Mandioniel Bay, Greneda. The abundance of phyllosoma and other crustacean macrozooplankton in the surface waters of eddies was found out by McWilliam and Philips (1983). Pollock and Goosen (1983) carried out a work to establish with certainity the whereabouts of late stage phyllosoma, the depth distribution etc. Barret and others (1984) collected macrozooplankton containing several different species of scyllarid including T.orientalis and described 4 larval stages. MacDiarmid (1985) investigated the diel timing of hatching of larvae of J.edwardsii in the laboratory and in the field. Miller (1986) obtained a late phyllosoma of J.tristani Holthuis. Philips (1986) reviewed the larval distribution dynamics of spiny lobsters. The pelagic phase of spiny lobster development was reviewed by Philips and McWilliam (1986) From the gulf of Carpentaria Philips & McWilliam (1986) collected phyllosoma and nistostages of Scyllarus martensii. The retention and recruitment of phyllosoma of California spiny lobster P.interruptus was reviewed by Pringle (1986).

Among authers in India Alikunhi (1948) was the first to observe the metamophoris of late phyllosoma larva. Prasad and Tampi (1957) reported the phyllosoma of Mandapam. Prasad and Tampi (1959) obtained the 1st phyllosoma of P.burgeri (=homarus) hatched in the laboratory. Prasad and Tampi (1959) collected Palinurid and Scyllarid phyllosoma ofrom the Laccadive seas. They (1961 a) collected phyllosoma of Scyllarid lobster from the Arabian seas. Prasad and Tampi (1961 b) described the newly hatched phyllosoma of S.sordidus in the laboratory. A preliminary report of the phyllosoma of the Indian seas collected by the Dana expedition was given by Prasad and Tampi (1965). Deshmukh (1966) observed the metamarphosis of puerulus of P.polyphagus from the Bombay coast. Prasad and Thampi (1968) described the 1st phyllosoma of P.sewelli. The 1st phyllosoma of P.sewelli hatched in the laboratory was obtained by Mohammed, Rao and Suseelan (1971). Shankoli and Shenoy (1973) were able to rear S.sordidus larvae ~~and~~ hatched in the laboratory to the 6th stage. Tampi (1973) gave an account of the phyllosoma larvae of the Indian Ocean. Dutt and Ravindranath (1975) reported the occurrance of puerili of P.polyphagus from the Bay of Bengal and gave the diagnositic character and key to the known to Indowest pacific Pueruli of Panulirus species.

The phyllosoma larvae collected by the International Indian Ocean Expedition was described by Tampi and George (1975). Radhakrishnan (1977) succeeded in rearing and breeding P.homarus in the laboratory under controlled conditions.

A detailed account of the phyllosoma collected by the Dana expedition was given by Prasad, Tampi and George (1980). Sarasu (1985) reported Palinurid and Scyllarid phyllosoma collected from the Andra coast during a cruise made by the Research Vessel Skipjack.

CHAPTER 3

Material and methods

The study involved two types of collection of material from the sea in addition to culture of phyllosoma larval stages, which in turn required culture of live feed organisms. The species selected for tracing the larval life history through laboratory hatching and further rearing of larval stages being *Panulirus homarus* the collection of live berried specimens of the species with least handling in order to be in full live condition, was the prime material to be collected. For this an area where the species occur in large numbers and also with nearby laboratory facilities for rearing the animals was absolutely essential. The south east coast of India supports a good fishery for the species and live berried specimens of the species could be collected in large numbers from this region and the Tuticorin Research Centre of Central Marine Fisheries Research Institute has excellent facilities for rearing the larvae and live feed culture. Therefore the experiments were conducted in this laboratory and live berried specimens were collected from Kayalpattinam, a fishing village 35 km south of Tuticorin.

1. Experiments in hatching of eggs and larval rearing

Only very fresh and fully alive berried specimens were selected and collected from nets and transported in tubs containing sea water by Jeep. In the laboratory they were transferred to fibreglass brood stock rearing tanks of 1 tonne water capacity containing clean sea water. The salinity, pH, temperature etc were maintained at levels close to those of the inshore water. Depending on the maturity condition of the berry, the eggs hatch out in 20-25 days after placing in broodstock rearing tanks. The 1st stage phyllosoma larvae hatched out from the eggs were separated and placed in small batches in small glass rearing tanks of 5 litre water capacity. Water was aerated in each container. The salinity, pH, dissolved Oxygen etc remained as those of the natural condition. The larvae were reared from 1st stage till 5th moult. The food supplied to the larvae was Artemia nauplii. Till the 3rd moult Artemia nauplii 1st stage and for later stages Artemia 2nd and 3rd instar nauplii was given.

Presence of ciliates in the culture water was one of the major causes of larval mortality. Ciliates like Vorticella started growing on the body of the larvae and ultimately resulted in the death of the larvae. Once they attack the larvae soon they develop colonies all over the body of the larvae making even the movements of the larvae impossible. To overcome this the sea water was first filtered through a biological filter bed consisting of the usual sand and charcoal. This filtered water again filtered through 25 microns sieve before taking for experimental purposes. For getting rid of the ciliates antibiotics were used. Streptomycin sulphate and Benzyl penicilin were used for treating the water.

2. Live feed rearing

The Artemia nauplii constitute the major food of the phyllosoma larvae. The Artemia nauplii for the purpose was cultured in the laboratory. Artemia is a Branchiopod crustacean commonly called Brine shrimp and forms the food of many marine animals that can be cultured in the laboratory. This can produce dry embryos or cysts when the salinity of the sea water goes above 150 ppt or so. These cysts can remain viable for a long

period. On immerson in seawater the cysts hydrate and with in 24 hours the cyst shell breaks and the freeswimming nauplii come out.

Natural population of Artemia is found in salt lakes with about 100 ppt salinity onwards. These can thrive very well in natural sea water also. Artemia feed on organic detritus and living organisms like microscopic algae and bacteria. Artemia grows from nauplius to adult in 2 weeks. They can be intensively cultured under controlled conditions. The optimum salinity range for the biomass production is 50 --100‰. Stocking should be done at the 1st stage instar after removing from the hatching solution. Rate of stocking depends on the food availability. 10,000 nauplii/litre is the maximum stocking density. Rice bran or the algal culture form the common food for Artemia culture. At a total length of 8mm in two weeks time the Artemia can be harvested. When the aeration is cut off of the Oxygen concentration drops down to a critical minimum, the Artemia concentrates at the water surface and they can be easily scooped out with a net.

Since Artemia nauplii form the food of the larval crustaceans such as prawns, lobsters, and Crabs, Artemia cyst is exploited from natural habitat or produced on a commercial scale. The Artemia cysts for the present study were collected from the salt pan areas at Tuticorin and also bought from the Tata company, Gujarat. The cysts were collected, processed and stored. For long duration the cysts should be dried well and stored. Up to a few months time this can be kept in clean saline. The cysts when put in sea water with vigorous aeration hatch into nauplii within 24 hours. The nauplii were separated from the unhatched cysts. The positive photoactic behaviour of the nauplii was made use of for separating them. After turning off the aeration, by directing a beam of light on the transparent hatching container, the larvae got accumulated towards the light and then siphoned off. The Artemia separated in the above way were supplied fresh to the phyllosoma larvae.

Other food materials given to the phyllosoma larvae were jelly fishes, Sagitta adult and small pieces of gills of edible oyster. The jelly fishes were collected from the shore areas near the laboratory. Adults of Sagitta obtained by collection of zooplankton on board the small research vessel of the Research centre from the Harbour areas of Tuticorin.

3. Methods in experimental studies on environmental parameters affecting larval growth and moulting

In order to study the effect of environmental parameters such as salinity, pH, temperature and dissolved oxygen on moulting and larval growth, experiments were conducted with different levels of all the above mentioned factors. Batches of larvae were reared in different level of the 4 parameters and optimum level determined.

Salinity

The salinity of the sea water used for the experiment was determined by Mohr titration method. (Strickland and Parson 1968). 10 ml of the standard sea water was titrated against silver nitrate solution with pottassium chromate as indicator to standardise the silver nitrate solution. Then 10 ml of the water sample was titrated against the standard silver nitrate solution in the same way. Care was taken to see the exact end point colouration in all the samples. The standard sea water was obtained from the Oceanography Institute, Copenhagen. Each sample was titrated three times and the mean values taken. Salinity of the sample sea water was calculated using the formula.

$\frac{V_2 \times S}{V_1}$ where

V_1 = Volume of silver nitrate for 10cc of standard sea water.

S = 34.99, salinity of standard sea water.

V_2 = Volume of silver nitrate used for 10 cc sample sea water.

The salinity grades in which the experiments were conducted were 26, 28, 30, 32, 34, 36 and 38 ppt. The water of different salinities was obtained by diluting with fresh water or adding common salt. The quantity of seawater (of known salinity) to be taken for dilution was calculated using an equation,

$\frac{\text{Required salinity} \times 1000}{\text{Known higher salinity of seawater}}$. This gave the quantity of sea water to be taken for making up 1 litre of the desired salinity seawater. Salinity was found out with Salinometer also. The reading shown by the salinometer was checked with the value obtained by titration.

pH.

For the measurement of the pH of the seawater a Biochem pH meter was used. Before taking the readings the meter was first calibrated with a pH 7 buffer

solution. Then depending upon acidic or alkaline sea water a further adjustment with pH 4 and pH 9 respectively was done. The pH grades selected for the present experiments were 6.1, 6.5, 7, 7.5, 8, 8.6 and 9.2. Medium with pH below 7 was prepared by adding sufficient quantity of .25% Sulphuric acid. Higher pH was obtained by mixing the sea water with adequate amount of 5% sodium hydroxide solution. pH of the sea water at the time of the experiment varied from 8. 1- 8.2.

Temperature:

Temperature of the seawater was recorded using 0-50°C high precision Thermometer. Different temperatures selected for study were 25°C, 27°C, 29°C, 31°C and 33°C. The normal water temperature at the time of the experiment was 31°C. Lower temperature of 25°C and 27°C were monitored in the Air conditioned room and 29°C temperature obtained by keeping the beakers containing the larvae in cool water. 33°C temperature was maintained by heating the water with immerson heater and the temperature regulated with Jumo thermometer and regulator.

Dissolved oxygen

The dissolved oxygen content of the seawater was determined by using the traditional winkler method.

The water sample was collected in 125 ml corning reagent bottles. One ml of winkler solution A and one ml of winkler solution B was added immediately after collection. After putting the stopper without entangling any air bubbles the bottle was shaken to disperse the precipitate uniformly through out the bottle. After the ppt was settled 2 ml Sulphuric acid was added to dissolve the precipitate. 100 ml of the solution was titrated against Sodium thiosulphate solution using starch as indicator. The sodium thiosulphate was standardized using Potassium iodate before tiration with the sample sea water. The experiment was repeated to get concordant values. Dissolved oxygen content was calculated using the equation,

$$\frac{\text{Vol of thio} \times N_2 \times 8 \times 1000 \times R}{100 \times 1.429}$$ where

N_2 = Normality of thiosulphate

R = 1.01, a correction factor

1.429= the weight of Oxygen in milligrams

Seawater with different levels of dissolved Oxygen taken for the experiment was 2.5, 3, 3.5 and 4ml/litre. These desired levels of dissolved oxygen were obtained by passing sufficient Nitrogen gas through the seawater.

4. **Collection of phyllosoma larvae from the plankton**

This forms the second type of material collected for the study involving collection of phyllosoma larvae from the wild namely plankton collection. The larval samples were collected during some of the research cruises conducted by the Fishery and Oceanography Research Vessel Sagar Sampada. The vessel has been acquired by the Department of Ocean Development Govt. of India, and the management of Scientific programmes of the vessel has been entrusted to CMFRI on behalf of the Indian Council of Agricultural Research. She is a multidisciplinary research vessel fully equipped with modern equipments for fishery, oceanography and meteorological research. The wheel house is equipped with a Radio station, VHF Radio telephone Radar, Radio direction finder, Gyro compass, Autopilot, Doppler speed boy, Echo sounder, Weather chart, fascimile recorder, satellite Navigation and satellite communication. The main physical,chemical and Biological laboratories are established in one common laboratory. There are photometric auto analyser for measurement of nutrients spectrophotometer for measurement of nutrient chlorophyll a,o.pigments, Spectrofluremeter for measurement of chlorophyl,

titrator for titration, microbalances, Recorders for quantameters measuring light quanta etc in the laboratory. All the isotope analysis take place in the carbon 14 laboratory. There is an Acoustic Detector room, materological Bouy, the EDP system with 6 desk top computers, Aquaria rooms and some additional facilities such as dark room, electro technical and mechanical workshops for service to all instruments and equipments are also provided in in the vessel. The overall length of the vessel is 71.50 mtrs. Dead weight is 1160 tonnes. The gross tonnage is 2661 tonnes and 500 Hp.

The Bongo 60 plankton net consisting of two 60 cm diameter rings and net cones was used, for the zooplankton collection. The net cones of 250 cm length attached to the rings are connected by a yoke. The Bongo net was operated by towing attached to the wire from the special plankton winch. While towing the yoke bar with the nets swing in a sleeve connected to the rope and take a horizontal position. A hydro-dynamically shaped cast iron depressor weighing 20 Kg is attached to the sleeve which helps to keep the equilibrium of the net during tow. The cones of the

net are of nylon material of 0.33 mm square mesh. As there are no bridles connected to the rings there is no obstruction to waterflow into the cones. A flowmeter is mounted centrally at the mouth of one of the cones. The zooplankton tows were of the continuous oblique type. Maximum depth of the haul was 100 m. The phillosoma larvae were sorted out from the Vessel's zooplankton collections of the cruises during 1985. From 12 stations different stages of phyllosoma larvae of the species P. homarus, P. versicolor, P. ornatus, P. penicillatus, P. polyphagus and P. longipes were collected. Details regarding cruises, station No; position etc are given in the relevant chapter.

CHAPTER 4

Laboratory spawning and rearing of larvae of Panulirus homarus.

Attempts to culture phyllosoma larvae commenced as early as 1911 when experiments to rear the larvae of Panulirus interruptus were conducted in California. Many investigators succeeded in hatching palinurid eggs in the laboratory, but failed to keep the larvae for sufficiently long time to rear the phyllosoma through all the stages up to the puerulus stage. Difficulties encountered in the laboratory culture of the phyllosoma indicate the lack of adequate information about the larval requirements. The nutritional requirement of the larvae is the most important factor in their rearing and very little is known about the natural food of the larvae, although some authors reported the phyllosoma seen attached to hydrozoan and scyphozoan medusae (Shojima 1963, Thomas 1963, Herrnkind et al. 1976). The lack of available studies on tracing the complete larval history of any Indian spiny lobster has prompted to take up this project on laboratory hatching of eggs and further rearing of larvae of the most important species of this, region, namely, Panulirus homarus.

Live berried lobsters from the field was brought to the laboratory for the first experiment on 9th August 1984 and kept in clean sea water. The carapace length of the animal was 70 mm and it weighed 400 gm. The water kept aerated, was of salinity 35 — 36 ppt, pH 8.1 — 8.2, temperature 29°C in the morning and 30°C at the noon and dissolved oxygen 4 — 4.2 ml/litre. The berried female was fed with clam meat, fish and edible oyster meat daily once. The water was changed with fresh clean sea water everyday taking precautions to keep the environmental parameters with in the range mentioned. On 26th the eggs hatched out, this period of hatching varying in further experiments depending on the developmental stage of the eggs. Hatching occurred mostly during night and the larvae were transferred to glass beakers of 5 litre capacity putting 10 numbers in each beaker. The same salinity, pH, temperature and dissolved oxygen as those into which the larvae hatched out where maintained in the beakers. Water in the larval rearing beakers was changed everyday with fresh filtered sea water. The water was kept aerated and freshly hatched Artemia nauplii were supplied as food for the larvae.

Hatching of eggs

The berried females kept for the purpose of hatching of eggs were not disturbed as far as possible.

Most of the time when the lobster was brought to the laboratory the colour of the berry was orange red . (Plate 1)

Egg

Size: The average size (diameter) of the egg was 428 μ. The colour of the egg gradually changed from orange red to brown and brownish black during the course of development. The eggs measured after 17 days of development in the tanks gave an average size of 625 μ. Once this size is reached the eggs began to hatch out.

Shape : The shape of the egg was spherical throughout the incubation period. (Plate 2 A & B)

Fecundity: The average fecundity of P. homarus determined by counting the eggs in a known constant volume of egg mass from 4 berried P. homarus in the length range of 60 —70 mm carapace length was 3,40,000.

Hatching

Hatching of eggs in the laboratory was repeated several times. Complete hatching of all the eggs in the berry took place in a maximum of two days. It was found that larvae hatched out from the berried female brought to the laboratory in an advanced stage of development of the eggs (ie, eggs hatched with in 2 or 3 days after keeping in the laboratory tanks) did not survive more

Plate 1: Berried *P. homarus*.

PLATE 1

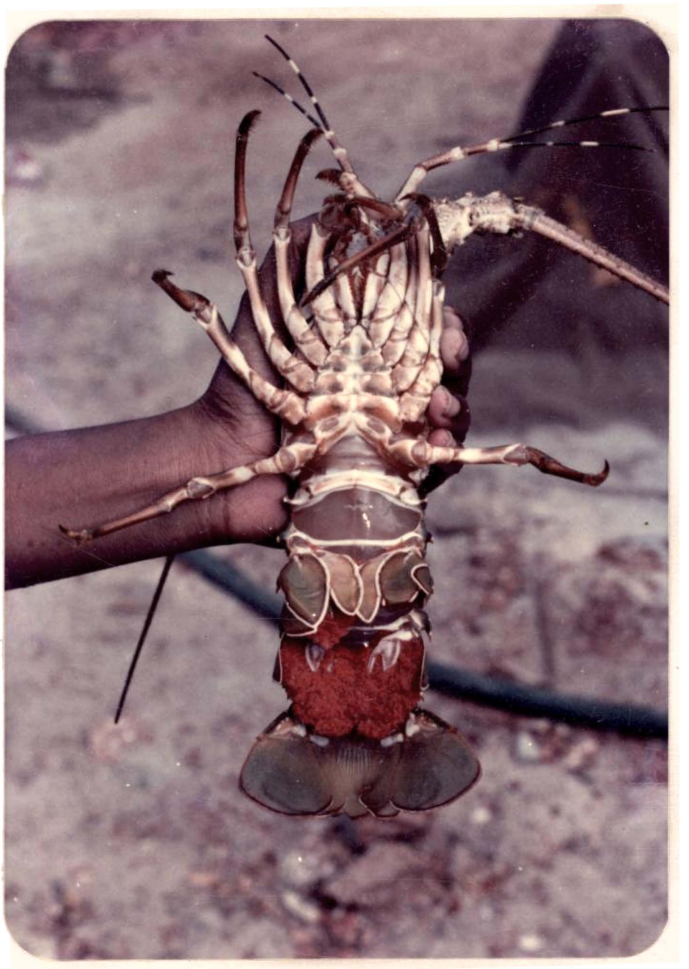
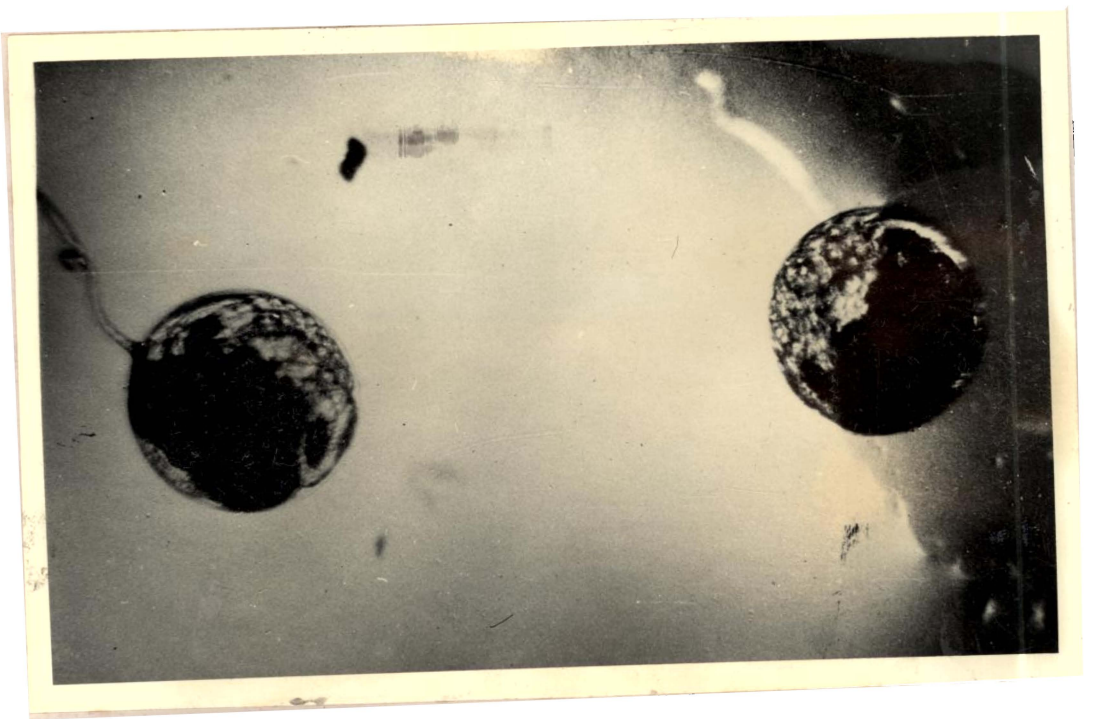
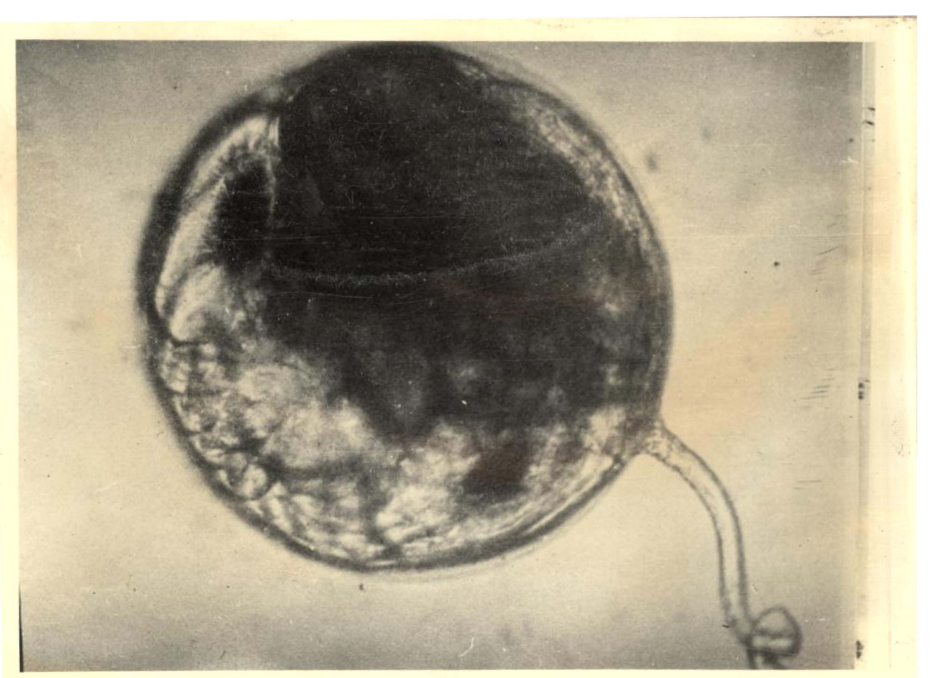


Plate 2: A & B. Eggs of *P.homarus*.

PLATE 2





B

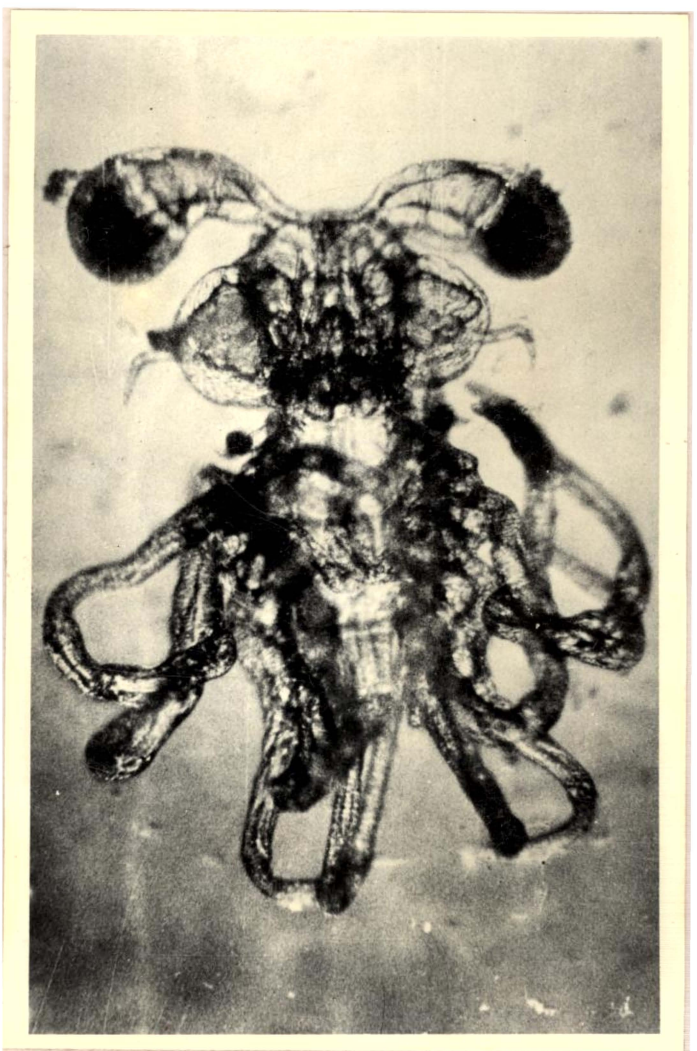
than 15 days. Larvae hatched from berried females kept in the laboratory tanks for 20 - 25 days survived better and were alive more than 50—60 days.

After hatching the mother lobster was immediately separated. No egg loss was found and almost all the eggs hatched out. On one occasion the spawned female again produced eggs after a few days without any moulting as reported by Uchida & Dotsu (1973). However these eggs were not found developing and after a few days the female shed all the eggs.

Every occassion when the hatching was observed in the early morning it was noticed that the larvae just hatched from the eggs were a little different from the 1st phyllosoma. The larvae were not found swimming. The appendages of the larvae were found in a folded condition as described by Prasad & Tampi (1959) in P. burgeri (= homarus). This seems to be the stage described by some authors as naupliosoma, Prenaupliosoma or prephyllosoma (Plate 3). However, it was observed this form lasted for 5-6 hours and became a phyllosoma 1st stage without any moulting. Apparently this does not seem to be a separate stage.

Plate 3: Nauplisoma of *P.homarus*

PLATE 3



The 1st phyllosoma of *P. homarus* actively fed on *Artemia* nauplii. Mortality of some of the larvae was observed from the 2nd day onwards after transferring to the beaker. One of the important causes of mortality was the attack of ciliates, like *Vorticella* on the phyllosoma. These ciliates soon developed colonies all over the body of the larvae making them inactive and ultimately resulting in death of the larvae. This was overcome to a certain extent with the help of antibiotics, Streptomycin sulphate and Benzyl penicillin. One gram of each of this was dissolved in 100 ml of distilled water and added to 125 litres of rearing media. Before treating with the antibiotics the seawater was filtered through a 25 microns sieve. For all the larval culture experiments filtered sea water treated with antibiotics was used. Out of the four rearing experiments done each time from a total of 250 larvae taken in 25 beakers 70 - 73% moulted to the 2nd stage after 6—8 days. Of these 70-75% moulted to the 3rd stage after 10—12 days. To the 4th instar 40-50% of the 3rd stage moulted after 9-11 days. Out of this only 30-40% moulted to the 4th stage after 13—15 days. In 41-45 days the larvae moulted 4 times. The fourth stage larvae were kept alive for more than 20 days but none moulted and all the larvae gradually died out. It was

Plate 4: Experimental setup for Phyllosoma culture.

PLATE 4

obvious that the main cause of mortality was the lack of a suitable food material after the 3rd stage. 1st to 3rd stage larvae consumed newly hatched Artemia nauplii while other instars were fed on Artemia nauplii 3rd or 4th instar. The nutritive value of these Artemia nauplii is very less when compared to the 1st nauplii.

Description of larval stages.

Stage 1 (Fig., 1 a & b)

The 1st stage larvae hatched out was similar to that described by Prasad and Thampi (1959) Berry (1974) Prasad, Tampi and George (1980).

Size of the larvae: The total length of the larvae was 1.2 — 1.4mm. Orange red coloured chromatophores were present on the coxal segment of the pereopods and base of the 1st and 2nd antenna as described by Prasad & Tampi (1959). The chromatophores were found to disappear on preservation.

Cephalic shield: The cephalic shield more or less oval in shape. The length of the cephalic shield and hind body almost equal in this stage. Width of the cephalic shield more than the hind body.

Eye: Eyes not stalked in this stage.

1st Antenna: Antenna 1 single and longer than the 2nd antenna, 4 setae on the tips.

2nd Antenna: Uniramous and shorter than the 1st antenna.

Maxilla 1 : 2 segmented and the distal segment with 4 long setae.

Maxilliped 1 : Maxilliped 1 absent Prasad & Tampi (1959) observed rudimentary 1st maxilliped in the 1st phyllosoma of P. burgeri (=homarus) hatched in the lab. However even rudiment was not seen in the present specimens.

Maxilliped 2: Without exopodite

Maxilliped 3: Biramous and the exopod bore 6 setae. No ventral coxal spine observed on 3rd maxilliped. Prasad & Tampi (1959) did not mention the ventral coxal spine on this appendage. However Berry (1974) and Prasad et al. (1980) noticed this spine on 3rd maxilliped of 1st stage P. homarus collected from plankton.

Pereopods: Legs 1 — 3 with Ventral coxal spine and sub exopodal spine. Exopod present as bud on the 3rd pereopod. Exopod of 1st and 2nd leg setose Dorsal coxal spine absent on all legs.

Abdomen: The abdomen ended in two pointed tips bearing 4 or 5 setae.

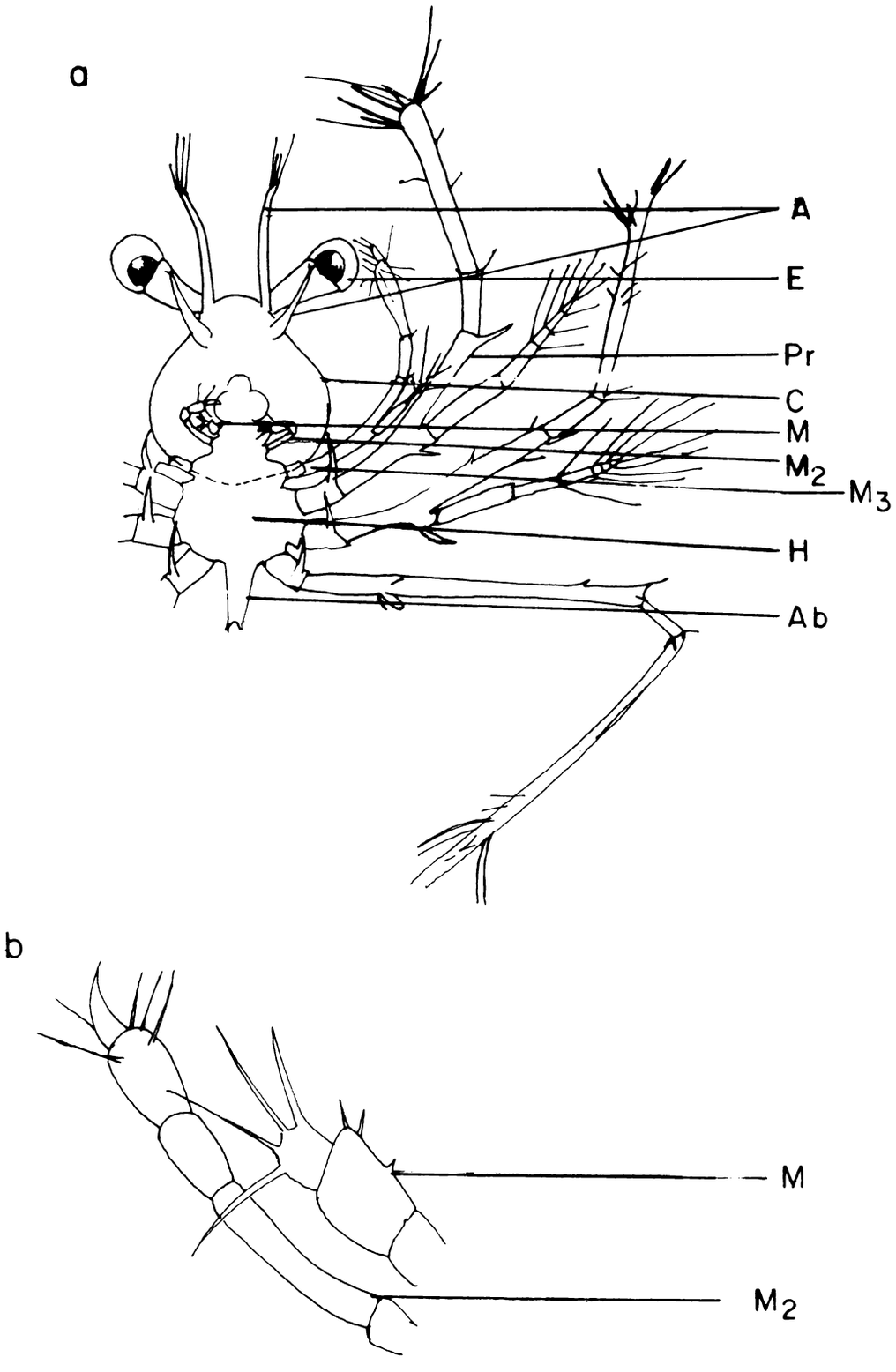
Fig. 1

a. Stage 1 phyllosoma of *P.homarus*

b. 2nd Maxilla and 2nd Maxilliped

A - Antenna, E-Eye, C-Cephalic shield, M-Maxilla 2,
M_2- 2nd Maxilliped, M-3 - 3rd Maxilliped, H- Hind body,
Pr.- Pereopod, Ab.- Abdomen.

Fig. 1



Stage II (Fig. 2 a & b)

The 1st stage larvae moulted to the 2nd stage after 6—8 days. The larvae were quite similar to the 2nd stage larvae of P. homarus described by Berry (1974) and Prasad et al.(1980) from Plankton collection.

Size of the larvae: The total length of the larvae was 1.4—1.8 mm. The total length of Berry's specimen was 2.2.—2.9 mm and that of Prasad's specimen was 2.1—2.9mm. Thus the present stage II larvae appear to be small.

Eye: Eyes stalked.

1st antenna: Longer than in the 1st stage.

2nd antenna: Longer than in the 1st stage larva

Cephalic shield: Length of the cephalic shield a little more than that of hind body.

Maxilliped 1: Maxilliped 1 still absent.

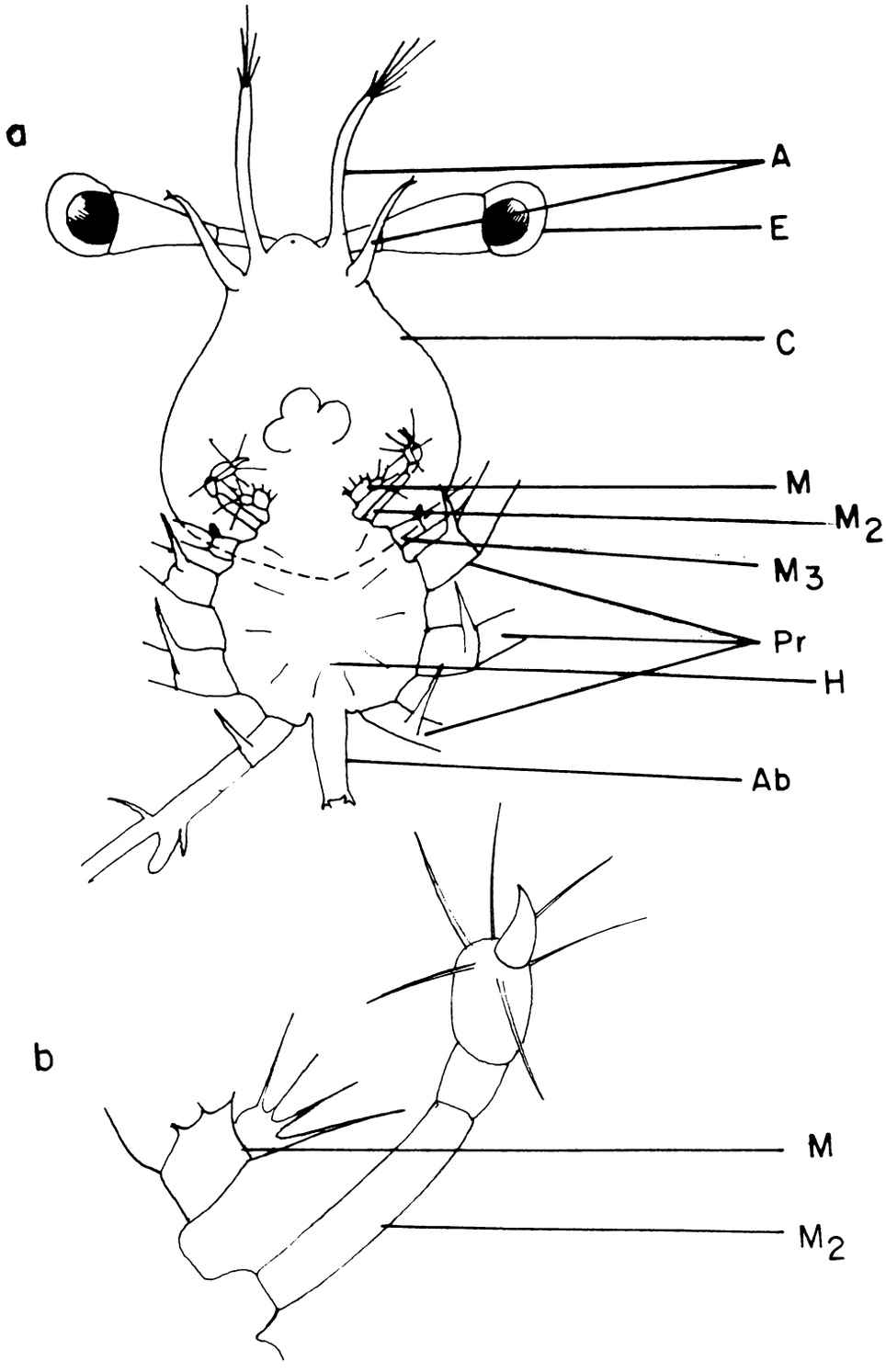
Maxilliped 2: 2nd maxilliped without exopod.

Maxilliped 3: 3rd maxilliped with setose exopod and ventral coxal spine. Sub exopodal spine not found on 3rd maxilliped.

Pereopods: Ventral coxal spine and subexopodal spines present on legs 1-3. Exopod of 3rd leg not setose. Rudiment of 4th pereopod not seen unlike reported by Thampi and George (1975) in 2nd stage.

Fig. 2 a. Stage 2 phyllosoma of *P.homarus*
b. 2nd Maxilla and 2nd Maxilliped.

Fig. 2



Stage III (Fig.3, a & b)

Size of the larvae: Total length of the 3rd stage larvae varied from 2 -- 2.1.mm.

Cephalic shield: Here also the length of the Cephalic shield was more than the hind body.

Antenna: Antenna 1 & 2 not segmented.

Maxilla 2: Distal segment of maxilla 2 with 4 setae and the other segment with 3 short setae.

Maxilliped 1: Bud of 1st maxilliped not found in this stage. Berry (1976) did not mention the presence of the bud of 1st maxilliped in the collected specimens of 3rd stage P. homarus. But Prasad, Thampi & George (1980) observed bud of 1st maxilliped in this stage.

Maxilliped 2: 2nd maxilliped without exopod.

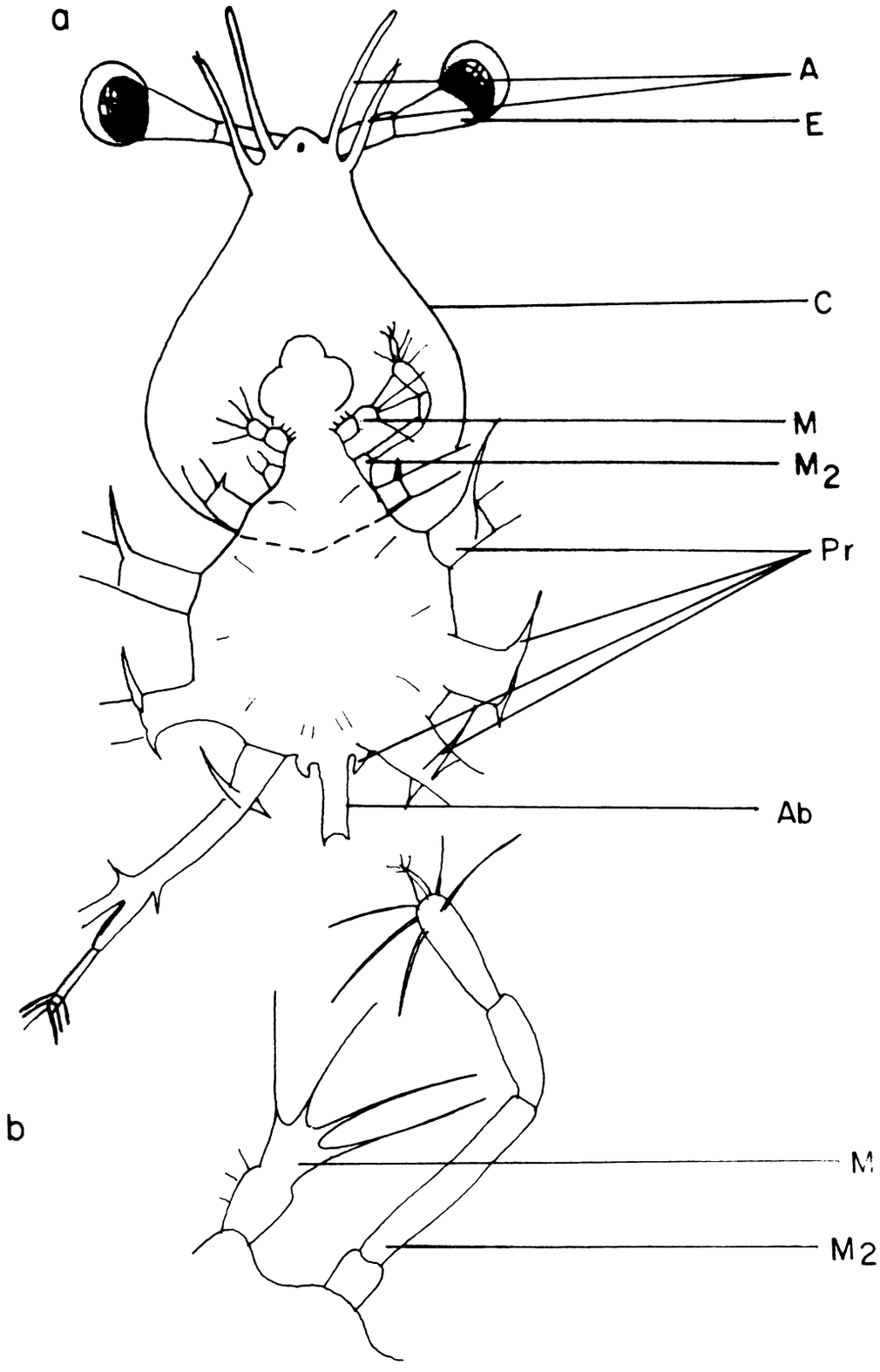
Maxilliped 3: 3rd maxilliped possess ventral coxal spines, but no subexopodal spines.

Pereopods: Pereopod 1--3 with ventral coxal spine and subexopodal spine. Dorsal coxal spine present on legs 2 & 3. Exopod of leg 3 setose, with 6 setae. Berry had taken this character for the identification of 3rd stage P. homarus collected from the Natal coast. Pereopod 4 present as bud in this stage. Thampi & George (1975) observed 4th pereopod as long as the abdomen and rudiment of 5th leg in 3rd stage P. homarus collected from the

Fig. 3 a. Stage 3 phyllosoma of *P.homarus*

b. 2nd maxilla and 2nd maxilliped.

Fig. 3



plankton. Rudiment of 5th pereopod was lacking in the present stage obtained by moulting. Prasad, Thampi & George (1980) did not observe rudiment of 5th leg on 3rd stage larvae of P.homarus from Plankton.

Moult 4 (Fig.4)

Size of the larvae: Total length of the instar was 2.5 -- 2.7 mm. This instar cannot be included under the 4th stage as there was only minor morphological changes from the 3rd stage. Berry (1974) has given a key for identification of stages of P.homarus. The bifid nature of the 4th leg has been taken as the distinguishing character of the 4th stage. In the 4th instar obtained here the 4th pereopod was a little longer than that in the 3rd stage but not reaching the tip of the abdomen and was not bifid. So based on this, this form is regarded as an instar before the 4th stage.

Antenna 1 & 2 were slightly longer than in the 3rd stage.

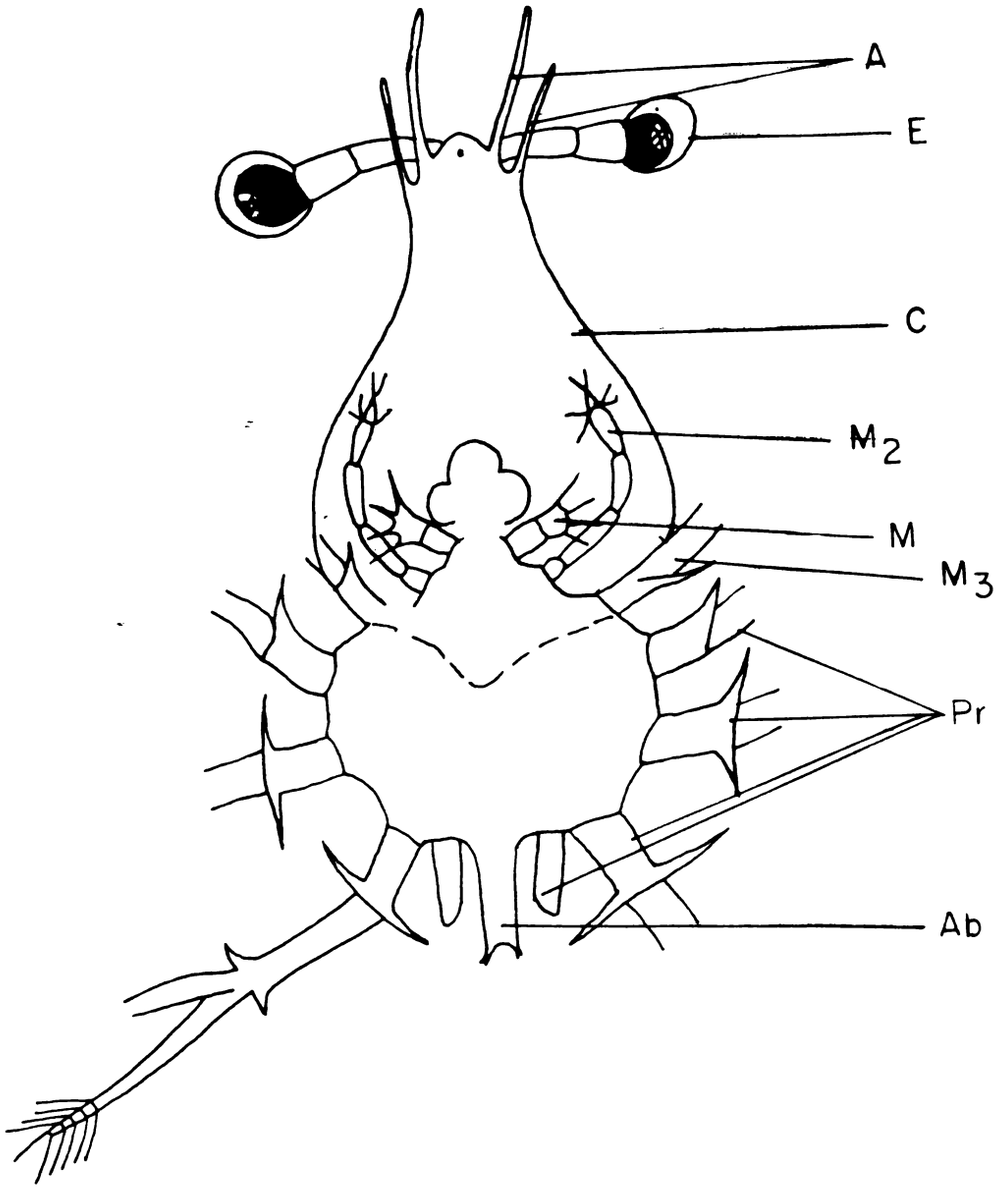
Maxilliped 1: Still absent

Maxilliped 2: Without exopod

Maxilliped 3: With ventral coxal spine but without subexpodal spine.

Fig. 4 4th instar phyllosoma of *P.homarus*

Fig. 4



Peraeopods. Legs 1—3 had ventral coxal spine and sub exopodal spine. The 2nd and 3rd peraeopod had dorsal coxal spine also. Exopod of leg 3 had 10 setae in this instar. Peraeopod 4 was a little longer than that of the 3rd stage but was not bifid.

Stage IV (Fig 5 a & b)

The 4th instar moulted to the 4th stage.

Size of the larvae: Total length of the larvae was 3—3.1 mm.

Antenna 1 & 2 not segmented

Maxilla 2: Only 4 setae on distal segment

Maxilliped 1: absent in this stage also.

Maxilliped 2: Without exopod bud.

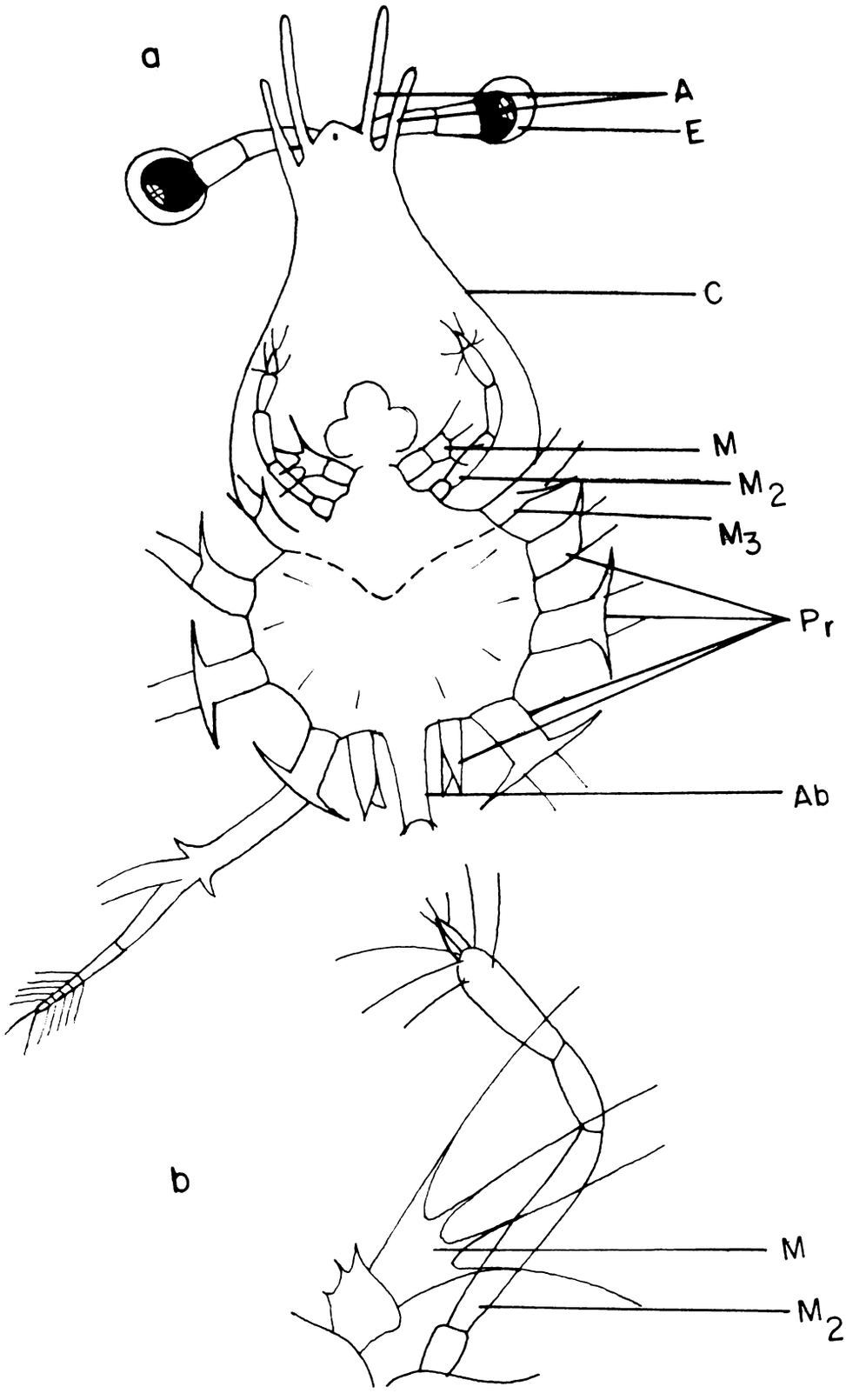
Maxilliped 3: 3rd maxilliped with setose exopod and ventral coxal spine. No subexopodal spine on 3rd maxilliped.

Peraeopods: Legs 1—3 had ventral coxal and subexopodal spines. Dorsal coxal spine seen only on legs 2 & 3. The exopod of 3rd leg had 12 setae in this stage. Peraeopod 4 was bifid and the length almost reached to the tip of the abdomen. In the key given by Berry (1974)

Fig. 5 a. Stage 4 phyllosoma of *P.homarus*

b. 2nd maxilla and 2nd maxilliped.

Fig. 5



for identification of the stages of *P. homarus* the bifid nature of the 4th leg was taken as the distinguishing character of the 4th stage. The present observation confirms this. Brain *et al.*(1979) included specimens with bifid 4th leg in the identification of 4th stage larvae of *P.gyrinus* George. Rudiment of 5th leg was not seen in this stage as described by Tampi & George (1975) All further attempts in repeated experiments to get the next stage larvae by moulting failed.

Discussion

In spite of repeated attempts during the study it has not been possible to rear the phyllosoma larvae of the species of lobster through all the stages,everytime, total mortality of the larvae taking place at the 4th stage. Although in scyllarid lobster complete larval history.has been traced in the laboratory, the tracing of larval history in the case of Palinurid lobster in the laboratory has not been successfully carried out so far. Various reasons could be atributed for the failure of the complete larval culture. Robertson (1968) obtained the complete larval stages of *Scyllarus americanus* moulting to the last stage, taking place in 32-40 days. Thus in scyllarid lobster the duration of the phyllosoma larval

life is less than about 60 days. The duration of the larval life and the number of phyllosoma stages of Palinurid lobster by circumstantial evidence has been given by many authors. Prasad & Tampi (1959) assumed 10 stages in the development of P.penicillatus. Johnson (1971) was of the opinion that it may take probably 7—8 months to become a puerulus larva. Berry (1974) described 9th stage P. homarus and considered it as the last phyllosoma and 4—6 months of larval duration. But Prasad et al.(1980) and Sarasu (1985) described 10th stage larva of P. homarus from the plankton. Chittleborough and Thomas (1969) calculated 9—11 months, duration for P.cygnus larvae and Brain et al.,(1979) proposed 9 stages in the development. Eleven phyllosoma stages of P.japonicus were obtained by Inoue (1978) by rearing and assumed the 11th stage as the last stage phyllosoma. But as his 11th stage larva did not possess gills and did not moult to the puerulus stage, the assignment of these larvae as the last stage may not be correct. All these definitely show the long larval life of Palinurid lobster and this long larval life duration is definitely one of the important reason for the failure of the complicate larval rearing of Palinurid in the laboratory.

Another important difficulty encountered in the laboratory rearing is the diet of the larvae. Almost all of the culture experiments were reported as using Artemia nauplii as feed for the larvae. There is no doubt that Artemia can be used as an alternate food but the fact remains that it is not the natural food of the larvae as development takes place in the sea. Other foods such as planktonic organisms like jelly fishes, Sagitta etc were found acceptable to the larvae but their availability in comparison to Artemia nauplii in the laboratory is very very limited and for lengthy laboratory studies, steady supply of these would be extremely difficult Artemia nauplii is found suitable only for the early larval stages. For later stages the particle size of the Artemia nauplii 1st stage is very small compared to the size of the phyllosoma larvae.

Saisho (1962) obtained 10 ecdysis of P. japonicus larvae on brine shrimp as food. Inoue and Nonaka (1963) gave Artemia nauplii and adult

Artemia to *P. japonicus* larvae and reared it to the 7th stage in 40—48 days. Saisho (1966) observed *P. japonicus* larvae moulted 16 times in 178 days, feeding on brine shrimps. Robertson (1968) successfully fed *S. squamosus* with *Artemia*. Dexter (1972) reared phyllosoma of *P. interruptus* to the 6th stage on *Artemia* nauplii, Chaetognaths, ctenophores, Mytilus gonad and Tubifex eggs in 114 days. Inoue (1978) cultured phyllosoma of *P. japonicus* on *Artemia* nauplii, adult Sagitta and fish fry of several species. In the present experiments larvae of *P. homarus* were given *Artemia* nauplii pieces of jelly fish, adult *Sagitta*, *Crassostrea* species etc and these were found acceptable to the larvae. The larvae readily ate *Sagitta* but the difficulty in getting these planktonic organisms daily in the laboratory renders it impracticable to use them as food in the culture experiments.

Phyllosoma larvae of scyllarid lobster have been reported accompanying jellyfishes by many workers (Shojima 1963, Thomas 1963, Hernkind *et al.* 1976). About 20% of the 500 medusae examined by Hernkind *et al.* (1976) had phyllosoma attached. However nobody has reported about providing jellyfish as food to the Palinurid phyllosoma. In the present study it was found that phyllosoma of

P. homarus fed on pieces of jelly fish added to the medium, indicating that jellyfish probably is one of natural food of the Palinurid phyllosoma. This is the case with Sagitta also. Dexter (1972) gave Chaetognaths and Ctenophores to the larvae of P. interruptus. P. japonicus larvae were reared by Inoue (1978) on Artemia, Sagitta and fish fry. All these point to the fact that successful culture of the phyllosoma larvae lies in the availability of a suitable food other than Artemia nauplii for the larvae after the 3rd stage.

It was observed in the present experiment that each moult did not correspond to a stage. In other words more than one moult may occur, between stages as recorded by some of the earlier workers. (Saisho 1962, 1966, Dexter 1972, Inoue 1978) Saisho's 10th moult larvae correspond to the 5th stage larvae of P.interruptus described by Johnson. Dexter (1972) observed 8 months for P.interruptus to become the 6th stage and also observed that the larvae were significantly smaller than larvae collected from the plankton. The 5th moult obtained during the present experiments is the 4th stage

described by Berry (1974) Till the 3rd stage only one moult resulted in the next stage. The 3rd stage moulted twice to become the 4th stage. The intermoult period between 1st and 2nd stage was 6—8 days, 2nd & 3rd 10-12 days, 3rd and 4th 9-11 days and 4th & 5th 13-15 days. Thus as the development progresses the intermoult period was found increasing. One of the reasons for this may be the deficiency of proper food in the laboratory. It has to be admitted that the size of the larvae obtained in the laboratory was very small compared to the size of the same stage of the same species from plankton, described by Berry (1974) Prasad, Tampi and George (1980) Tampi and George (1975).

The presence or absence of a naupliosoma stage in the development of spiny lobsters remains a controversy. Sheard (1949) reported naupliosoma in the larval development of P. cygnus. Prasad & Tampi (1959) observed a nauplisoma in P. burgeri (= homarus). George (1962) was of opinion that the naupliosoma may not be regarded as a distinct stage separated by a moult. From Plankton collection Sims (1965) obtained

naupliosoma of P. argus. Deshmukh (1968) observed this form in P.dasypus (= homarus) and proposed the name pre phyllosoma. Lesser (1974) observed similar form in J.Verreauxi. In the present investigation also a form with folded legs and drooping eyes and folded antennae like the naupliosoma form was observed, lasting 5-6 hrs after which it became 1st phyllosoma stage. However, there was no moulting to the 1st phyllosoma stage. Philips and Sastry (1980) reviewed all the literature on naupliosoma and stated that "the naupliosoma stage probably represents an embryonic form occurring as a result of premature rupturing of the eggs in most species although the findings of prenaupliosoma of P. argus in the plankton by Sims(1965) shows this is not universal". The question whether the naupliosoma is a stage of the normal development or the result of premature hatching is yet to be ascertained. Sims (1965) eventhough collected prenaupliosoma from plankton found that P. argus normally hatch as first phyllosoma in the laboratory. He observed that a form identical to the prenaupliosoma of P. argus and S. squamosus can be produced from eggs of late development by placing the eggs in seawater of low

salinity. If the naupliosoma is the result of restrictions in the laboratory experiments Sims(1965) could not have collected it from the natural environment.

In the present study the embryonic development of the larvae was observed everyday and all the yolk material was found utilised before hatching and the naupliosoma was well developed except that the appendages were folded and the eyes and antenna drooping. Considering these aspects the naupliosoma cannot be an embryonic form hatched by the premature rupture of the egg shell. This is the 3rd report of the naupliosoma like form of P.homarus. Prasad and Tampi (1959) observed the naupliosoma covered with a membrane and after shedding this membrane this form assumed the 1st phyllosoma stage. No such membrane was observed in the present study. So it is concluded that the naupliosoma cannot be considered as a distinct stage seperated by a moult. However there certainly exist such a form prior to the 1st phyllosoma in Panulirus homarus as observed in some other species by earlier authors.

CHAPTER - 5

Studies on Environmental factors affecting larval survival and moulting.

Apart from some of the attempts to rear the phyllosoma larvae and the identification and description of larval samples from plankton collection, no detailed investigations have been carried out on the physiological aspects of the larvae and the optimum environmental factors so far. For proper growth and moulting in the laboratory an environment similar to that of the natural condition is highly necessary. The best suited environmental factors for fast growth and maximum survival should be known and studies towards these aspects are lacking. In view of this rearing experiments were conducted with different grades of the environmental parameters such as salinity, pH, temperature and dissolved oxygen in order to determine the optimum levels of these factors for maximum survival and growth of the early stage phyllosoma of *Panulirus homarus*.

Salinity.

To determine the optimum salinity for maximum survival of the 1st stage larvae, experiments were conducted in salinity grades of 26.0, 28.0, 30.0, 32.0, 34.0, 36.0 and 38.0 ppt. The rearing experiments were conducted in

glass beakers of 5 litre capacity. In each beaker 4.5 litres of sea water with different levels of salinity was taken. Salinity of sea water at the time of experiment was 36.0 ppt. All the experiments were carried out in triplicate. The stocking rate was 10 animals per beaker. Before transferring to different salinities the larvae were acclimated to each salinity. The acclimation started the same day of hatching and depending on the salinity of sea water at the time of the experiment every day one ppt was increased or decreased for acclimation test till the desired level was reached. When the desired level reached, larvae were transferred to it. During the course of the experiment the larvae were fed with Artemia nauplii only. Water in each beaker was changed daily with fresh clean sea water of the same salinity and aeration was given in each beaker. The sea water for all the experiments was filtered through a biological filter bed and 25 µ sieve. Then it was treated with antibiotics as in the rearing experiments.

Mortality occurred on each day and the number of larvae moulted to the 2nd stage were recorded. The larvae in the 36.0 ppt salinity started moulting after 7 days. 60% survival and no moulting to the 2nd stage

were observed in 26.0 ppt. 20% survival and 0% moulting in 28.0 ppt. 33.34% survival and 0% moulting in 30.0 ppt. 46.65% survival and 0% moulting in 32.0 ppt. 73.34% survival and 10% moulting in 34.0 ppt. 53.34% survival and 33. moulting in 36.0 ppt. 66.66% survival and 10% moulting in 38.0ppt were recorded. Statistical analysis of the data showed that the optimum level of salinity for growth and moulting is in between 34.0 and 36.0 ppt. (Fig. 6).

pH

The optimum pH for phyllosoma larvae was determined by conducting experiments in sea water with 6.1, 6.5, 7, 7.5, 8, 8.6 and 9.2 pH. The pH of the sea water at the time of the experiment was 8.1 - 8.2. In this case also the experiments were conducted in triplicate and all the procedures were same as in the salinity experiment. Acclimation to different pH levels were done before transferring the larvae. Survival and moulting of the larvae in each pH levels were recorded. Larvae started moulting after 5 days in 7, 7.5, 8 and 8.6 pH. In 6.1, 6.5 and 9.2 pH moulting started after 6 days. The maximum survival and moulting of the larvae took place in a pH ranging from 7.5 - 8.6. In pH above and below this level the rate of moulting and survival declined. Statistical analysis of the data showed that the optimum pH is 8 - 8.6 (Fig 7 & 8).

Plate 5 : Experimental setup for salinity and pH

PLATE 5

Table - 1

Percentage survival and moulting of Ist stage phyllosoma reared in different salinities of 2.00 ppt intervals. (Total No. of animals in each salinity was 30)

Salinity ‰	Survival %	Moulting %	Mortality %
26.0	60.00	0	40.00
28.0	20.00	0	80.00
30.0	33.34	0	66.66
32.0	46.67	0	53.33
34.0	73.34	10.00	26.66
36.0	53.34	33.33	46.39
38.0	66.66	10.00	33.33

Fig. 6. Effect of salinity on survival and moulting of 1st stage phyllosoma of *P. homarus*.

Fig. 6

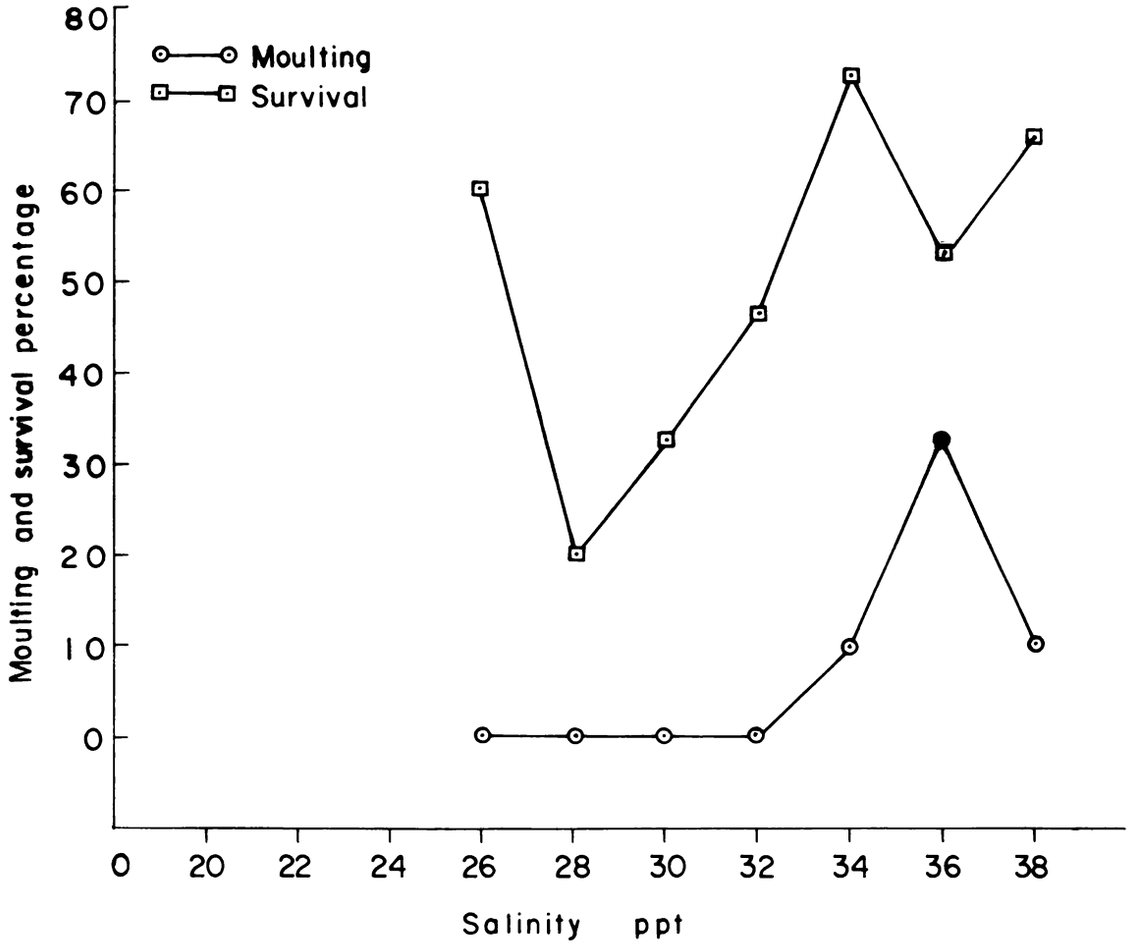

Moulting
Survival
Moulting and survival percentage
80
70
60
50
40
30
20
10
0
0
20
22
24
26
28
30
32
34
36
38
Salinity ppt

Table - 2

Percentage survival and moulting of 1st stage phyllosoma reared in different pH seawater. (Total No. of animals in each pH was 30.)

pH	Survival %	Moulting %	Mortality %
6.1	23.40	43.30	76.60
6.5	40.00	36.60	60.00
7.0	66.67	46.60	33.00
7.5	80.00	70.00	20.00
8.0	90.00	83.33	10.00
8.6	93.34	60.00	6.66
9.2	53.34	3.33	46.66

Fig. 7 Effect of pH on survival of 1st stage phyllosoma of P.homarus.

Fig.7

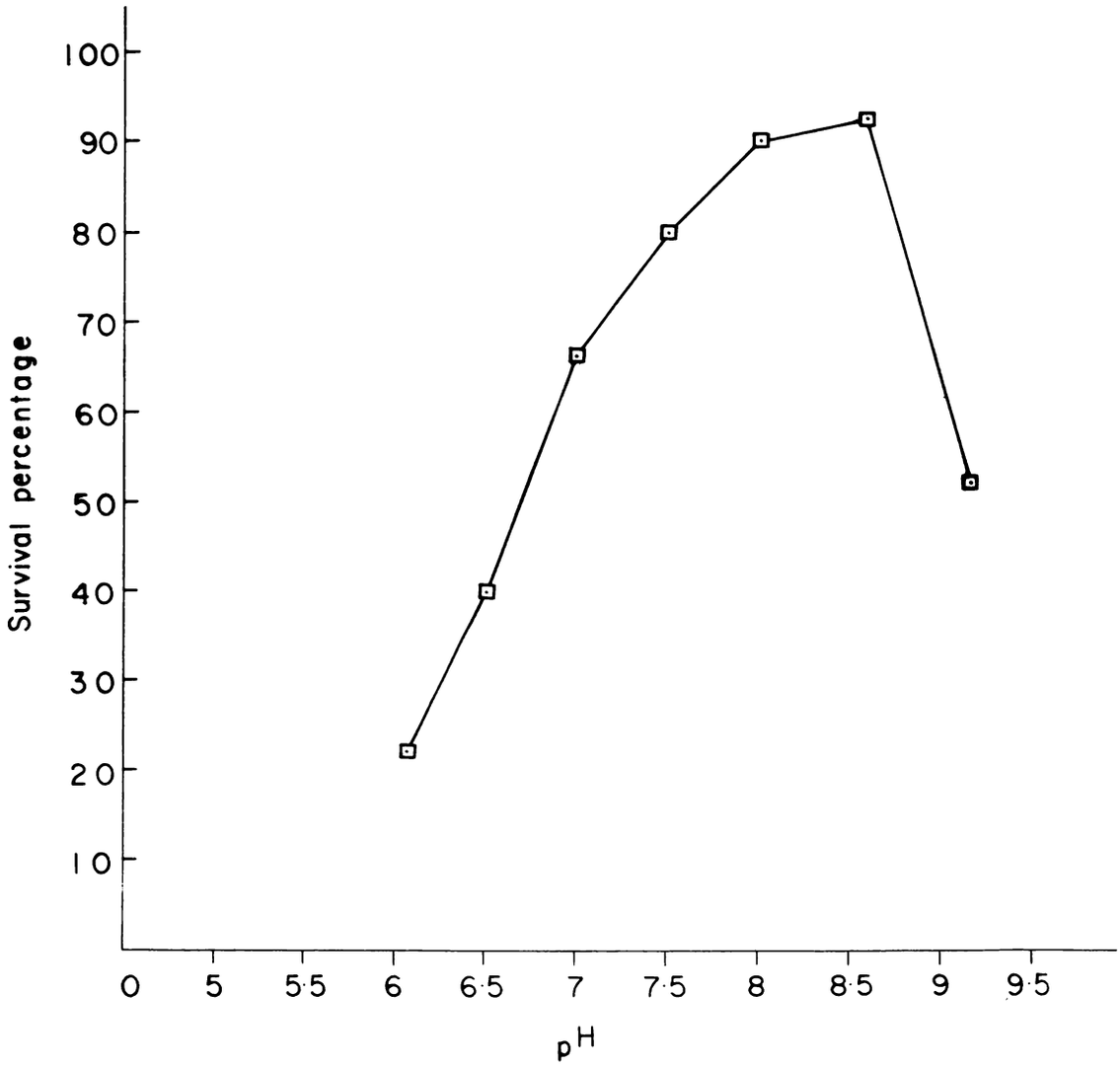

Survival percentage
100
90
80
70
60
50
40
30
20
10
0
5
5·5
6
6·5
7
7·5
8
8·5
9
9·5
pH

Fig. 8 Effect of pH on moulting of 1st stage phyllosoma of *P.homarus*.

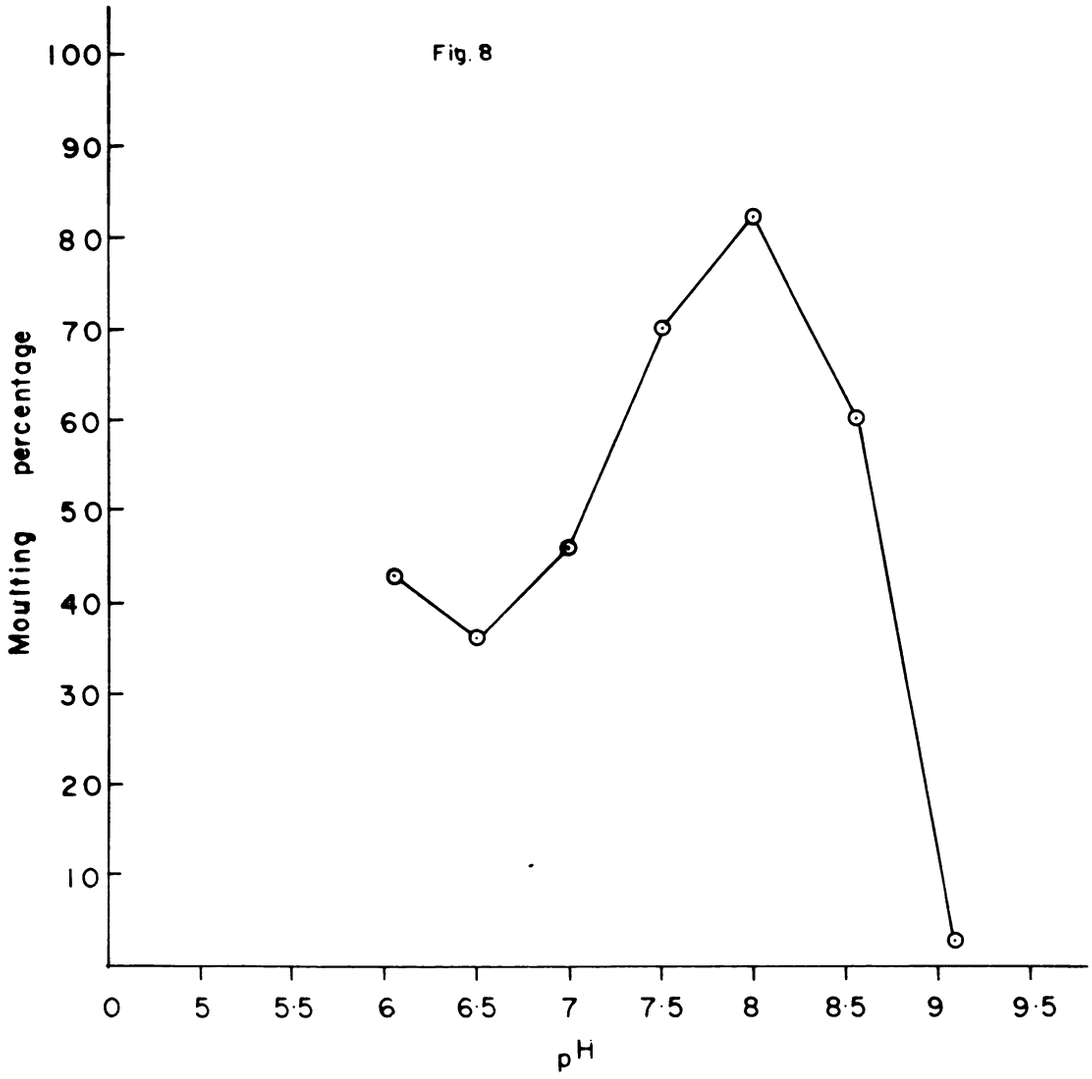


Fig. 8
Moulting percentage
100
90
80
70
60
50
40
30
20
10
0
5
5·5
6
6·5
7
7·5
8
8·5
9
9·5
pH

Temperature.

To find out the suitable temperature for the phyllosoma a series of 25°C, 27°C, 29°C, 31°C and 33°C were maintained in the laboratory and larvae were transferred to each temperature after proper acclimation. The normal water temperature at the time of the experiment was 31°C. All the treatments were same as in the previous experiments. Mortality and moulting of the larvae were recorded. It as observed that 100% survival and 73.33% moulting occurred in 31°C temperature. In 25°C and 27°C no animals were found moulting. In 31°C temperature moulting was started on the 6th day after hatching. In 33°C the larvae gradually died and in 5-6 days, total mortality was noticed. The survival in 25° and 27°C was more than in 29°C and also the attack of ciliates was very much reduced in these two temperatures. 31°C was found the suitable temperature for the best growth and moulting by statistical analysis also (Fig.9).

Dissolved Oxygen.

Sea water with dissolved Oxygen levels 2.5, 3, 3.5 and 4 ml/litre was taken to determinethe effect of these levels on moulting and survival. 4.1 ml/litre was the dissolved Oxygen content of the normal sea water at the time of the experiment. Acclimation to different

Plate 6 : A. Experimental set up for Temperature

B. Experimental set up for Dissolved oxygen.

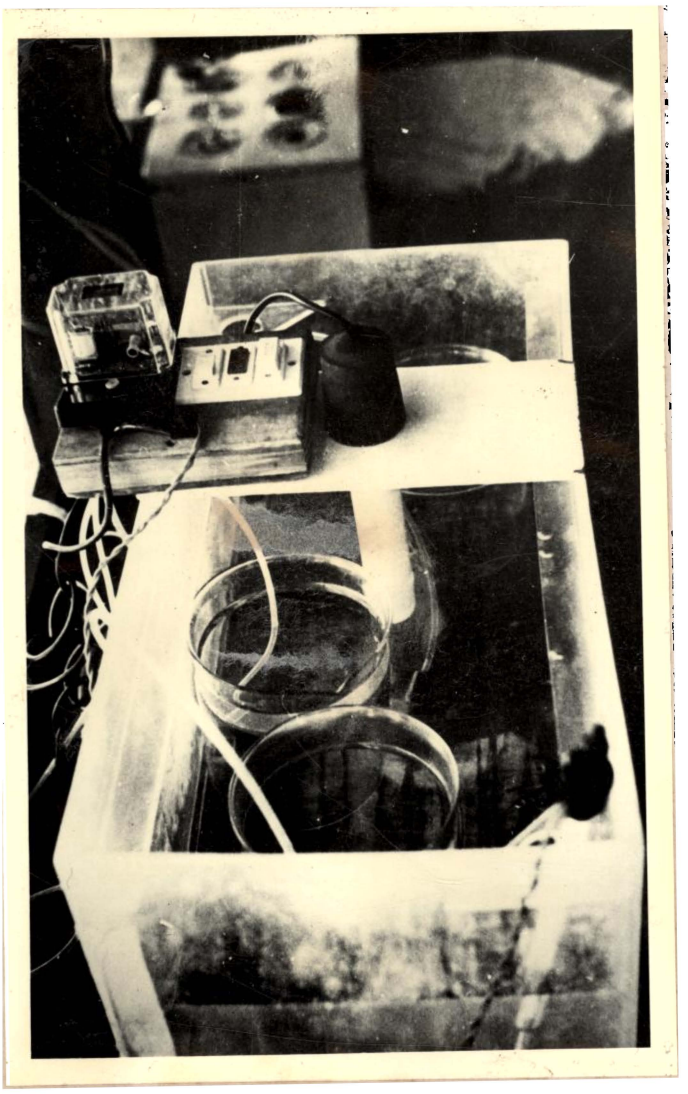


PLATE 6

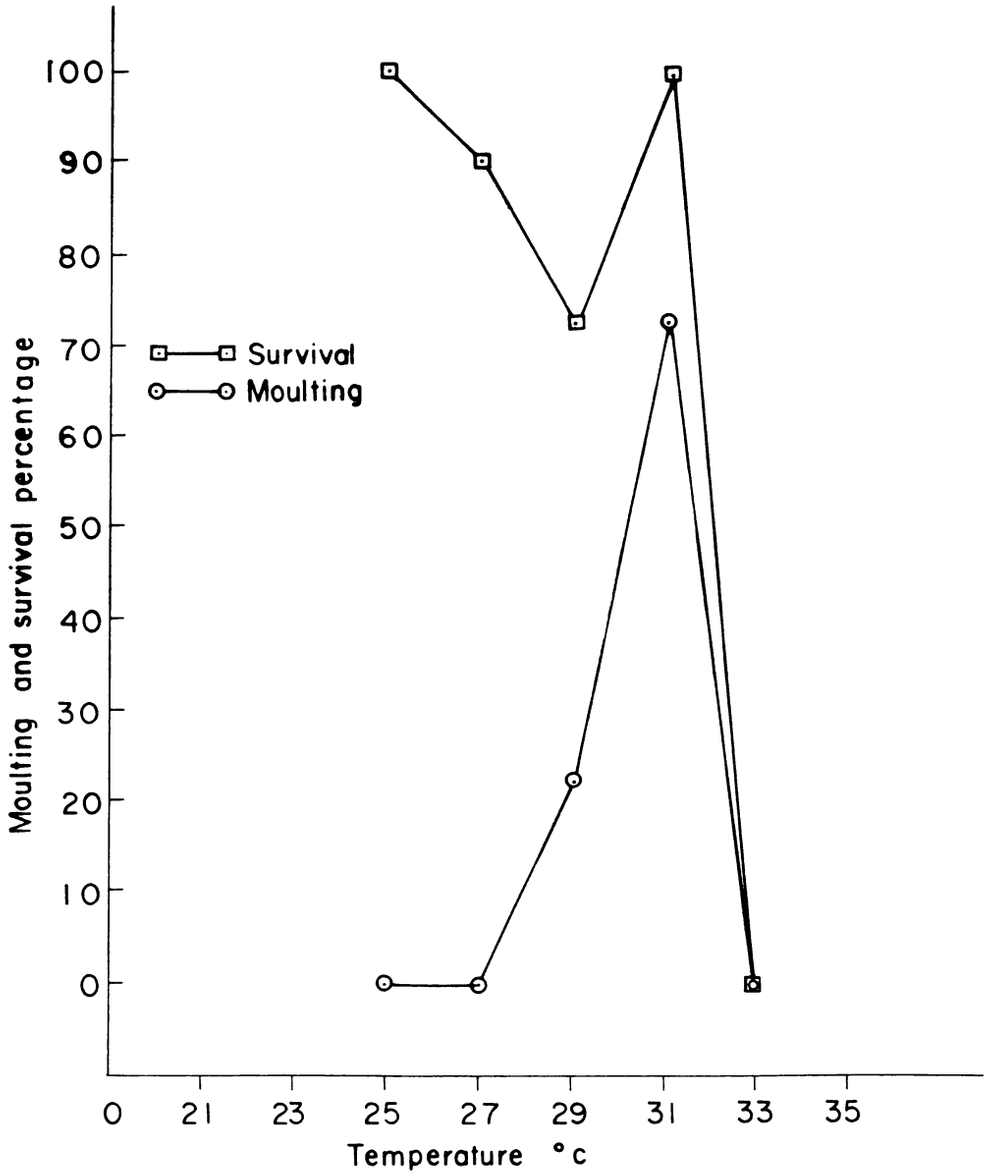
Table - 3

Percentage survival and moulting of 1st stages phyllosoma reared in different temperatures of 2°C intervals. (Total No. of larvae in each temperature was 30)

Temperature °C	Survival %	Moulting %	Mortality %
25	100	0	0
27	90.00	0	10.00
29	73.34	23.33	26.66
31	100	73.33	0
33	0	0	100

Fig. 9 Effect of Temperature on survival and moulting of 1st stage phyllosoma of *P.homarus*.

Fig.9


100
90
80
70
60
50
40
30
20
10
0
Moulting and survival percentage
Survival
Moulting
0
21
23
25
27
29
31
33
35
Temperature °c

levels of dissolved Oxygen was carried out before putting the larvae in each media. In order to prevent the diffusion of Oxygen into the experimental water liquid paraffin was added to each beaker and the water was not aerated. Experimental water changed everyday with seawater having the same level of dissolved Oxygen. All other procedures adopted were similar to the other experiments. 73.34% survival and 70% moulting was noticed in sea water with 4 ml/litre of dissolved Oxygen. Moulting and survival declined considerably in seawater with dissolved Oxygen levels below 3.5 ml/litre. Statistical analysis of the data also showed that 4 ml/litre is the optimum level for maximum survival and moulting (Fig. 10).

Statistical analysis of the data obtained in each experiment was carried out for mean comparison and variance. The results of these are given in tables 5 and 6. Analysis was carried out to study the effect of different levels of salinity, pH etc on the mortality rate. The analysis was conducted on transferred data (arc sine root transformation) (Snedecor, 1967). The result of the analysis are given in table 5. The mean comparison between different levels of salinities pH etc was made by the least significant difference method. Results are given in Table 6. The highly significant levels are clearly indicated by them tables.

Table - 4

Percentage survival and moulting of 1st stage phyllosoma reared in different levels of dissolved Oxygen of .5ml/litre intervals. (Total no. of larvae in each level was 30)

D.O ml/litre	Survival %	Moulting %	Mortality %
2.5	23.40	3.33	76.60
3.0	33.34	10.00	66.66
3.5	53.34	36.60	46.66
4.0	73.34	70.00	26.66

Fig. 10 Effect of Dissolved Oxygen on survival and moulting of 1st stage phyllosoma of *P. homarus*.

Fig. 10

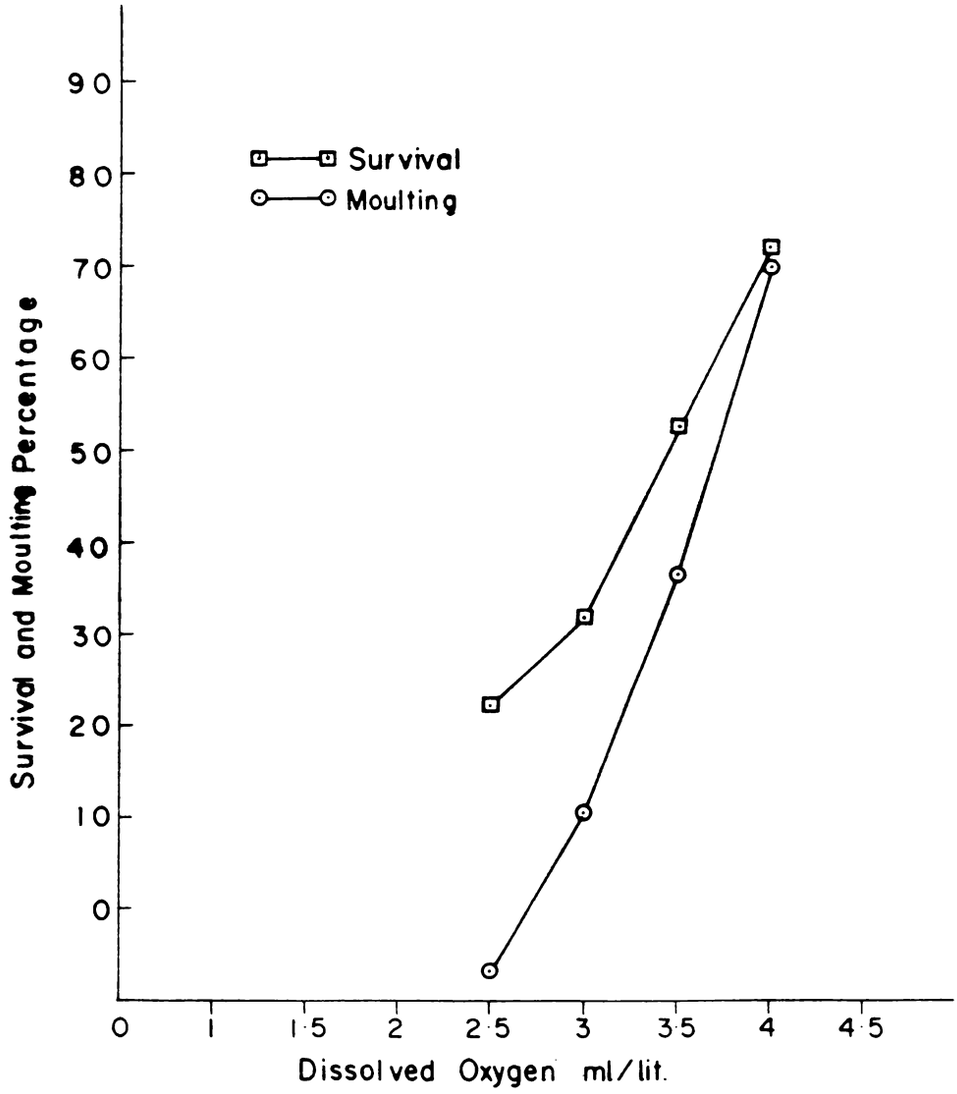

Survival
Moulting
Survival and Moulting Percentage
90
80
70
60
50
40
30
20
10
0
0
1
1·5
2
2·5
3
3·5
4
4·5
Dissolved Oxygen ml/lit.

Table - 5

ANALYSIS OF VARIANCE

Source	df	SS	MS	Source	df	SS	MS
Salinity	6	2453.49837	408.9166**	pH	6	6258.04992	1043.00832**
Error	.14	3463.2711	72.12662	Error	14	1693.50616	120.06473

Source	df	SS	MS	Source	df	SS	MS
Temperature	4	16525.2649f	4131.316LY**	Dissolved Oxygen	3	79.784	26.59466**
Error	10	229.OLY69	22.90LY6	Error	8	5.23521	0.65440

Note **: Highly significant ($\alpha < 0.01$)

Table - 6

Mean comparison

Salinity	$\bar{X}$	pH	$\bar{X}$	Temperature	$\bar{X}$	Dissolved Oxygen	
26	39.15^{ab}	6.1	61.22^{f}				
28	63.93^{c}	6.5	50.85^{fe}	25	0^{a}	2.5	16.07^{a}
30	54.99^{cde}	7	35.01^{de}	27	18.43^{a}	3	14.95^{b}
32	47.01^{bd}	7.5	21.93^{cd}	29	30.29^{b}	3.5	12.46^{c}
34	30.29^{a}	8	15^{bc}	31	0^{a}	4	9.36^{d}
36	42.99^{abd}	8.6	12.29^{b}	33	90^{c}		
38	34.92^{ab}	9.2	43.07^{fe}				

Note: Means with different superscripts differ significantly.

($P < 0.05$)

Discussion.

Experimental studies to find out the optimum levels of the different environmental parameters have not been conducted as far as the phyllosoma larvae are concerned. Chittleborough and Thomas (1969) found that the larvae of *Panulirus cygnus* preferred salinity range of 35.4 - 36.0‰ . and the late stage phyllosoma did not appear in the coast until a wedge of low salinity water extended along the coast disappeared. Philips (1978) reported that there appear to be no relationship between salinity and phyllosoma stage. Density of stage IX phyllosoma of *P.longipes cygnus* has no relationship with water salinity according to Rits (1972). However in the experimental study conducted the statistical analysis of data shows that the optimum salinity for *P.homarus* larvae is in the range of 34.0 - 36.0 ‰. In salinity of 34.0 ppt the best survival and in 36.0 ppt the maximum moulting obtained. In the case of *Homarus americanus* larvae Scarrat and Raine (1967) found that newly hatched larvae avoided water with salinity 21.4‰. They found that the larvae swam in 31.7 ppt seawater but were much more active in 26.7 ppt than in 31.7 ppt. Zein eldin and Aldrich (1965) studied the salinity tolerance of post larvae of prawn *Penaeus aztecus*, *P.setiferus* and *P.duorarum* and found that excellent survival in salinities of 2.0, 7.0,

10.0, 25.0 and 40.0 ppt. Rao (1973) noticed post larvae of P.indicus occurring in salinities ranging between 25.0 and 30.0 ppt in inshore waters of Cochin. Post larvae of P.setecus belonging to size group 13-20 mm exhibited salinity tolerance from 8.5 to 31.0 ppt (Venkataramiah et al. 1974).

Salinity tolerance of Zoea of the crab Scylla serrata was studied by Hill (1974) and found that exposures to salinity below 17.0 o/$_{oo}$ caused considerable mortality (50%). Lowthion (1974) conducted experiments to find out the effect of high salinity on survival of young Limanda limanda found that salinity above 55.0 ‰ have harmful effect. Salinity tolerance of laboratory reared larval California grunion was determined by William and Donald (1974) and found salinity tolerance dicreased with age from 4-67.5 ‰ at hatching and 5-57 ‰, 30 days after hatching. Bhatacharya and Kevalramani (1976) observed the best survival of post larvae of P.indicus in between 21.0-28.0 ppt sea water. Suseelan & Kathirvel (1980) recorded large quantities of post larval penaeids of 8-17 mm size occurring at an average salinity of 15.9-33.7 ppt during October to May in the Cochin backwater, but during the peak of Monsoon (July, August) these were scarce near the shore and in plankton collection and the salinity recorded during this period ranged from 0.38 - 0.83 ppt. Raj & Raj

(1980) reported high survival rate in low salinity levels of 5.15 and 25.0 ppt. Aziz and Greenwood (1981) conducted laboratory studies to find out the salinity tolerance of juvenile Penaeus bennettae and found that acclimated animals could tolerate salinity from 1.0 -62.0 ‰. Dall (1981) made an investigation to find out the osmoregulatary ability of juvenile penaeid prawns. He observed that early juveniles were highly efficient osmoregulators. Francis and Gilbert (1982) found that Zalerion maritimum showed optimum growth in 29.7 - 33.0 ppt. Lakshmikantham (1982) studied the salinity tolerance of post larvae of P.indicus and reported that these can tolerate a wide range of salinity varying from 4.0 ppt - 5.0 ppt if acclimated properly. Marian & Allen (1982) recorded post larvae of Macrobrachium rosenbergi survived in lower salinity from 7.0 - 21.0 ppt to which they were acclimated.

The veliger of Amphibola showed slow growth in salinity below 18.0 ‰ (Colin et al. 1984). Sankarapillai (1984) noticed that larvae of Liza parsia hatched in salinities 18.0 - 36.0 ppt were normal and those hatched in 6.0 - 9.0 ‰ were abnormal and had problems in movement, the optimum being 26.63‰. Nigel (1985) determined the survival, growth and development of the larval stages of M.bennettae and concluded that maximum survival and

growth of larvae depends on conditions during rearing prior to experimental salinity treatment.

A comparison of optimum salinity of the 1st phyllosoma with the larvae and post larvae of prawn, crabs or fish may not be correct. But in general, salinities between 25.0 - 35.0 ppt are preferred by most of the animals. In nature normally the salinity is not always changing and it may not be going lower than 25.0 and above 38.0 ppt. The plankton as well as the other forms are better suited to such levels in their natural habitat. But animals if acclimated to different levels of salinity can tolerate a wider range. In the Tuticorin bay from where the sea water for the experiments was collected, the salinity ranged from 30.0 - 38.0 ppt in the course of one year and almost levels close to this was obtained as optimum levels in the laboratory experiments conducted here.

The phyllosoma larvae were found to tolerate a pH ranging from 6.1 - 9.2. In the present experiment the optimum pH for survival and growth was found in between 7.5 - 8.6. In 8.6 the maximum animals survived and in 8 the maximum moulting obtained. Earlier literature on the influence of this parameter on phyllosoma larvae is not available.

Krishna (1953) reported trout eggs showed mortality above 9 pH and below 4 & 5 pH no mortality occurred. pH value 5.8 - 6.2 were found lethal to young Atlantic salman

Salmo salar and Salmo trutta (Beshai 1960). Velodin (1960) showed that a pH value of 8 killed 50% of the eggs of barbot and the various developmental stage showed difference in sensibilities to alkaline water. Campbell (1967) observed no correlation between pH value and growth rate of brown trout in a range of 4.9 - 8.4 pH. In solutions of pH 5 & 6 the growth rate of the brown trout was stunted (Carter 1964). Lloyd & Jordan (1964) found that the median lethal values for rainbow trout were 9.86, 9.91 and 10.13 for batches acclimated to pH values 6.55, 7.5, and 8.4 respectively. Sprague (1964) reported that only 5% of a batch of 40 yearlings of Atlantic Salmon died within 6 weeks when kept in pH of 9.5. Reduced egg development was reported on Mercenaria mercenaria in pH less than 6.7 and 7.0 (Calapresse & Mavis, 1966). Daye & Garside (1975) estimated the lethal levels of pH for fingerlings of brook trout and found pH 3.5 & 9.8 were the lethal limits.

Kwain (1975) found that no rainbow trout eggs survived at pH below 4.5 and brook trout fry incubated at pH 8.07 when subjected to pH 5.73 and 4.97, the survival was below 75.3% and 66.1%. Milbrink & Johnson (1975) reported reduced viabilities in the eggs of perch in pH below 5.5 and 4.7. At lower pH of 5.2 reduction in the number of normal post larvae of freshwater fish Coregonus commersoni due to increased deformities was observed by Trojnar (1977).

Subbaraju et al.(1982) found that the sporelings of Padina tetrastromatica showed a tolerance of pH 8-8.5 and beyond this range mortality was high. Sankarapillai (1984) observed that more hatching of Liza Parsia occured in 7.8 & 8.15 pH and the optimum was 7.5. Larvae hatched in pH of 6.0 were abnormal and in pH 10.0 no eggs hatched. The post larvae of P.indicus showed better survival and growth in pH 8 (Sarada 1984).

From the general comparison of the pH tolerance of various animals with phyllosoma larvae, in most cases it was found that the optimum pH level is somewhere between 7 & 9. Below and above this level mortality was higher and most of the animals showed abnormal behaviour. In the case of the phyllosoma larvae also in pH above 9, although morethan 50% survived, the moulting was only 3%. The survival of phyllosoma in higher and lower pH is due to the gradual acclimation to these levels. In pH below 7.5 survival and moulting were reduced.

The optimum temperature for the phyllosoma larvae have been experimented by a few authors. Inoue and Nonaka (1963) adjusted the water temperature for rearing Panulirus japonicus larvae, in between 22-28°C. Saisho (1966) found that water temperature of 22-29°C range was suitable for phyllosoma of P.japonicus. Lazarus (1967) observed that the growth of stages of phyllosoma of J.lalandii were directly

related to temperature and salinity. Robertson (1968) obtained post larvae of S.americanus in 32-40 days at 25°C and suggested that complete development is possible at 30°C in less than a month. Dexter (1972) observed the development of P.interruptus larvae progressed more rapidly in 25°C temperature. Rits (1972) found no relationship between phyllosoma larval densities and surface water temperature. Belman & childress (1973) measured the Oxygen consumption of phyllosoma of P.interruptus under different temperatures in the laboratory. They found that between 12.5°C and 24.6°C range markedly affected the respiration rate of the larvae and suggested an optimal level around 24.6°C. No apparent relationship between catches of puerulus and temperature was noticed by Philips (1978). In the present experiment a range between 25-31°C was found suitable for survival of the larvae but moulting was found decreased below 29°C.

Zein Eldin & Aldrich (1965) studied the effect of temperature and salinity on post larvae of Penaeus setegus. They found that the growth rate increased with temperature between 15°C - 32°C.and decreased markedly at 35°C. Costlow & Brookhout (1970) found that the highest percent of survival of mud crab larvae was in between 30° - 25°C. Zoea of Scylla serrata when exposed to temperature above 25°C caused considerable mortality and were inactive

below 10°C (Hill 1974). William & Donald (1974) observed that larvae of the California grunion acclimated at 22°C and 30°C could acclimate gradually at 8°C and 35°C respectively.

Development of Homarus americanus required 25 days at 15°C and at 19-20°C the time was reduced to 15 days (Scarrat, 1968). Gruffydd et al.(1975) compared the growth and temperature tolerance in the larvae of H. americanus and H. gammarus. They found that larval mortality at each stage increased with temperature. Below 28°C no mortality was observed but above 36°C complete mortality was recorded in the case of H.gammarus larvae and when the exposure time extended 6 hrs all the larvae died above 30°C. No obvious difference was found in temperature tolerances of both the species. In the experiment conducted here a similar result was obtained. Here also there was no high mortality below 29°C and complete mortality occurred at 33°C. The exposure time of the experiment was 8 days and mortality in 33°C occurred only gradually; but in the case of H.gammarus and H.americanus mortality above 30°C took place when the exposure time exceeded 6 hrs. Sastry and Zetlin-Hale (1977) reported H.americanus larvae can complete the development in 18 days in 30.0 $^{o}/_{oo}$ salinity at 20°C.

Tay and Geraide (1975) incubated mummichog eggs in temperatures 15, 20, 25 & 30°C. Highest percentage of hatch and normal larvae obtained in 20°C. Catidral et al. (1977) worked on the effect of temperature on the survival and growth of P.monodon larvae, reported that 73% survival obtained at 29-32°C and increased to 78% at 32°C. Patricia et al. (1981) measured the growth of shell in young Mytilus edulis and found that above 20°C the growth rate declined sharply. Karl and Geraldon (1982) compared the relationship between temperature-specific rate of yolk utilisation and temperature preference of larvae of California grunion. They found that the yolk sac larvae experienced difficulty in metabolising protein at and above 25°C, and below 15°C had problem with fat metabolism. The preferred temperature of the larvae was in between 18-23°C.

Cockcroft and Emmerson (1984) determined the effect of temperature on larval development of the prawn Macrobrachium africanus. It took 13-15 days at 25°C and 25 days at 15°C for the nauplius 1 to become the post larvae. Mortality was low for the naupliar stages at 25, 22 and 18°C and at 15°C only 52% of the larvae reached nauplius 6. Mortality was high from nauplius 6 to protozoea 1, 17, 21 & 18% at 25, 22 & 18°C respectively. In the case of the phyllosoma larvae, moulting to the 2nd stage started first in 31°C after 5 days and in 29°C after 7 days. In 25°C

and 27°C no moulting was found in this period, but survival was very high in these two temperatures. Jan (1984) reared larvae of the gastropod Crepidula fornicata at 18 & 24°C to determine the relation between the rate of development and ability to delay metamorophosis and found that larvae gradually grew more quickly at high temperature. Sarada (1984) found that the optimum temperature for maximum growth and survival of post larvae of P.indicus was 30°C - 32.5°C. Temperatures above this level were found lethal to the larvae. Nigel (1985) studied the effect of temperature on hatching success and survival growth and development of larvae and found that at 26°C eggs were more tolerant and found that maximum hatching success depend on conditions during spawning and maximum survival and growth of larvae depend on conditions during rearing prior to experimental treatment.

The effect of different levels of dissolved Oxygen on various larval forms was worked out by many authors. Studies on phyllosoma larvae with respect of this aspect is almost absent. In the present experiment it was observed that in lower levels of dissolved Oxygen the survival and moulting of phyllosoma was lowered. A comperison with similar works on other larval forms also indicate more or less the same result.

Kutty (1967) found that the metabolic rate of adult prawn P.indicus declined with decrease in ambient Oxygen concentration. Brown (1971) observed that brown shrimp P.aztecus maintained in ponds with dissolved Oxygen concentration as low as 2 ppm showed defenite signs of stress, while shrimps maintained at concentration 4 and above showed no sign of stress. Kuttyamma (1980) reported that the rate of Oxygen uptake was found decreased gradually due to the declining Oxygen tension in different salinity media in Metapenaeus dobsoni. The marine shrimp Palaemon adspersus showed an Oxygen consumption rate that is independent of water Oxygen tension and this respiratory independency was found associated with maintanence of a relatively constant arterial haemoglobin tension (Hagerman & Roy, 1981). Michiyori (1981) found that at Oxygen concentration below 10% saturation the haemoglobin is considered to function for intake of the major portion of Oxygen from the water in the case of Daphnia magna. Pramila (1982) determined the Oxygen requirement of prawn larvae in the hatchery system. She found that Oxygen consumption increased with ~~fmm~~ increasing size and stage of developing larvae. In the case of nauplius the total Oxygen consumption in 12 hrs was 0.6390 ml/larva hr. in full Oxygen saturation. The uptake was

relatively high in the Ist hr and then fall to a fairly constant trend in her studies. Different species of brachiopod when exposed to declining Oxygen tension showed various degrees of Oxygen independence (Sandra 1982). Sandra & Marsden (1982) measured Oxygen consumption of the marine Amphibola crenata and observed that Oxygen consumption increased with temperature up to 25°C. Agnew & Tailor (1985) found that two species of amphipods when subjected to conditions of declining Oxygen tension in the laboratory exhibited high degree of respiratory independence and compensated for low Oxygen tension. Donna & Barbara (1985) observed 100% mortality of zoea of crab after 22 days in place where the Ulva lactuna was cultured for 24 hrs which produced low oxygen tension.

These works indicate in general that low Oxygen saturation has an adverse effect on animals and the decreased survival and moulting of the phyllosoma in Oxygen level below 3.5 ml/litre shows the same fact.

CHAPTER 6

Taxonomy of phyllosoma larvae from Plankton Collections

Most of the studies available on the phyllosoma larvae are based on samples collected from plankton and this makes it difficult for identification of the species to which the larval stages belong. However quite a lot of work on the taxonomy of phyllosoma larvae collected from plankton has been carried out in different regions of the world, mostly based on assignment to species by circumstancial evidence and in certain cases partial rearing of the larvae. From Indian waters also such works are available and these have been reviewed in an earlier chapter. A collection of phyllosoma larvae sorted out from plankton samples collected during the cruises of FORV Sagar Sampada in 1985 available for study and a taxonomic analysis of the larvae in the collection is given here.

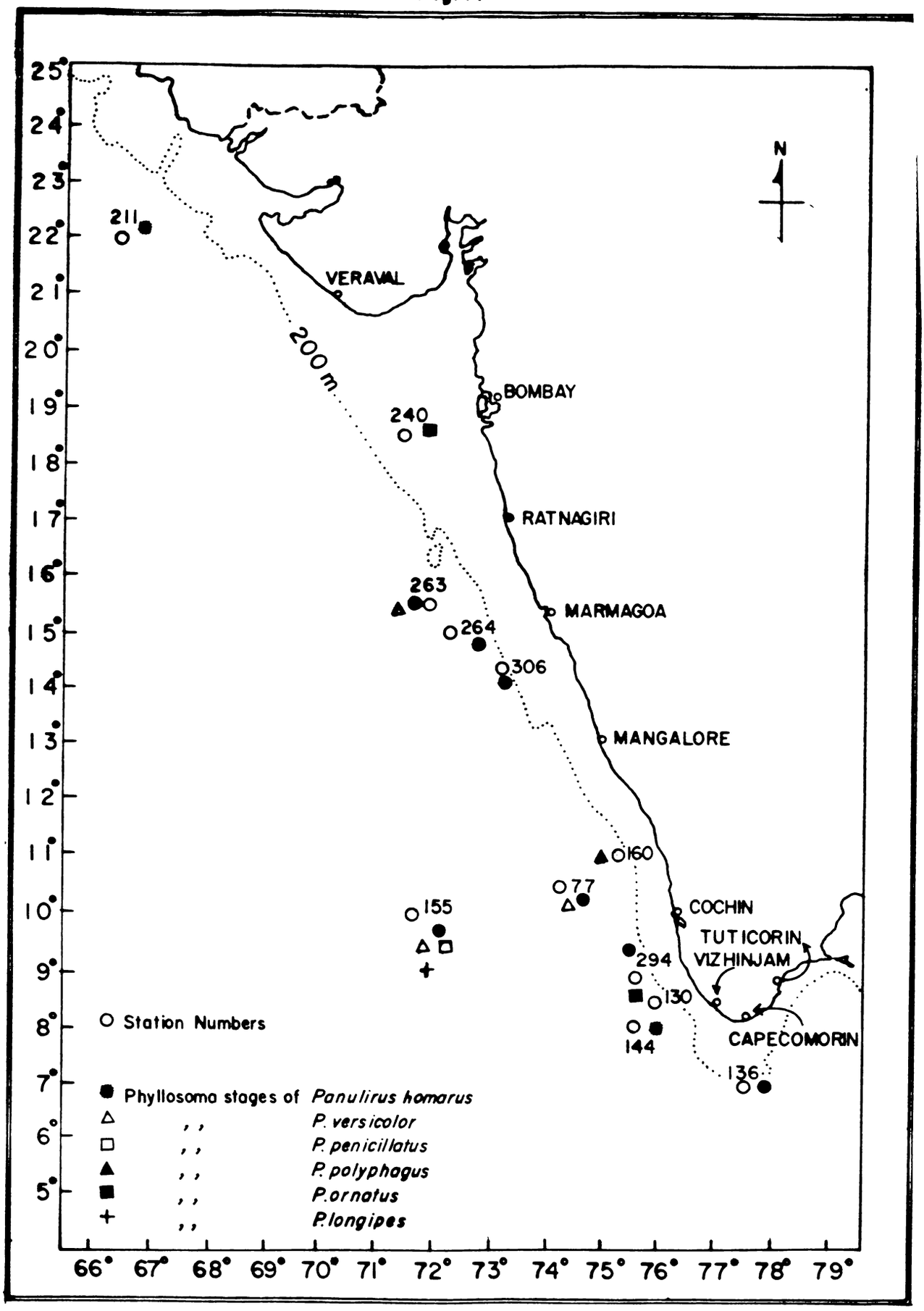
The collection contained a total of 54 larvae obtained from 12 stations of different latitude and longitude (Fig. 11). Details concerning the position of stations, species stages of larvae etc are given in tables 7, 8 & 9. Phyllosoma stage 3—9 of P. homarus,

Table - 7

Sl.No.	Cruise No.	Station No.	Date	Time	Position		Depth of station	Gear
					Lat. °N	Longitude °E		
1.	SS/038/85	77	26.4.85	12.50	10°29.30'	74°14.8'	112.5 m	Bongo 60
2.	SS/05/85	130	21.7.85	13.55	08°30.1'	76°01.5'	950 m	"
3.	SS/06/85	136	01.8.85	9.20	07°00'	77°30'	997	"
4.	SS/06/85	184	05.8.85	07.30	09°00'	75°38.4'	1716	"
5.	SS/06/85	155	10.8.85	22.30	10°02.7'	71°39.1'	2063 m	"
6.	SS/06/85	160	12.8.85	14.00	11°00.2'	75°19.6'	65	"
7.	SS/08/85	211	19.9.85	15.15 16.35	22°00'	66°30'	2709	"
8.	SS/09/85	240	11.10.85	05.06	18°30'	71°30'	150 m	"
9.	SS/9A/85	263	27.10.85	21.40 23.00	15°30'	72°05'	679	"
10.	SS/9A/85	264	28.10.85	02.38 04.00	15°00'	72°21'	1902	"
11.	SS/10/85	294	04.12.85	04.00	08°57'	75°36'	367	"
12.	SS/10/85	306	10.12.85	22.30	14°20'	73°14'	190	"

Fig. 11 Map showing the position of collection of phyllosoma larvae belonging to different species.

Fig.11


N
VERAVAL
BOMBAY
RATNAGIRI
MARMAGOA
MANGALORE
COCHIN
TUTICORIN
VIZHINJAM
CAPECOMORIN
200 m
211
240
263
264
306
160
77
155
294
130
144
136
O Station Numbers
Phyllosoma stages of Panulirus homarus
,, P. versicolor
,, P. penicillatus
,, P. polyphagus
,, P. ornatus
,, P. longipes
25° 24° 23° 22° 21° 20° 19° 18° 17° 16° 15° 14° 13° 12° 11° 10° 9° 8° 7° 6° 5°
66° 67° 68° 69° 70° 71° 72° 73° 74° 75° 76° 77° 78° 79°

Stages 7, 8, 9 and 10 of P.verricolor, stages 9, 10 & 11 of P.penicillatus, stages 6, 7 and 9 of P.polychaetus stages 4 & 10 of P.ornatus and stage 9 of P.longipes were identified and described.

Description of larvae

Pamilicus homarus

Stage 3 (Plate 7,A, Fig.12a)

Collected from station No.155 (Ref: map); Total length 4 mm.

Antenna: Antenna 1 and 2 not segmented

Cephalic shield: Length of the cephalic shield more than the length of the hind body; length of Ceph.shield 2.5 mm and hind body 2 mm.

Maxilla 2: 2nd maxilla 2 segmented distal segment with 4 setae.

Maxilliped 1: absent

Maxilliped 2: without exopod

Maxilliped 3: Exopod setose and ventral coxal spine present.

Pereopods: Legs 1--3 with ventral coxal spines and sub-exopodal spines. Dorsal coxal spine seen on legs 2nd and 3. Exopod of 3rd leg setose; 4th leg present as bud.

Stage 4 (Plate 7 B, Fig.12 b)

16 specimens: 12 from stations 264, 2 from 263, 1 from 211 and 1 from 294.

Table - 8

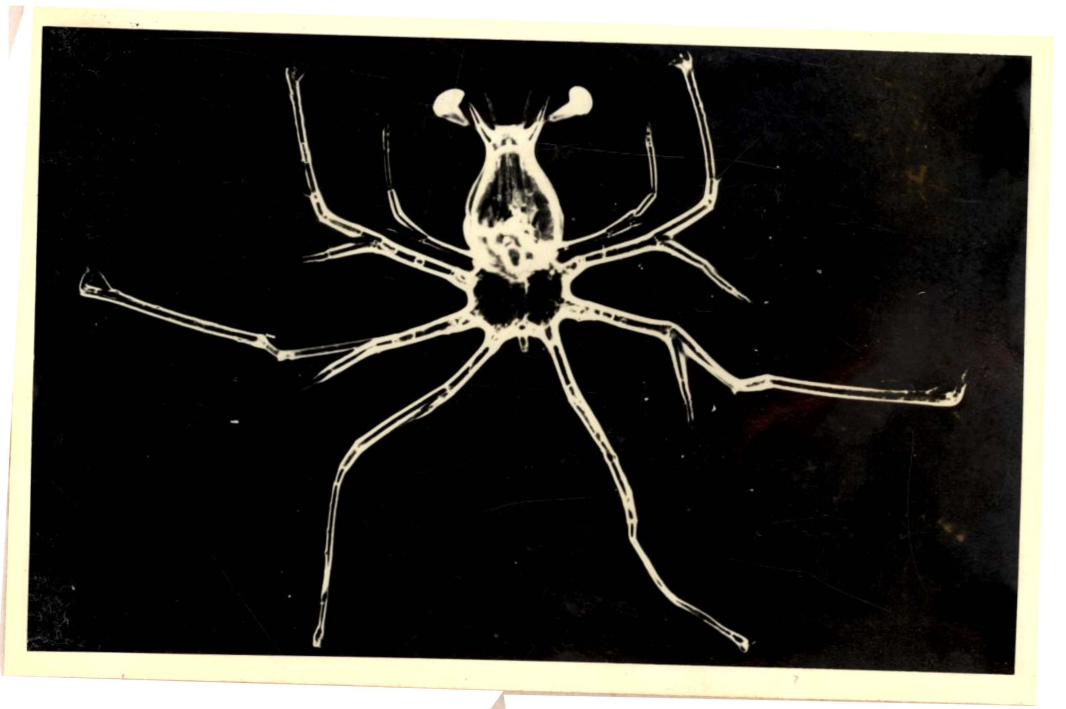
Puerulus larvae

Stage	Station	Position Latitude °N	Position Longitude °E	No. collected
3	155	10°02.7'	71°39.1'	1
4	211	22°00'	66°30'	1
	263	15°30'	72°05'	2
	264	15°00'	72°21'	12
	294	08°55'	75°36'	1
5	263	15°30'	72°05'	3
6	155	10°02.7'	71°39.1'	1
	211	22°00'	66°30'	1
	263	15°30'	72°05'	1
	306	14°20'	73°14'	2
7	144	08°00'	75°14'	1
	263	15°30'	72°05'	2
	294	08°57'	75°36'	4
8	136	07°00'	77°30'	3
9	77	10°29.3'	74°14.8'	2

Plate 7 A. 3rd stage *P.homarus* phyllosoma

B. 4th stage *P.homarus* phyllosoma

PLATE 7



A

B

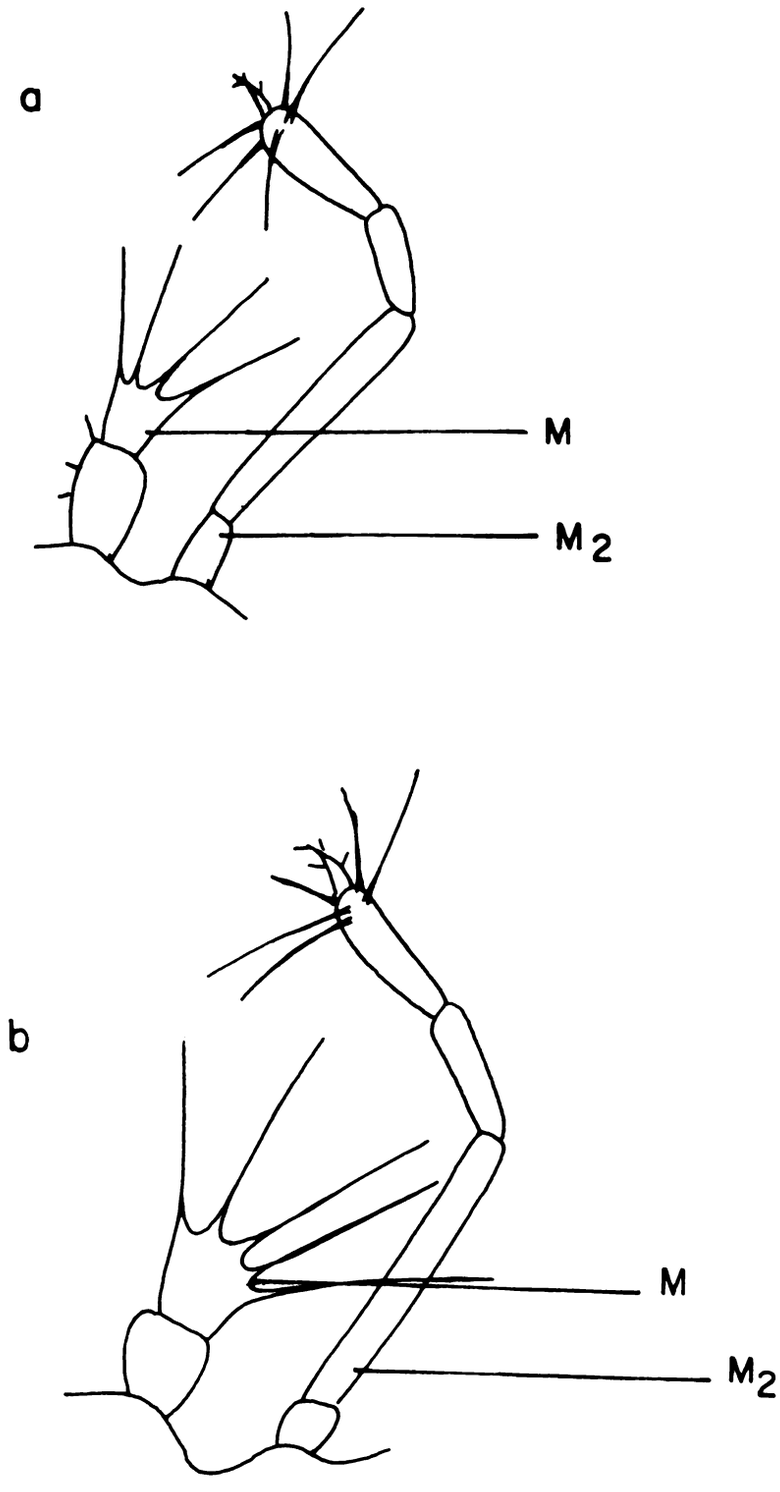
Fig. 12 a. 2nd maxilla and 2nd maxilliped of 3rd stage P.homarus phyllosoma.

b. 2nd maxilla and 2nd maxilliped of 4th stage P.homarus phyllosoma.

M - Maxilla 2

M2- Maxilliped 2

Fig. 12



Total length of these larvae ranged from 4 to 7 mm. 11 specimens collected from stations 264 showed similar characters and the rest were a little different from these larvae.

Antenna: Antenna 1 of the 11 specimens were 3 segmented and antenna 2 not segmented. Antenna 2 of the 2 specimens collected from station 211 and 294 were not segmented but A_2 of the specimens from station 263 and 264 were 2 segmented. Antenna 1 of the other specimens were 4 segmented and with a small projection of endopod. The length of A_2 was a little more than that of A_1.

Maxilla 2: Maxilla 2 of the 8 specimens were 2 segmented and the distal segment bore 4 setae maxilla 2 of the other specimens bore more than 4 setae and the distal segment was more broad.

Maxilliped 1: absent in all specimens.

Maxilliped 2: 5 segmented and without exopod.

Maxilliped 3: Ventral coxal spine and setose exopod.

Pereopods: Pereopods 1—3 with setose exopod and ventral coxal spine. Legs 2 & 5 with dorsal coxal spine also. 4th leg of the 11 specimens bifid and the length almost reached the tips of the abdomen. Length of 4th leg of

the other specimens reached beyond the abdomen but exopod was not setose. Leg 5 seen as bud in all specimens.

Stage 5 (Plate 8 A, Fig.13 a)

Three specimens collected from station 263. Total length 9mm.

Antenna: 1st Antenna 4 segmented and endopod bud present. 2nd antenna 2 segmented and was longer than 1st antenna.

Maxilla 2: more broad and many setae present

Maxilliped 1: seen as small bud

Maxilliped 2: Exopod of maxilliped 2 present as buds.

Maxilliped 3: Ventral coxal spine present.

Pereopods: Legs 1--3 with subexopodal spines 2 & 3 with dorsal coxal spine also and ventral coxal spine on leg.1. 4th pereopod with setose exopod. 5th leg only rudimentary bud.

Uropod: Uropod bud seen in this stage.

Pleopod: Low bud of pleopod also seen.

Stage 6 (Plate 8 B, Fig. 13 b)

Total 5 larvae of 6th stage obtained from stations 155, 211, 263 and 306 Length range of the specimens 9--14mm.

Antenna: 1st antenna 4 segmented. Endopod distinct; 2nd antenna 2--4 segmented.

Plate 8 A. 5th stage *P.homarus* phyllosoma
B. 6th stage *P.homarus* phyllosoma

PLATE 8

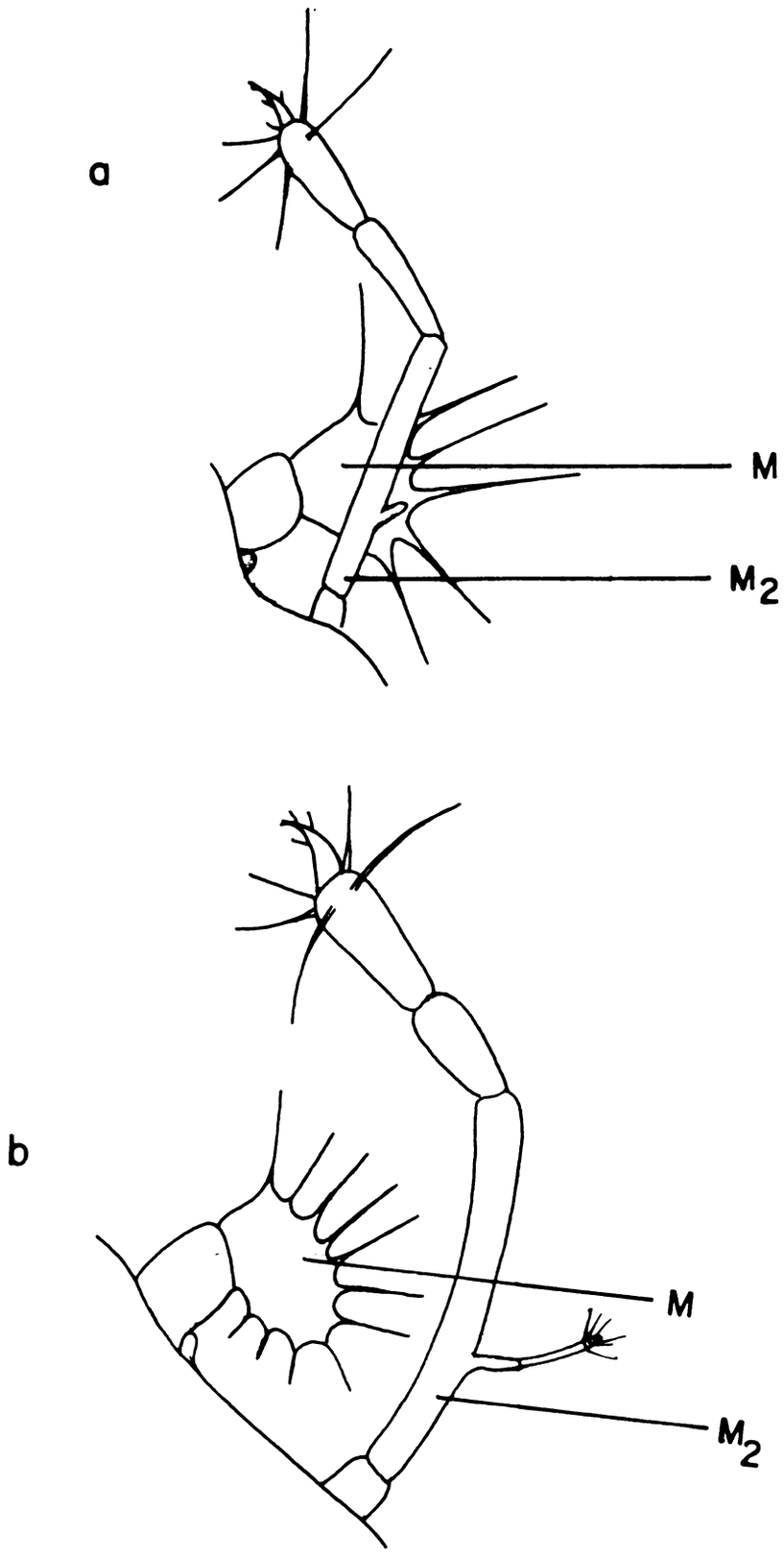
A

B

Fig. 13 a. 2nd maxilla and 1st & 2nd maxilliped of 5th stage P.homarus phyllosoma .

b. 2nd maxilla and 1st & 2nd maxilliped of 6th stage P.homarus phyllosoma.

Fig. 13



Maxilla 2: more leaf like.

Maxilliped 1: present as small buds

Maxilliped 2: with setose exopod

Maxilliped 3: Ventral coxal spine present.

Pereopods: Leg 1-3 with sub exopodal spines. Ventral Coxal spine present only on 1st leg. 2--4 with dorsal coxal spine. Sternal spine seen at 2nd and 3rd leg. Segmentation of 5th leg seen in specimens collected from stations 263 and 155.

Pleopod: bud

Uropod : slightly segmented.

Stage 7 (Plate 9A, Fig.14 a)

Total 7 phyllosoma collected from stations 294, 263 and 144 Length of the specimens ranged from 14--17 mm.

Antenna: 1st Antenna 4 segmented endopod long and minute setae present. 2nd antenna 3--5 segmented and longer than the 1st.

Cephalic shield: Length of the cephalic shield 11-13 mm. and width 8-10 mm.

Maxilliped 1: bud only

Maxilliped 2: setose exopod.

Maxilliped 3: Ventral coxal spine present

Hind body: Length 5--6.5 mm and width 6.5 -- 8 mm.

Peraeopods: Legs 1—3 with sub exopodal spines. 1st leg with ventral coxal spine. Legs 2—4 with dorsal coxal spine. Sternal spine seen on legs 1—4. 5th Peraeopod 2 segmented.

Pleopod: slightly bifid

Uropod: clearly demarcated.

Stage 8 (Plate 9B, Fig.14 b)

Three specimens collected from stations 136.

Total length of specimens 18-20 mm.

Antenna: 1st antenna 4 segmented, 2nd antenna 5 segmented and longer than Antenna 1.

Cephalic shield: Length of cephalic shield 13 — 14 mm and width 10-11 mm. The posterior region round in shape.

Maxilla 2: broad.

Maxilliped 1: slightly demarcated

Maxilliped 2: Exopod with numerous setae.

Maxilliped 3: Sternal spine and ventral coxal spine present.

Hind body: Length 8—9.5 mm and width 8-9.5mm.

Peraeopods: Legs 1—3 with subexopodal and sternal spines. Ventral coxal spine seen on 1st leg only. Peraeopod 2—4 with sternal spine and dorsal coxal spine. 5th leg 5 segmented and sternal spine present.

Pleopods: Bifid

Plate 9 A. 7th stage P.homarus phyllosoma
B. 8th stage P.homarus phyllosoma

PLATE 9

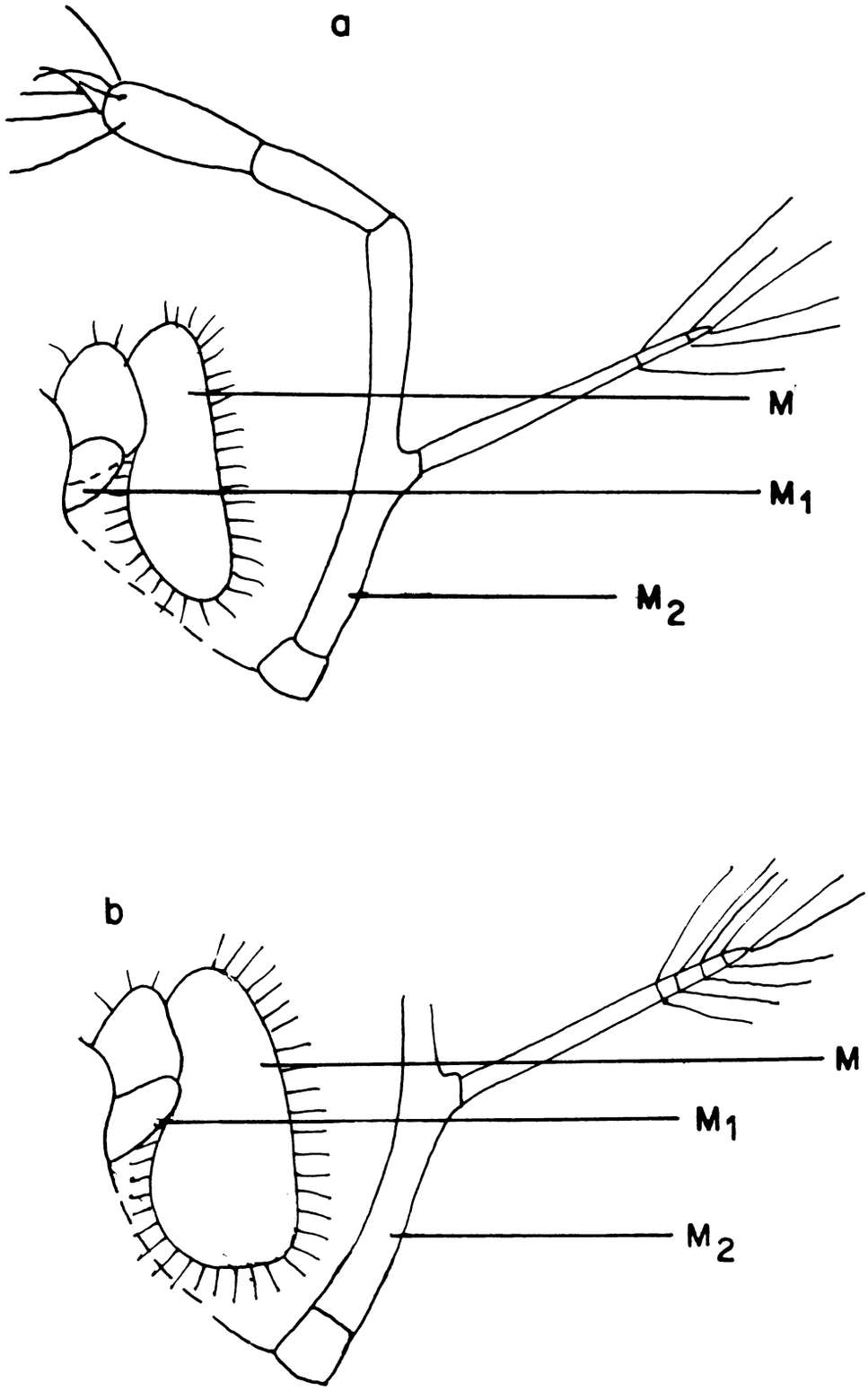
B

Fig. 14 a. 2nd maxilla and 1st & 2nd maxilliped of 7th stage P.homarus phyllosoma.

b. 2nd maxilla and 1st & 2nd maxilliped of 8th stage P.homarus phyllosoma.

M1 - Maxilliped 1

Fig. 14



Uropod : Bifid and long

Stage 9 (Plate 10, Fig.15)

Two specimens collected from station 77 total length 20--22 mm

Antenna: 1st antenna 4 segmented and endopod long. 2nd antenna 6 segmented.

Cephalic shield: Length 13mm and width 10mm.

Maxilliped 1: Trilobed

Maxilliped 2: Setose exopod

Maxilliped 3: Sternal spine and ventral coxal spin- present.

Hind body: Length 10mm and width 9mm.

Pereopods: Legs 1--3 with sub exopodal spines. Ventral coxal spine only on 1st leg. Legs 2--5 with dorsal coxal spine and sternal spine. 5th leg 5 segmented.

Gills: Bud present on legs 1--4

Pleopod: 2 lobed.

Uropod: Long.

Discussion

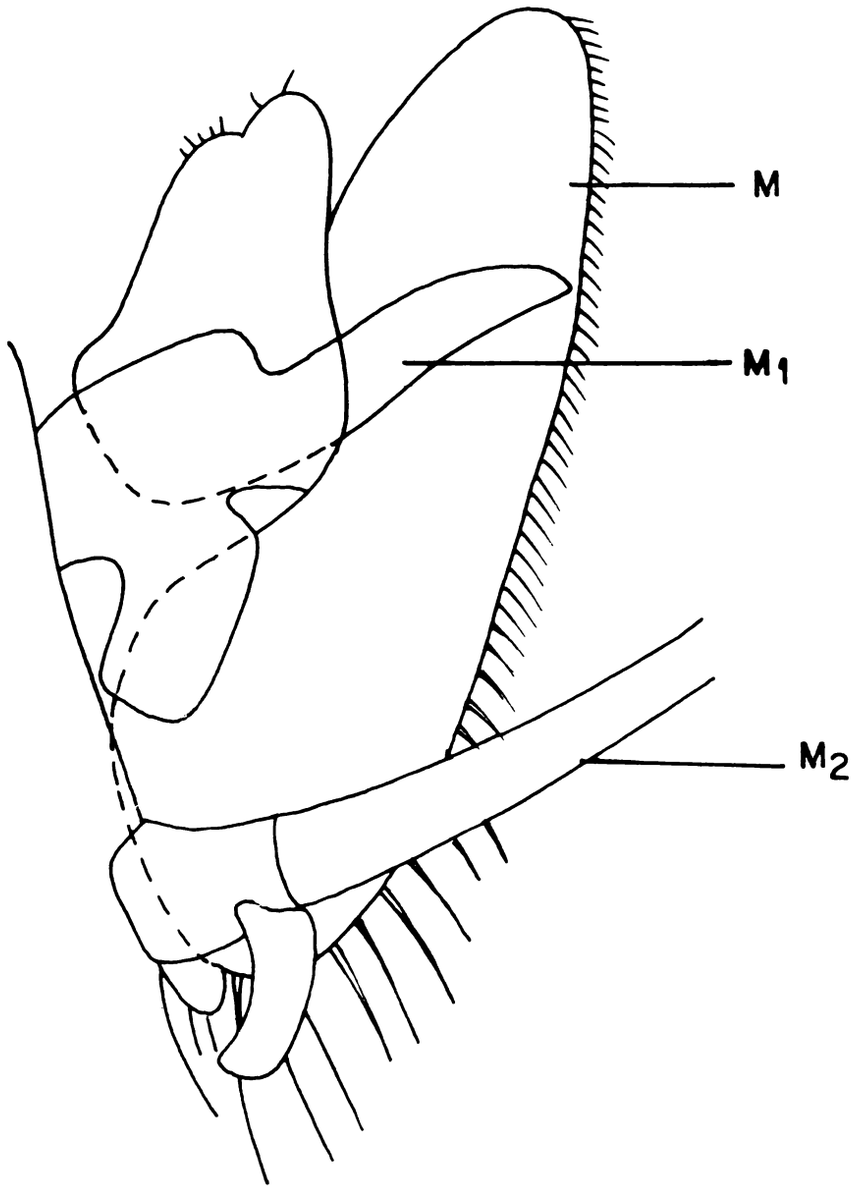
Different stages of phyllosoma larvae of various species collected from plankton samples have been described by many authors. The 3rd stage P.homarus phyllosoma has been described by Berry (1974) Tampi & George (1975) and Prasad, Tampi & George (1980) The setose exopod of 3rd

Plate 10: 9th stage *P.homarus* phyllosoma.

PLATE 10

Fig.15 2nd maxilla and 1st and 2nd maxilliped of 9th stage P.homarus phyllosoma.

Fig. 15



leg and the uniramous 4th leg were taken for fixing the stage (Berry 1974) In the present forms the 4th leg was only bud. Tampi and George (1975) described 3rd *P.homarus* larvae having 4th pereopod as long as or slightly longer than the abdomen. Maxilliped 1 was absent in this form. Prasad *et al.* (1980) obtained 3rd *P. homarus* larvae having 4th pereopod as long as or slightly longer than the abdomen. Maxilliped 1 was absent in this form. Prasad *et al.* (1980) obtained 3rd stage *P. homarus* with bud of maxilliped 1. Presence of 5th pereopod was reported by Berry (1974) and Prasad *et al.*(1980) In this form 5th pereopod was seen. Pereopod 5 was seen in Tampi and George's (1975) 3rd phyllosoma of *P. homarus*. The specimen obtained by rearing didn't possess the redimentary 5th leg. The 4th leg was bud as seen in the collected specimen and maxilliped 1 was absent in both the specimens. The distinguishing character of the 4th stage *P.homarus* is the bifid nature of the exopod of 4th leg. In the specimen obtained here the 4th leg was bifid and in some forms the length of 4th leg reached the tip of the abdomen and in some others the length was beyond the length of the abdomen. The 4th leg, of the 4th stage

obtained by rearing almost reached the tip of the abdomen. The 1st antenna of the present form was 3--4 segmented. Antenna 2 was single or 2 segmented. In the reared 4th stage the 1st and 2nd antenna was not segmented. 1st and 2nd antenna of Berry's (1974) 4th stage *P. homarus* larvae were not segmented. Prasad *et al.* (1980) didn't observe segmentation of 1st and 2nd antenna, in 4th stage *P.homarus* phyllosoma. Maxilliped 1 was absent in the present forms and in the cultured larvae also 1st maxilliped was absent. Prasad *et al.* (1980) observed bud of 1st maxilliped in 4th *P. homarus* phyllosoma.

The 5th stage phyllosoma is destignuished by the presence of setose exopod of 4th leg and the 2nd maxilliped without exopod bud. In the 5th stage *P.homarus* phyllosoma obtained in this collection the 4th leg had setose exopod but the 2nd maxilliped had low exopod bud. Prasad *et al* 's (1980) 5th *P.homarus* phyllosoma had exopod bud. Ventral coxal spine was present on the 3rd maxilliped in the present form. Tampi and George (1975) did not observe ventral coxal spine on 3rd maxilliped of 5th *P.homarus* larvae. Dorsal coxal spine was absent

on 4th leg in this specimen. Berry (1974) observed dorsal coxal spine on the 4th leg of 5th phyllosoma of P.homarus. Prasad et al.(1980) also did'nt observe this spine on the 4th leg in the same species.

The 2nd maxilliped without a setose exopod is the distinguishing character of the 6th stage phyllosoma of P.homarus. In the specimen obtained here only 2 had 1 or 2 small setae developed on the exopod of 2nd maxilliped, but these cannot be included in the 7th stage, since the segmentation of the 5th leg was not clear in these forms. All other character are same as those described by Berry (1974) Tampi and George (1975) Prasad et al.(1980).

In the 7th stage described here the exopod of 2nd maxilliped was setose and the 5th leg was 2 segmented and these are the distinguishing characters of 7th stage. The 5th periopod of Berry's (1974) 7th P.homarus was not segmented. Prasad et al. (1980) observed 3 segmented 5th leg in 7th P.homarus phyllosoma. Towards this stage the posterior portion of the cephalic shield becomes more circular.

The 5 segmented 5th leg and the absence of pleurobranchs are the distinct characters of 8th stage, P.homarus phyllosoma. The biramous 1st maxilliped, pleopod and uropod also help in assigning the stage. Gills were totally absent in this form. Berry (1974) recorded podobranchs and arthrobranchs in 8th P.homarus. Prasad et al. (1980) have not mentioned about gills in any stage of P.homarus. The shape of the cephalic shield and the presence of the coxal spine in all stages is a characteristic feature of P.homarus larvae.

In the 9th stage obtained here gills were present only on the coxal segments of the pereopods. All the 3 types of gills were observed in 9th phyllosoma of P.homarus described by Berry (1974) and he assumed the 9th stage as the last phyllosoma of P. homarus. The characters of 9th stage obtained here shows that one more stage may be present in the development. Prasad et al. (1980) also described 9 stages of P.homarus phyllosoma and found the 9th stage obtained by him is not the last stage phyllosoma and so included one more stage in the developmental series. Sarasu (1985) was

able to collect a 10th phyllosoma of P.homarus from Andhra coast.

It was noted that slight differences were found by different authors in the same species and same stage; for example the number of segments of antenna, 5th leg, pleopod or uropod and like that. In the present case also the 16 stage 4 larvae obtained from 4 stations showed variations. The 11 specimen obtained from one station showed similar characters and the other larvae collected from other stations were slightly different. The 4th leg of 11 specimens reached the tip of the abdomen while in all others it reached beyond the abdomen. (see the description of larvae for more details) Berry (1974) obtained 9 stages of P.homarus and he considered the 9th stage asthe last stage. But Prasad et al. (1980) opined the presence of a 10th stage larva in its development and Sarasu (1985) obtained a 10th stage P.homarus from Andra coast. So based on the present evidence it can only be assumed that there are either 10 stages in the phyllosoma life of P.homarus or development varies in different areas. Certain authors (Saisho 1962, 1966, Dexter 1972, Inoue 1978, indicated that in the laboratory conditions more than one moult occurr between

stages. In the present rearing experiment also the 3rd stage larvae moulted 2 times to become the 4th stage. The differences noticed in the 4th stage collected larvae may be due to a 2nd moult of the 4th stage before reaching the 5th stage in the wild as in the case indicated in the laboratory conditions.

The presence of ventral coxal spine on the 1st leg throughout the stages and the dorsal coxal spine from 3rd stage onwards and sub exopodal spine on legs 1—3 are characteristic features of P.homarus larvae. In the later stages from the 7th stage onwards the posterior region of the shield becomes round in shape. In P.versicolor also in later stages the posterior region of the cephalic shield is round, but the presence of subexopodal spine on the 4th leg separates it from P.homarus larvae. In P.homarus larvae, the cephalic shield is more oblong and compared to this the shield of P.versicolor is compressed.

Prasad & Tampi (1959) collected phyllosoma stages of a palinurid lobster from the Laccadive seas and assigned it as P.penicillatus larvae. But the shape of cephalic shield and the presence of coxal spines and subexopodal spines in the larvae clearly indicate that it cannot be identified as P.penicillatus larvae.

The shape of cephalic shield makes it clear that it is either P.homarus or P.versicolor. Tampi and George later (1975) opined that these larvae belong to P.versicolor mostly based on the presence of the species in that area in abundance. But they did not mention whether subexopodal spine was present on legs 1—4, neither is it shown in the figures given by them. So these larvae most probably belong to P.homarus and not P.versicolor.

Further the mouth parts of 3 larvae (1—3 stages) in their series are placed well above than that of P.homarus, P.versicolor and P.ornatus and so it is felt that these three stages may belong to some other species other than the above three species. These may well be the early stage larvae of P.penicillatus as the later stages of this species described by Johnson (1971) show the mouth parts situated much above.

Murano's (1971) larva Form D seems to be 9th or 10th P.homarus larva as evident from his description of the larva.

Panulirus versicolor

A total of 7 phyllosoma of P.versicolor of stages 7, 8, 9 and 10 were collected from stations 77, 155, and 263.

Table - 9

P. versicolor

Stage	Station	Position Latitude °N	Longitude °E	No.collected
7	263	15°30'	68°30'	1
8	263	15°30'	66°30'	2
	155	09°57.3'	71°40'	1
9	77	10°29.6'	74°14.8'	2
10	155	10°2.7'	71°39.1'	1
		P.penicillatus		
9	155	100°2.7'	71°39.1'	1
10	155	"	"	2
11	155	"	"	1
		P.polyphacus		
6	160	11°00.2'	75°19.6'	1
7	160	"	"	1
9	160	"	"	1
		P.ornatus		
4	240	18°30'	71°30'	1
10	130	08°30.1'	76°015'	1
		P.longipes		
9	155	10°02.7'	71°39.1'	1

Stage - 7 (Plate 11A, Fig-16a)

One specimen of total length of 10 mm was collected from station 263

Antenna: 1st antenna 5 segmented and endopod present as bud. 2nd antenna 3 segmented.

Cephalic shield: Length 7.5mm and width 5.5mm.

Maxilliped 1: not bifurcated.

Maxilliped 2: Exopod not setose.

Maxilliped 3: Exopod setose and ventral coxal spine present.

Hind body: Length of hind body 5mm and width also 5mm.

Pereopods: Pereopod 1-4 with subexopodal spines. Legs 2 and 3 with, dorsal coxal spine. Ventral coxal spine present only on 1st leg. 5th leg was bud only.

Pleopod: Small bud

Uropod : Bifid

Stage - 8 (Plate 11 B, Fig.16 b)

Total length of the specimen 15--17mm.

Antenna: 1st antenna 4 segmented; Endopod setose; 2nd antenna 4 segmented.

Maxilliped 1: Maxilliped 1 slightly demarcated.

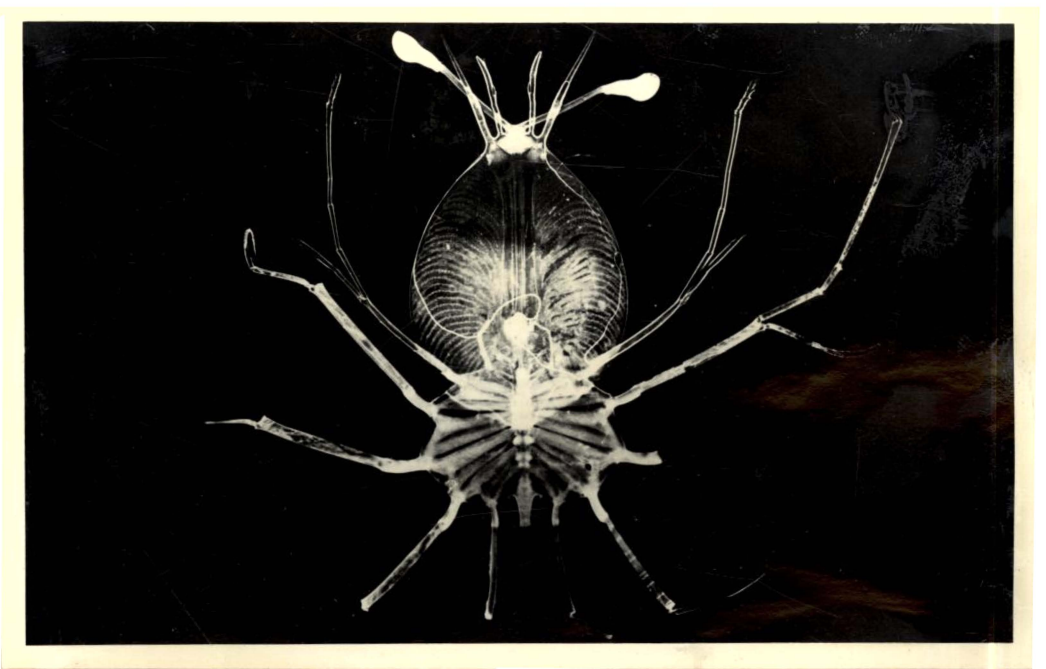
Maxilliped 2: Exopod setose

Maxilliped 3: Ventral coxal spine present.

Plate 11: A. 7th stage P.versicolor phyllosoma

B. 8th stage P.versicolor phyllosoma.

PLATE 11



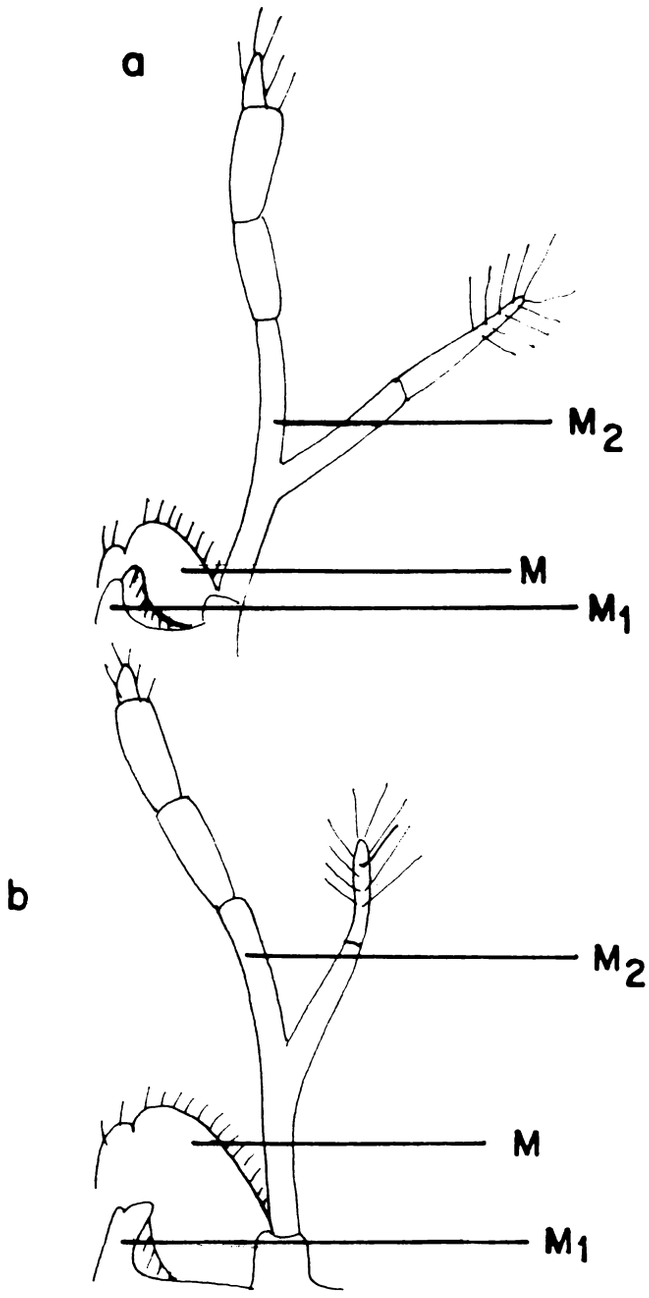
A

B

Fig. 16 a. 2nd maxilla and 1st & 2nd maxilliped of 7th stage P.versicolor phyllosoma.

b. 2nd maxilla and 1st and 2nd maxilliped of 8th stage P.versicolor phyllosoma.

Fig. 16



Cephalic shield: Length of cephalic shield 11—12.5 mm and width 8—9.5mm.

Hind body: Length of hind body 6—8mm and width 7-9mm

Pereopods: Legs 1—4 with subexopodal spines and sternal spines. Ventral coxal spine only on 1st leg. 2nd to 4th leg with dorsal coxal spine. 5th leg 2-3 segmented and sternal spine present.

Pleopods bifid.

Uropod : Bifid

Stage-2 (Plate 12 A, Fig. 17a)

Two specimens collected from station 77

Total length of the specimen 20—21 mm.

Antennae 1st antenna 4 segmented. Endopod setose

2nd antenna 4 segmented.

Maxilla-2: Broad.

Maxilliped 1: Slightly 3 lobed.

Maxilliped 2: Exopod setose.

Maxilliped 3: Ventral coxal spine present.

Cephalic shield:Length of cephalic shield 13 mm and width 10 mm.

Hind body: Length of hind body 10 mm and width 9 mm.

Pereopods: Ventral coxal spine found only on 1st leg. Subexopodal spine seen on 1—4 legs. Dorsal coxal spine present on 2—4 legs. 5th leg 4 segmented.

Pleopods: Long and bifid

Uropod : Well developed.

Gills : Buds present on the coxae of legs 1—4

Stage.10 (Plate 12 B, Fig.17 b)

One specimen of total length 30mm collected from station 155.

Antenna: Tip of 2nd antenna spatulate.

Cephalic shield: Length of cephalic shield 19mm and breadth 15 mm.

Maxilliped 1: Trilobed

Maxilliped 2: Setose exopod

Maxilliped 3: Sternal and ventral coxal spine present.

Hind body : Length of hind body 16mm and breadth 13mm.

Pereopods: Sternal spine on 1—5 legs. Subexopodal spine on 1—4 legs and dorsal coxal spine on legs 2—4. 5th leg 5 segmented.

Pleopods: Well developed.

Uropods : Well developed

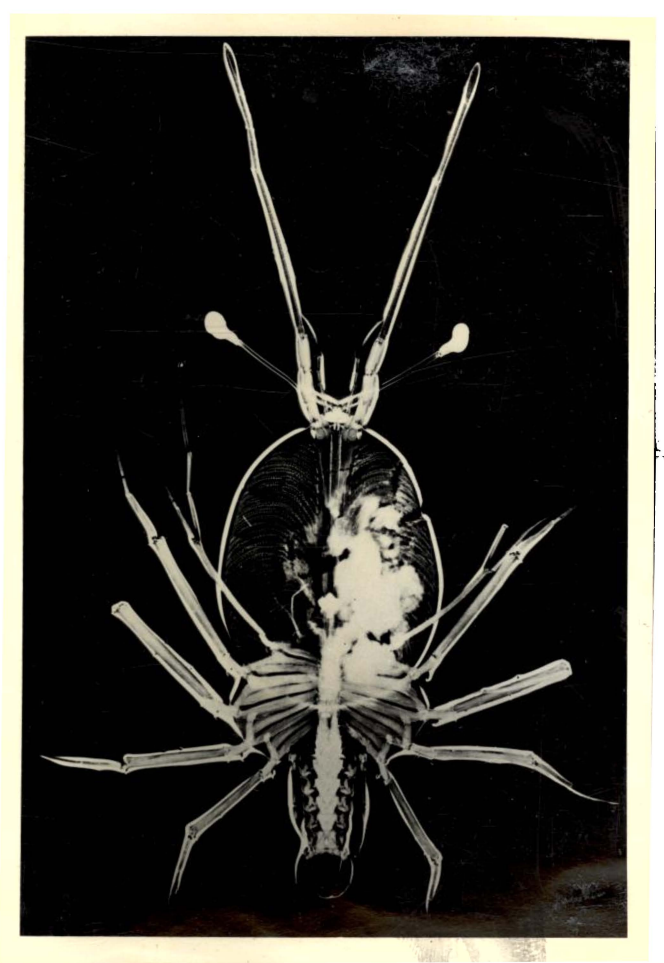
Gills : Arthrobranchs pleurobranchs and podobranchs present

Discussion

Stage 7 P.versicolor larvae have been described by Johnson (1971) Berry (1974) Tampi and George (1975)

Plate 12 : A. 9th stage *P.versicolor* phyllosoma
B. 10th stage *P.versicolor* phyllosoma

PLATE 12



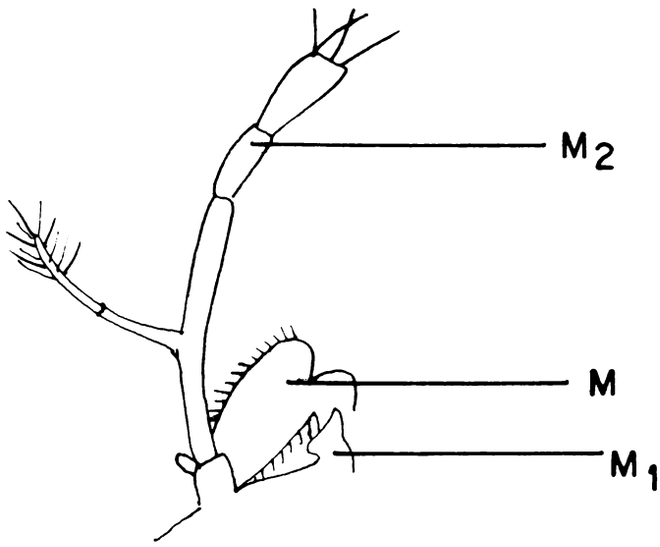
B

Fig. 17 a. 2nd maxilla and 1st & 2nd maxilla of 9th stage *P.vernicolor* phyllosoma.

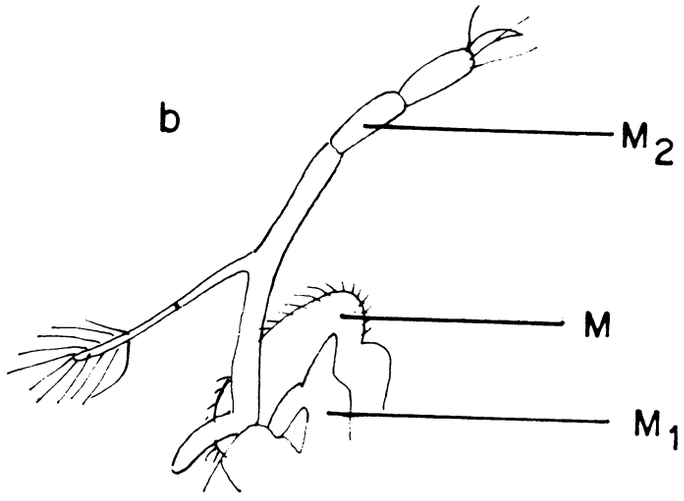
b. 2nd maxilliped and 1st and 2nd maxilla of 10th stage *P.vernicolor* phyllosoma

Fig. 17

a



b



and Prasad *et al.* (1980). The presence of sub exopodal spines on leg 1—4 readily separates the larvae of *P.versicolor* from that of *P.homarus* and *P.ornatus*. In the present form the presence of this spine confirms the identity of the larvae. In the 7th phyllosoma obtained here the exopod of the 2nd maxilliped was not setose. Johnson (1971) did not mention about the setose exopod of 2nd maxilliped in 7th Phyllosoma of *P.versicolor*. In Tampi and George's (1975) description also it is not clear whether 7th stage *P.versicolor* larvae had setose exopod of 2nd maxilliped. The 7th stage *P.versicolor* larvae obtained by Prasad *et al.*(1980) had exopod of 2nd maxilliped setose, but in their larvae the uropod was bifid. In Prasad *et al.* 's (1980) description, biramous nature of uropod appear in 8th stage, but the larvae was identified as 7th stage *P.versicolor*.

In the 8th stage phyllosoma of *P.versicolor* obtained here the 1st maxilliped was slightly demarcated and the 2nd maxilliped had setose exopod. Both pleopods and uropods were biramous in this stage. Dorsal coxal spine was present in this form. The 8th stage phyllosoma of *P.versicolor* obtained by Prasad *et al.* (1980) had biramous uropods but the 1st maxilliped was not segmented. The bifid nature of 1st maxilliped and biramous uropod clearly indicate that the larvae are 8th stage.

A 3 lobed 1st maxilliped and 5 segmented 5th leg was observed in the 9th stage described here Gill buds were present only on the coxae of the legs. These two characters are found in the 11th stage larvae in Prasad *et al*.'s (1980) description of this larvae. But the gills are only buds and so this stage is not the last stage described by Prasad *et al* (1980). Their 11th stage larva may probably be the 9th stage obtained here.

In the 10th stage larva of *P.versicolor* described here all the 3 types of gills are present. The maxilliped 1 was 3 lobed and 5th leg was 5 segmented. Pleopods and uropods were functional. From these characters it can be concluded that the 10th stage larva obtained here, is the last phyllosoma of *P.versicolor*.

The last stage phyllosoma of *P.versicolor* obtained by Berry (1974) had the tips of 2nd antenna spatulate. In the present specimen also it was spatulate. Berry (1974) expressed some doubts about the separation of *P.homarus* and *P.versicolor* phyllosoma in the light of Michel's (1971) description of *P.homarus* collected from Marquases Islands. Michel's larva had subexopodal spines

on legs 1—4 and spatulate antenna. On the basis of these it is clear that this larvae belong to P.versicolor instead of P.homarus. The final stage phyllosoma obtained here also have sub-exopodal spine on legs 1—4 and spatulate antenna and so there is no hesitation in assigning Michel's phyllosoma to P.versicolor. Berry's assumption that P.homarus from Marquases differ from those of Indian Ocean seems to be unnecessary. So far nobody has observed the presence of subexopodal spine on 4th leg of P.homarus larvae. If Michel's larvae can be considered as P.versicolor this is the third report of last stage of P.versicolor with spatuate tip of 2nd antenna.

Panulirus penicillatus

Four larvae belonging to stages 9, 10 & 11 were collected from station 155.

Stage 9 (Plate 13 A, Fig.18a)

One specimen of total length 28mm.

Antenna: 1st antenna 4 segmented and endopod long

2nd antenna 3 segmented.

Cephalic shield: Length of cephalic shield 20mm width of cephalic shield 15mm. The anterior portion of the cephalic shield more broad.

Maxilliped 1: Bilobed

Maxilliped 2: Exopod setose

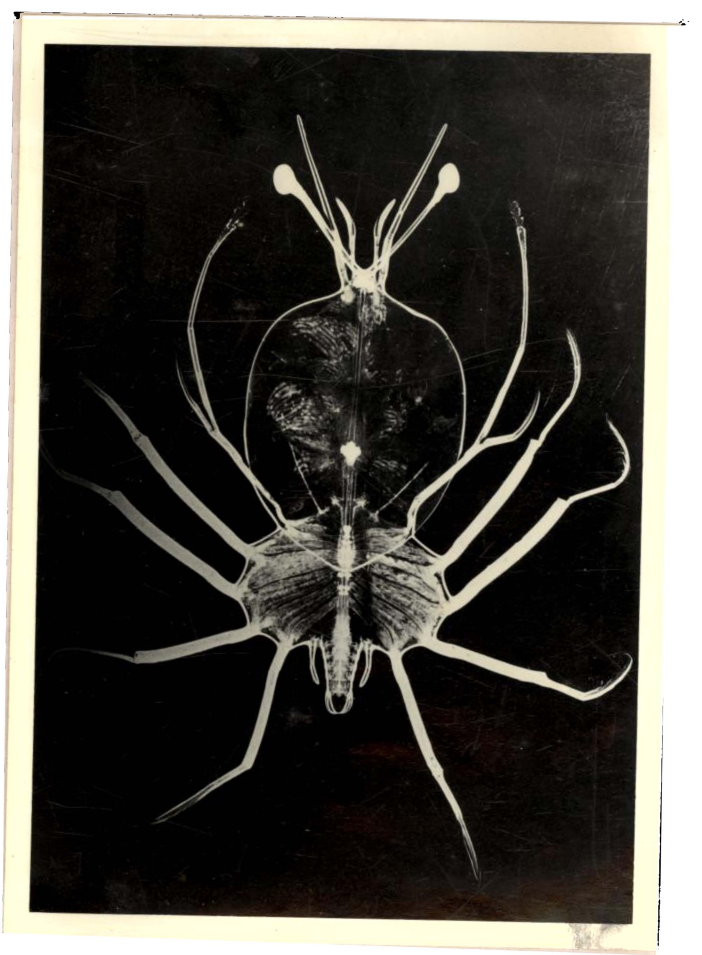
Maxilliped 3: Sternal spine seen on this.

Plate 13: A. 9th stage *P.penicillatus* phyllosoma

B. 10th stage *P.penicillatus* phyllosoma

PLATE 13

A



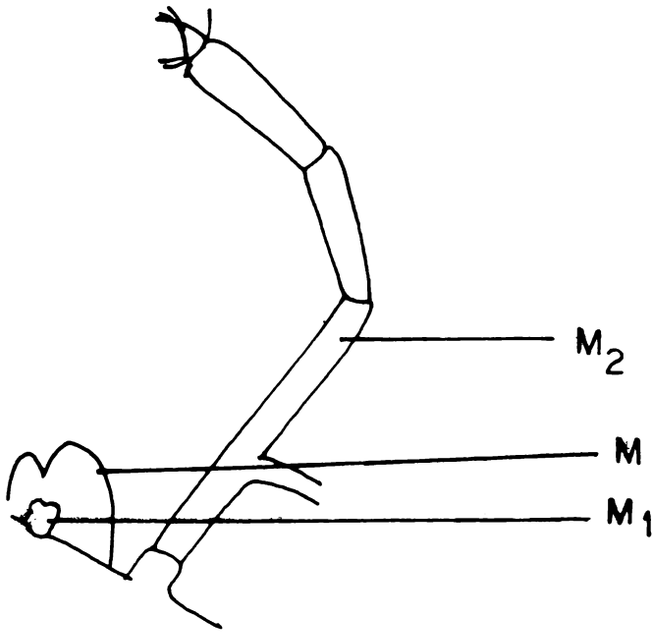
B

Fig. 18 a. 2nd maxilla and 1st and 2nd maxilliped of 9th stage P. penicillatus phyllosoma

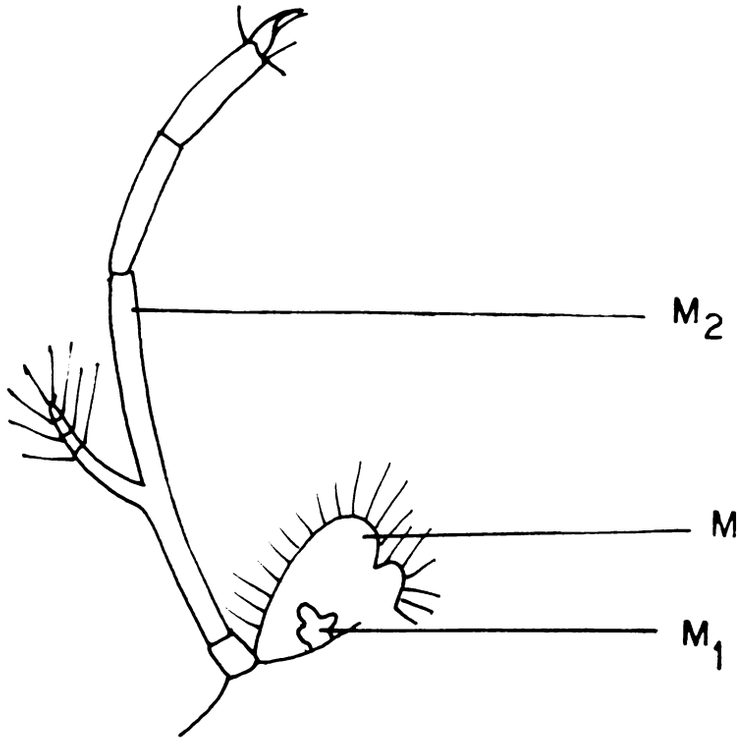
b. 2nd maxilla and 1st and 2nd maxilliped of 10th stage P.penicillatus phyllosoma.

Fig.18

a



b



Hind body: Length of hind body 12mm and width 14mm. The width of forebody and hind body more or less equal.

Pereopods: Coxal spines and subexopodal spines absent on all legs. 5th leg 4 segmented.

Pleopods : Bifid

Uropods : Bifid

Stage - 10 (Plate 13 B, Fig. 18 b)

Two specimens having total length 30mm.

Antenna 1: 4 segmented with setose endopod.

Antenna 2: 5 segmented.

Cephalic shield: Length of cephalic shield 21mm. and breadth 16 mm.

Maxilliped 1: slightly trilobed.

Maxilliped 2: Exopod of 2nd maxilliped setose.

Maxilliped 3: Sternal spine present

Hind body : Length of hind body 14mm and breadth 15mm.

Pereopods : Pereopods 1—5 with sternal spine only. 5th leg 4 segmented.

Pleopods : Bifid

Uropods : Bifid

Gills : Small buds present

Stage 11 (Plate 14, Fig.19)

One specimen of this stage of total length 39 mm.

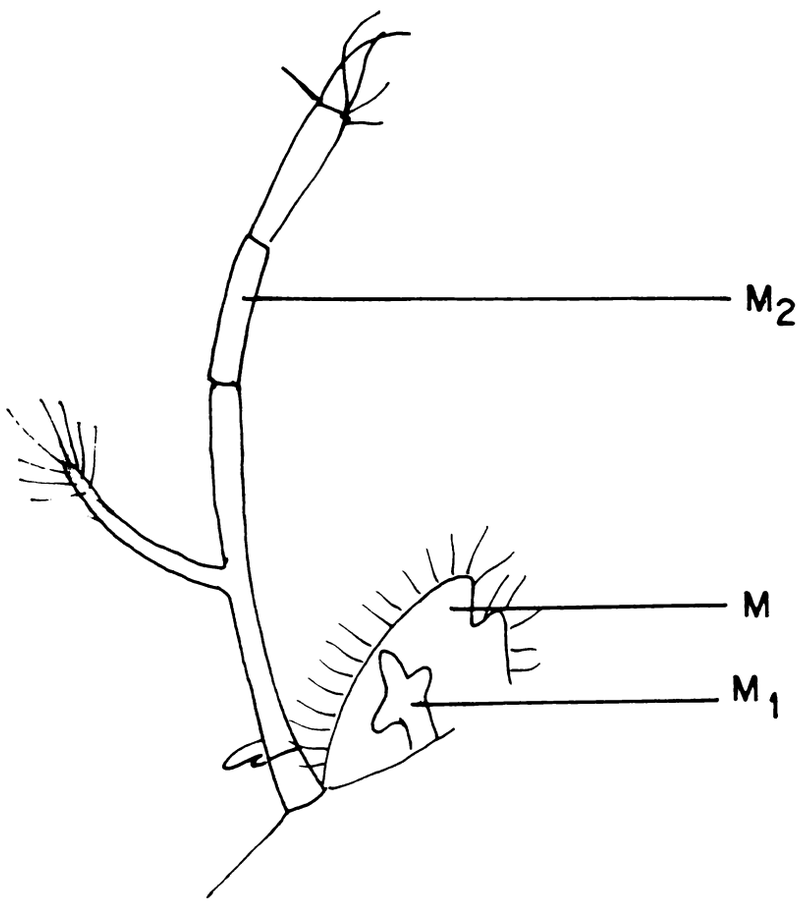
Antenna 1 : 5 segmented.

Plate 14 : 11th stage *P. penicillatus* phyllosoma.

PLATE 14

Fig. 19 2nd Maxilla and 1st and 2nd maxilliped of fifth stage P.penicillatus phyllosoma

Fig. 19



Maxilliped 1: trilobed.

Maxilliped 2: Exopod setose

Maxilliped 3: sternal spine seen

Cephalic shield: Length of cephalic shield 24mm and breadth 18 mm.

Hind body: Length 2 mm and breadth 17 mm.

Pereopods: Only sternal spine present on all legs 5th leg 5 segmented.

Pleopods: Functional

Uropods : Functional

Gills: Arthrobranchs, pluerobranchs and podobranchs present.

Discussion

The characteristic broad shape of the cephalic shield distinguishes the larvae of P.penicillatus from other Palimurid larvae. In the three phyllosoma of P.penicillatus obtained here the cephalic shield is wide unlike in other Palimurid larvae and the width of cephalic shield and there was more or less equal. The mouth parts were placed well above the 2nd maxilla and coxal spines and sub exopodal spines were absent. Johnson (1968, 1971) described P. penicillatus larvae. The exopod of 2nd maxilliped was not setose in Johnson's (1968) larvae.

In the present 9th stage larva the maxilliped 2 was setose and maxilliped 1 trilobed. Tampi and George (1975) also did not observe setose exopod of 2nd maxilliped in 9th larva of P.penicillatus. Prasad et al.(1980) recorded setose exopod of 2nd maxilliped in 10th stage larva but maxilliped 1 was bilobed in their larvae as in the present one. Sternal spines were observed in 1—4 legs as observed by Prasad et al. (1980). Also the biramous nature of the pleopods and uropods confirms this as the 9th stage.

In the 10th stage larva described here the maxilliped 1 was trilobed and small buds of gills were seen on the coxal segments of legs as in the 10th stage described by Johnson (1968). The 5th leg was 4 segmented in the 11th stage P.penicillatus larva described by Prasad et al. (1980) but the present 10th stage larva had 5th leg 4 segmented. 11th stage larva described by Prasad et al. (1980) may be the 10th stage described here and Johnson (1968). Since they have not mentioned about the gills also. Murano's (1971) form C is also 10th stage P.penicillatus. He has not mentioned whether all the three types of gills were present in this form.

The 11th stage larva described here is fully developed and it is the last phyllosoma of P.penicillatus

All the three types of gills were present and the 5th leg was 5 segmented. Pleopods and uropods were functional. This larva is in full agreement with Johnson's (1968) 11th stage P.penicillatus phyllosoma. Prasad et al.(1980) described 12 stages of P.penicillatus larvae. The only difference between the 11th and 12th stages according to them is that the 5th peraeopod was 5 segmented in the 12th stage. Presence of podobranchs arthrobranchs and pleurobranchs indicate the larva is the last stages phyllosoma, but Prasad et al.(1980) did not mention whether their 11th stage specimen had these three types of gills. Tampi and George (1975) observed all these gills in the 11th stage P.penicillatus larvae. In view of these it appears to be certain that there are only 11 stages in the development of P.penicillatus phyllosoma.

Panulirus polyphagus

Three specimen belonging to stage 6, 7 and 9 were collected from station 160.

Stage 6 (Plate 15A, Fig.20-a)

Total length of the specimen 10 mm.

Antenna: The 1st antenna 4 segmented; Bud of endopod present. 2nd antenna 3 segmented.

Cephalic shield: Length of cephalic shield 7.5 mm and width 4.5 mm.

Maxilla 2: 2nd Maxilla 2 segmented and distal segment small.

Maxilliped 1: Present as buds

Maxilliped 2: Exopod absent

Maxilliped 3: Exopod setose

Hind body: Length of hind body 3 mm and width 5 mm.

Pereopods: Coxal and sub exopodal spines absent on all legs. 5th pereopod bud.

Pleopods: absent

Uropod: bud

Stage 7 (Plate 15 B, Fig.20b)

One specimen of total length 12mm.

Antenna: 1st antenna 5 segmented. Endopod not setose 2nd antenna 3 segmented

Cephalic shield: Length of cephalic shield 9 mm and width 6 mm.

Maxilliped 1: Bud

Maxilliped 2: Exopod absent

Maxilliped 3: Setose exopod. Ventral coxal spine absent.

Hind body: Length of hind body 5 mm and width 7 mm.

Pereopods: Coxal spines and subexopodal spines. absent on all legs. Sternal spine present on 1—4 legs. 5th leg still bud.

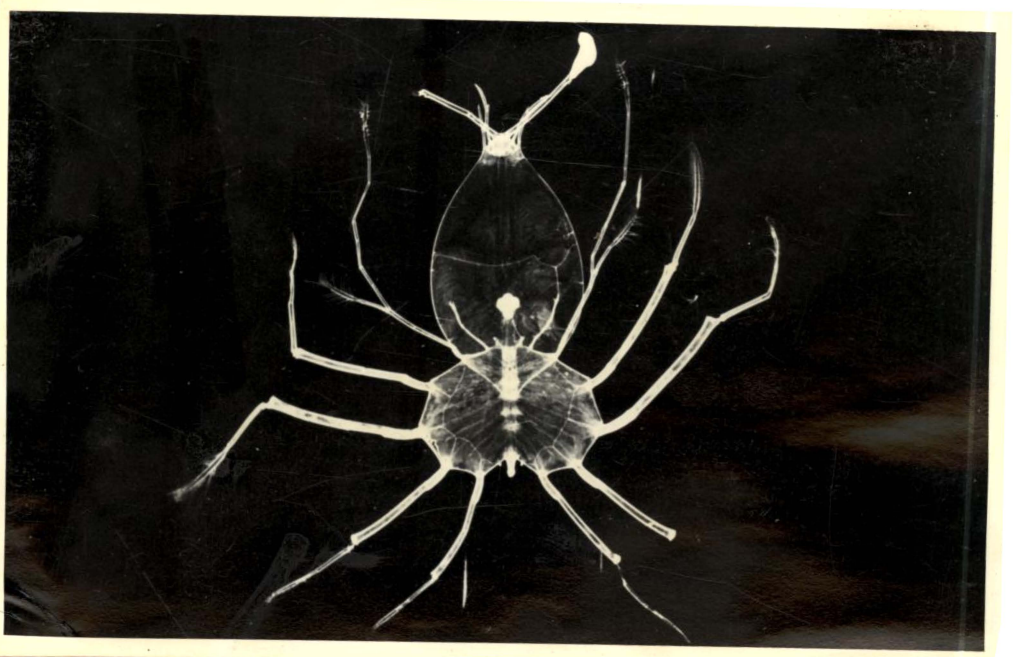
Pleopods: Present as buds.

Uropod: Not bifid.

Plate 15 : A. 6th stage *P. polyphagus* phyllosoma

B. 7th stage *P. polyphagus* phyllosoma

PLATE 15



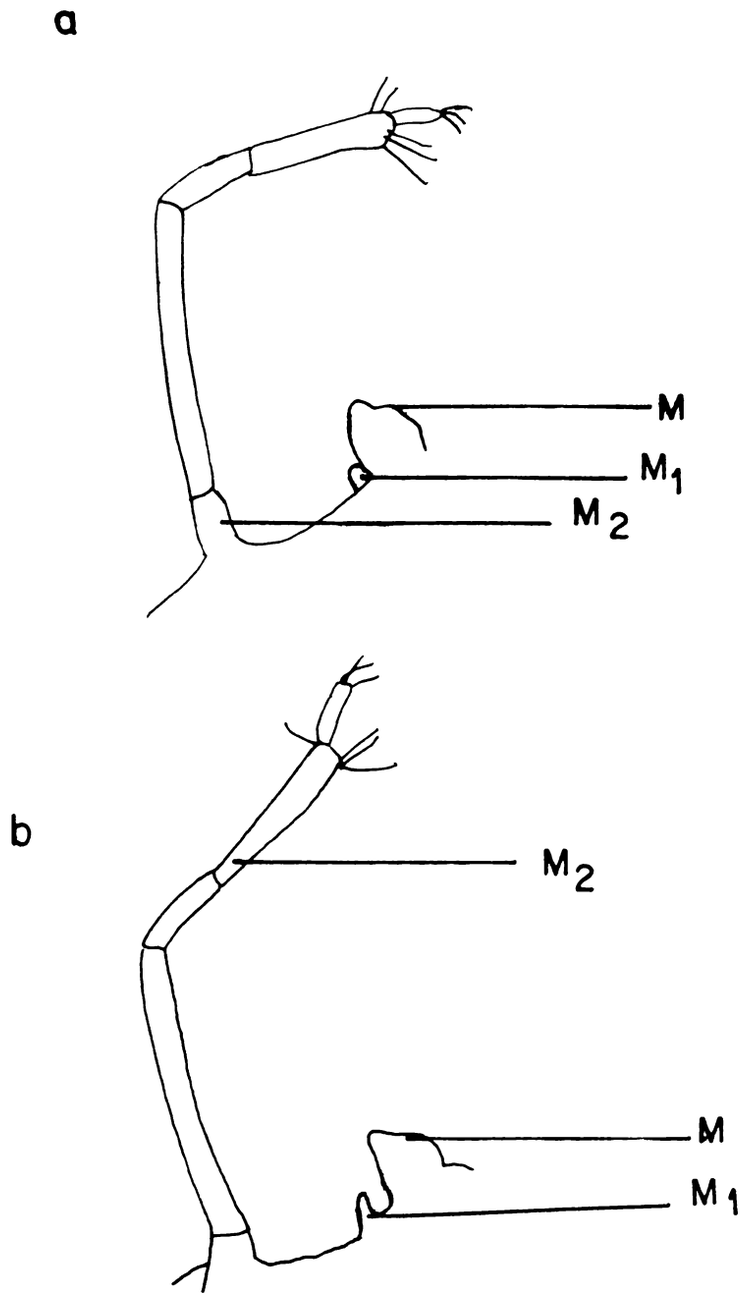
A

B

Fig. 20 a. 2nd maxilla and 1st and 2nd maxilliped of 6th stage *P.polyphagus* phyllosoma.

b. 2nd maxilla and 1st and 2nd maxilliped of 7th stage *P.polyphagus* phyllosoma.

Fig. 20



Stage 8 (Plate 16, Fig.21)

One specimen of total length 21 mm.

Antenna: 1st antenna with long endopod, but without setae. 2nd antenna 5 segmented.

Cephalic shield: Length of cephalic shield 15 mm and breadth 10 mm.

Maxilla 2: Broad

Maxilliped 1: Bifurcated

Maxilliped 2: Exopod not setose

Maxilliped 3: Ventral coxal spine absent

Hind body: Length of hind body 9 mm and breadth 11 mm.

Pereopods: No spine except sternal spine present on legs 1—4; 5th leg 3 segmented.

Pleopods: Bifid

Uropods Bifid

Discussion

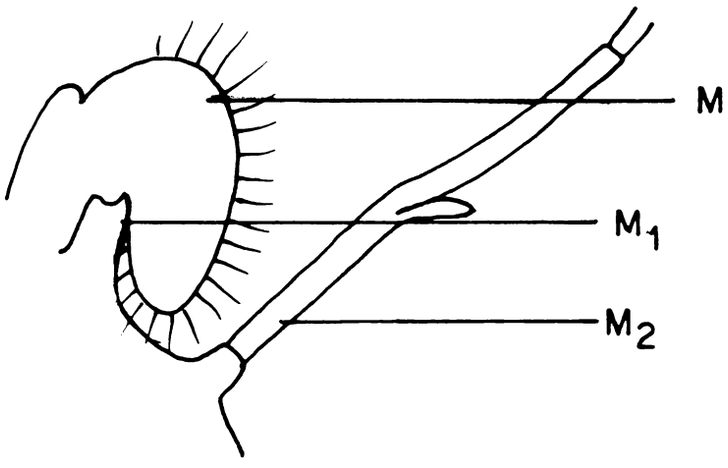
In P.polyphagus the breadth of hind body is more than that of the cephalic shield. The absence of coxal spines, sub exopodal spines and the placement of mouth parts well above the 2nd maxilla distinguishes the larvae of P.polyphagus from P.homarus, P.versicolor and P.ornatus. The shape of cephalic shield distinguishes P.polyphagus and P.penicillatus larva. It is not known whether the early stage P.polyphagus larvae have coxal spines. The 1st phyllosoma of P.polyphagus larva

Plate 16: 9th stage *P. polyphemus phyllosoma*

PLATE 16

Fig. 21 2nd maxilla and 1st and 2nd maxilliped of 9th stage *P. polyphagus* phyllosoma.

Fig. 21



described by Deshmukh (1968) had sub exopodal spines. So it can only be assumed that the early stages of P.polyphagus larvae have spines on the coxae of pereopods, otherwise 1st stage described by Deshmukh (1968) belong to some other species.

In the 6th stage P.polyphagus larvae described by Prasad et al. (1980) the maxilliped 1 was seen as buds, there was no exopod on 2nd maxilliped and the 5th leg was bud. Pleopods were absent and uropod buds were seen. In the present 6th P.polyphagus,phyllosoma also similar characters are seen. So based on these character the larvae were assigned to stage 6 P.polyphagus.

The 7th stage P.polyphagus had pleopod bud as described by Prasad et al. (1980) and uropod was not bifid. Here also the 2nd maxilliped had no exopod. 5th leg was not segmented. Sternal spines were present in the stage. The presence of sternal spine was observed only in the 9th stage P.polyphagus by Prasad et al. (1980). Tampi and George (1975) did not mention about the sternal spine in the 7th stage P.polyphagus. The description of P.polyphagus larvae is limited to these and based on these characters the present larva was grouped with the 7th stage.

The 9th stage phyllosoma of P.polyphagus had a bilobed 1st maxilliped. Exopod of the 2nd maxilleped was long but not setose. The 5th leg was 3 segmented. These character together with the biramous pleopod and uropod helped in identifying the stage. Stage 9 phyllosoma of

P.polyphagus has not been reported before. Berry (1974) has given a key for the identification of Panulirus species of the Indian Ocean. But he has not given any characters for P.polyphagus and assumed that if P.polyphagus has sub exopodal spines on legs 1--4 the separation of these larvae from P.versicolor P.ornatus and P.homarus are difficult. On the present evidence P.polyphagus has no coxal spines or subexopodal spines at least in later stages and the anterior mouth parts are placed well above the 2nd maxilla unlike in P.homarus P.versicolor and P. ornatus. Eventhough in the early stages identification based on the shape of the cephalic shield is difficult the position of the mouth parts readily separates P.polyphagus. larvae from these three species and in the later stages, only on the shape of the cephalic shield it can be separated from these larvae.

Panulirus longipes
Stage 9 (Plate 17, Fig.22)

One specimen of total length 21mm. Collected from station 155.

Antennae: 1st antenna 4 segmented and 2nd antenna 4 segmented.

Cephalic shield: Length of cephalic shield 15mm and breadth 10mm.

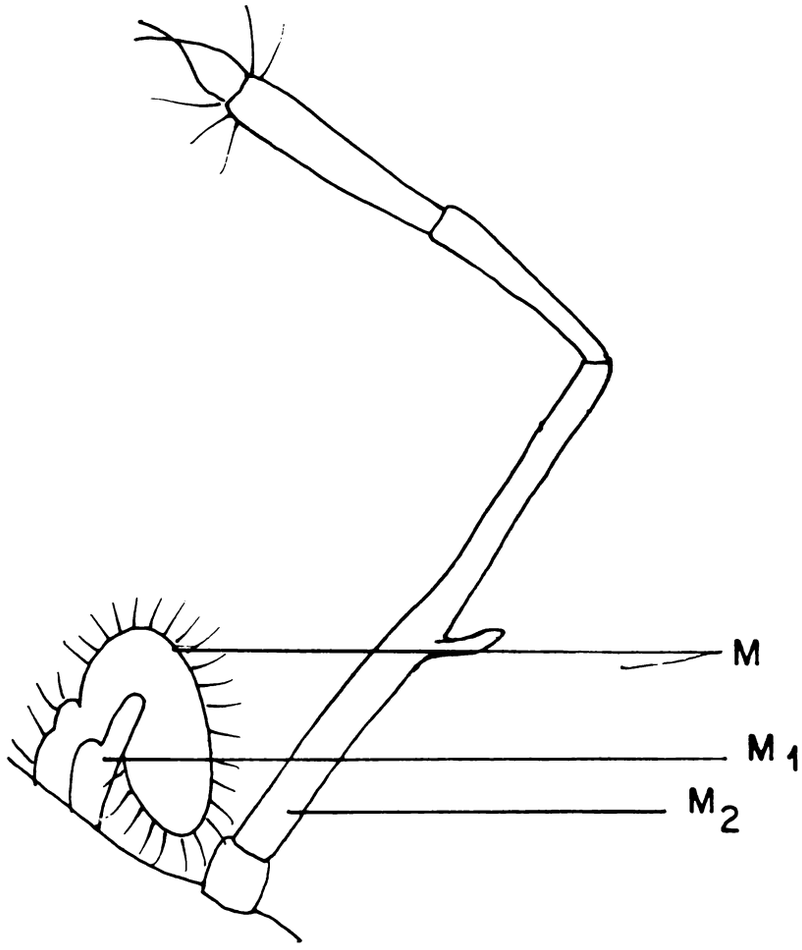
Maxilla 2: Broad.

Plate 17: 9th stage *P.longipes* phyllosoma

PLATE 17

Fig. 22 2nd maxilla and 1st and 2nd maxilliped of 9th stage P.longipes phyllosoma.

Fig. 22



Maxilliped 1: slightly demarcated.

Maxilliped 2: Exopod bud present

Maxilliped 3: Ventral coxal spine absent.

Hind body: Length of hind body 9 mm and breadth 11 mm.

Pereopods: Only sternal spine seen on legs 1—4; 5th leg 2 segmented.

Pleopods: Bifid

Uropods: Bifid

Discussion

The 9th stage P.longipes larva was similar in most of the characters with the P.polyphagus larva. The bifid pleopopod and Uropod, the presence of exopod bud on 2nd maxilliped and the slight demarcation of the 1st maxilliped showed the larvae in the 9th stage of development. The character of P.longipes and P.polyphagus are more or less similar. The shape and size of fore and hind body and the position of mouth parts for both the species are alike. In the present specimen exopod of maxilliped 2 was present as bud. In the key for identification of species given by Tampi and George (1975) it was given that in P.longipes the exopod of 2nd maxilliped appears in early stage. But here only one stage was obtained and so it is not known whether the exopod was present in earlier stages also. This character alone is not satisfactory in the separation of the two species as far as the similarities are concerned. In both the species,

coxal spines and subexopodal spines are absent and only sternal spine observed. In such a situation, the separation of P.longipes larvae from P.polyphagus is found difficult. A slight difference observed here is in the shape of the cephalic disc of the two. In P.polyphagus the cephalic disc is more pointed towards the anterior end. In P.longipes it is a little broad and in the figure given for both the species the difference is clear. The two sides of the posterior region of the cephalic disc appear like a straight line in P.longipes but in P.polyphagus it is not so straight. Apart from this no other characters have been found for separating P.polyphagus and P.longipes larvae.

The bilobed 1st maxilliped and exopod bud on 2nd maxilliped was found in the 8th stage P.longipes obtained by Tampi and George (1975). In their specimen the 5th leg was not segmented but where as the 5th leg was 2 segmented the larvae was assigned in the 9th stage. Prasad et al's (1980) 9th stage P.longipes had 2 segmented 5th leg but the bilobed maxilliped 1 was observed in their 10th stage. The 9th stage P.longipes described by Johnson (1971) had setose exopod of 2nd maxilliped and the 5th leg was 4 segmented.

Pseudiranus serratus

Two specimen collected from stations 240 and 130

Stage 4 (Plate 18A, Fig.23a)

One specimen of total length 5 mm collected from station 240.

Antenna: 1st Antenna 3 segmented; Endopod small bud.
2nd antenna 2 segmented.

Maxilla 2: 2 segmented, distal segment with 5 setae.

Maxilliped 1: 2 segmented, distal segment with 5 setae.

Maxilliped 2: No exopod

Maxilliped 3: Exopod setose. Ventral coxal spine present

Pereopods: Dorsal coxal spine absent. Ventral coxal spine seen on 1—4 legs. 4th leg bifid.

Sub exopodal spines present on legs 1—3. 5th leg present as bud.

Pleopod: absent

Uropod : absent

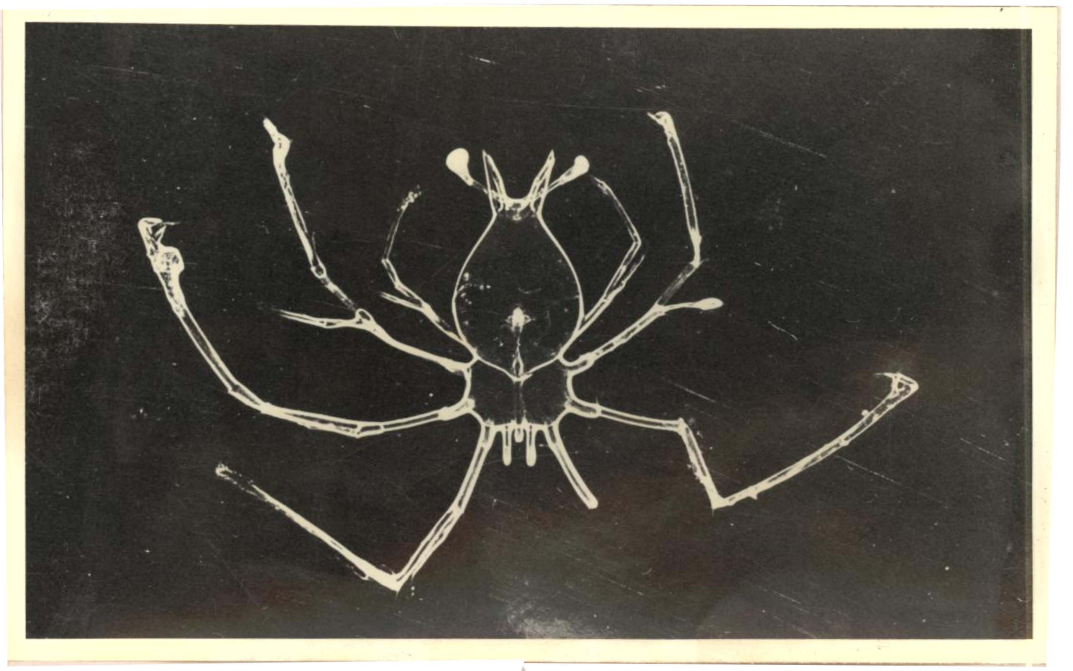
Stage 10 (Plate 18B, Fig.23b)

One specimen of total length 24mm collected from station 130.

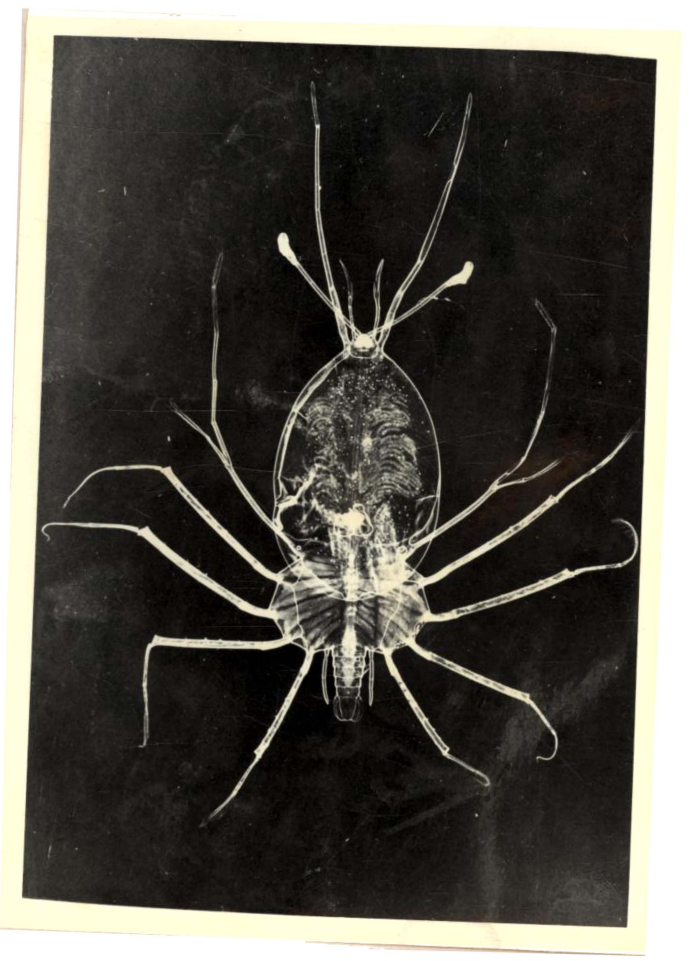
Antenna: 1st Antenna 5 segmented Endopod long
2nd antenna 6 segmented.

Plate 18 : A. 4th stage *P.ornatus* phyllosoma
B. 10th stage *P.ornatus* phyllosoma

PLATE 18



A

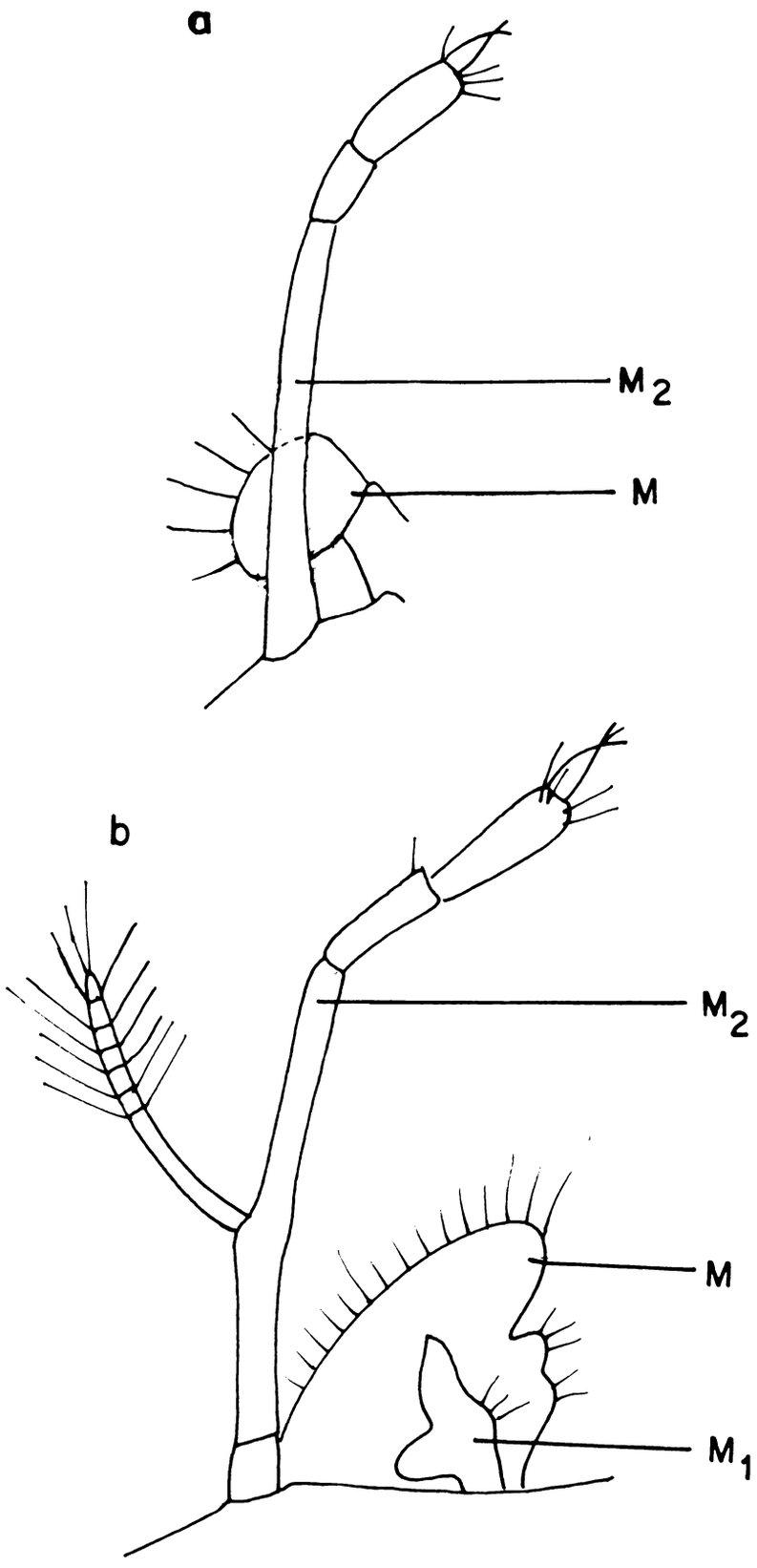


B

Fig. 23 a. 2nd maxilla and 2nd maxilliped of 4th stage P.ornatus phyllosoma.

b. 2nd maxilla and 1st and 2nd maxilliped of 10th stage P.ornatus phyllosoma.

Fig. 23



Cephalic shield: Length of cephalic shield 16mm and breadth 11 mm

Maxilla 2: Broad

Maxilliped 1: Trilobed

Maxilliped 2: Exopod setose

Maxilliped 3: Ventral coxal and sternal spines present

Hind body: Length of hind body 12mm and breadth 10 mm.

Peraeopods: Legs 1—3 with subexopodal spines.

Sternal spine at leg 1—5. Ventral coxal spine seen only on leg 1. Dorsal coxal spine absent. 5th leg 5 segmented.

Pleopods: well developed

Uropod: well developed

Gills: only on the coxae of legs.

Discussion

The 4th stage P.ornatus larva was distinguished by the presence of sub exopodal spines on legs 1—3 and absence of dorsal coxal spine. In P.homarus dorsal coxal spine appear in stage 3. (In the specimen obtained by rearing also this spine appeared in the 3rd stage) Prasad et al. (1980) observed dorsal coxal spine on 2nd and 3rd leg of P.ornatus from the 3rd stage onwards. Tampi and George (1975) in their key for identification of species stated that in P.ornatus dorsal coxal spine appear approximately at stage when exopod of 2nd maxilliped ~~xxxxxx~~ becomes setose. But the 4th stage described by them had dorsal coxal spine on 2nd and 3rd legs and exopod of

maxilliped 2 was not setose in the stage. If their statement is correct the 1—6 stages of P.ornatus described by Prasad et al. (1980) may belong to some other species like P.homarus since in these larvae exopod of 2nd maxilliped was found setose in the 7th stage only. In the early stages the separation of P.ornatus from P.homarus is found difficult but if the dorsal coxal spine appears only at the time of exopod of maxilliped 2 becomes setose in P.ornatus, based on this character the identification after the 3rd stage is easy In Berry's (1974) key also this character is mentioned for P.ornatus. Johnson (1971) also found dorsal coxal spine on 3rd legs in stages 8 & 9.

In the 10th stage P.ornatus described here 1st maxilliped was trilobed and maxilliped 2 had setose exopod. This larva was similar to Johnson's (1971) XIth stage P.ornatus except that gills were found only on the coxae of legs in the specimen and based on this the larvae is assumed to be the 10th stage and one more stage may be present with pleurobranchs, arthrobranchs and podobranchs. Dorsal coxal spine was present on the 3rd leg in the 9th P.ornatus described by Johnson (1971) Dorsal coxal spine was found

on 2—4 legs of 10th stage P.ornatus given by Prasad et. al.(1980). In the present 10th stage larva dorsal coxal spine was not observed on any legs. Ventral coxal spine found only on 1st leg and maxilliped 3. Sternal spine was present on legs 1—5.

The phyllosoma larvae collected in a cruise of the Research vessel belonging to the Central Marine Fisheries Research Institute, R.V.Skipjack from the Andhra coast in 1983 was made available for study during the course of this work. A short note was published on the taxonomy of these larvae in the Indian Journal of Fisheries Vol.32 No.4 1985. This is included in the thesis as it is the original work of the author during the course of the project work.

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NOTES ON A COLLECTION OF PHYLLOSOMA LARVAE FROM THE COASTAL WATERS OF ANDHRA PRADESH

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CAS in Mariculture, CMFRI, Cochin-1.

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On a cruise of R. V. Skipjack of the Central Marine Fisheries Research Institute, from 13.7.1983 to 18.7.1983, some pelagic trawl collections that were made off Visakhapatnam, in depths up to 550 m, were found to contain a few specimens of phyllosoma larvae of both palinurid and scyllarid lobsters. The area of collection was between Lat. 20.40'-21.07' N and Long. 87.20'-88.53' E. These larvae being collections from the region as far as known for the first time, an attempt was made at identifying them, making use of the accounts given by Berry (1974) Tampi and George (1975) and Prasad et al (1975). The results are presented in this contribution.

Panulirus homarus (Linnaeus 1758)

Material: 2 phyllosoma larvae obtained from pelagic trawl operated off Visakhapatnam.

Based on the diagnostic key for palinurid phyllosoma given by Tampi and George (1975) these are identified as larvae of *P. homarus* (Fig. 1).

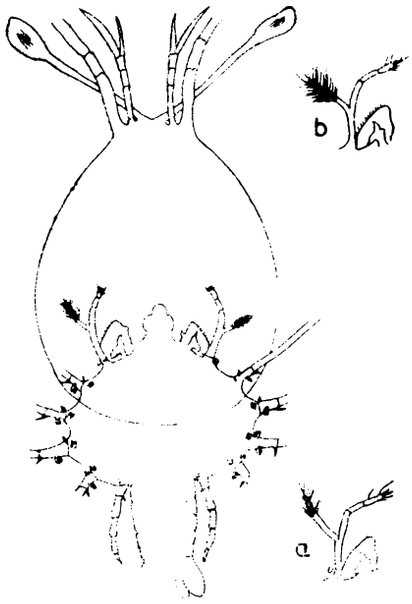

FIG. 1. Phyllosoma of *P. homarus*. a: anterior appendages of Stage 9; b: anterior appendages of Stage 10.

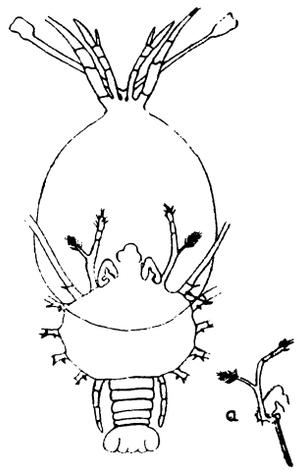

FIG. 2. Phyllosoma of *P. versicolor*. a: anterior appendages.

Stage 9: One of the specimens measures 21 mm in total length and, following Prasad et al (1975), is fixed at stage 9. The diagnostic features of the larvae of the species, namely, the presence of sub-exopodal spines on legs 1-3 and the characteristic shape of the cephalic disc (i.e., the anterior portion slightly pointed and the posterior region almost rounded), make it easy to identify the phyllosoma as belonging to *P. homarus*. The bilobed nature of maxilliped 1 and the presence of sternal spine at the base of the 5-segmented 5th pereopod help to determine the larva to be in stage 9.

Stage 10: Total length 32 mm. Except for the increased size of the specimen, the characters are more or less same as in the stage 9 mentioned above. But a minute projection can be seen in addition to the two lobes of the 1st maxilliped. Lateral spines on the uropod are more prominent than in stage 9. Arthrobranchs, podobranchs and pleuro-branchs are developed.

Although Berry (1974) has included both the above sizes as belonging to the same stage, the changes in character of the two specimens are deemed sufficient to treat them as belonging to the two consecutive stages of the larva, as has been done by Prasad et al (1975).

Panulirus versicolor (Latreille 1804)

Material: 1 specimen, obtained from a pelagic haul made off Visakapatnam.

The features of the larvae are quite in agreement with the description given by Johnson (1971), Murano (1971), Berry (1974) and Prasad et al (1975) for *P. versicolor* and hence there is no difficulty in assigning this larva to this species (Fig. 2).

The anterior region of the cephalic shield, unlike in *P. homarus*, is broader. Subexopodal spines present on legs 1 to 4.

Stage 10: Total length of the specimen is 29 mm and, as it tallies with the description of Prasad et al (1975), it can be assigned to stage 10. Maxilliped 1, bilobed; pereopod 5, 4-segmented.

The larva is recorded for the first time from this area. Recently, however, Shri Satyanarayana is reported to have come across an adult specimen of this species from Andhra coast (personal communication).

Scyllarus martensii (Pfeffer 1881)

Material: 1 larva, obtained in a pelagic trawl operated off Visakhapatnam.

Stage 9: The characteristic trapizoidal shape of the cephalic shield in the later stages and the ending of the tips of the uropods in sharp points leave no doubt in identifying this phyllosoma as that of *S. martensii* (Fig. 3). Total length is 10 mm, and this is probably the 9th stage, which is also a gilled stage. First maxilliped is bilobed and exopod is present as bud both in the second and in the third maxillipeds. The eyes are missing in the specimen.

Scyllarus martensii is a widely distributed species in Indian waters and thus its phyllosoma have been observed by Berry (1974), Tampi and George (1975) and Prasad et al (1975). But, there being no specific record of the species or its larvae from the coastal waters of Andhra Pradesh, this is the first record from this area.

Scyllarus rugosus (H. Milne Edwards 1837)

Material: 7 larvae obtained in pelagic trawls operated in Visakapatnam coastal waters.

Stage 11: Total length of the larvae ranges from 14 to 15 mm. From the descriptions already available, these larvae are assigned to 11th stage (Fig. 4). The characters of all the specimens agree with the earlier description. 2nd antenna shorter than the first, but almost equal in one or two specimens. Telson bears posterio-lateral spines.

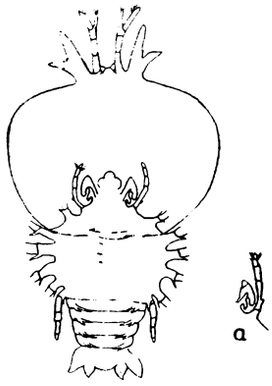

FIG. 3. Phyllosoma of *S. martensii*. a: anterior appendages.

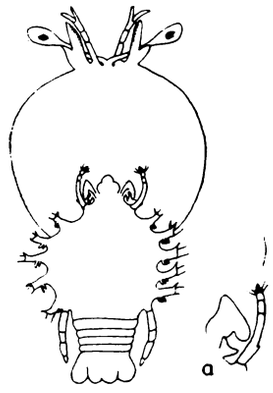

FIG. 4. Phyllosoma of *S. rugosus*. a: anterior appendages.

Prasad and Tampi (1960, Fig. a-D) described similar larvae as *Scyllarus* sp., and later Prasad et al (1975) identified the larvae as that of *S. rugosus*.

General remarks

In general, the number of phyllosoma larvae appearing in the plankton collections has been very limited. As for example, as was reported by Tampi and George (1975), the number of phyllosoma that were collected in plankton samples during all the cruises of various research vessels took part in the International Indian Ocean Expedition (IIOE) for the entire period of five years (1960-65) have amounted only to 84. Similarly, in most of the plankton collections made in several areas during routine plankton collections in the inshore regions, too, the phyllosoma larvae were meagrely represented. The present collection, however, contained comparatively larger number of larvae, probably because the collections were made with pelagic trawl instead of a plankton net.

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SUMMARY

The larval biology of spiny lobsters has been investigated. The major aspects of study included hatching of the eggs and rearing of the phyllosoma larvae in controlled conditions to the maximum stages possible. The effect of major environmental parameters such as salinity, pH, temperature and dissolved oxygen on larval moulting and survival in the laboratory have been determined. A systematic study of the phyllosoma collected during the cruises of FORV Sagar Sampada and R.V. Skipjack was also conducted. The important results are the following:-

1. Rearing experiments were conducted at Tuticorin Research Centre of CMFRI during the period 1984-1986. Berried females of Panulirus homarus were collected from the fishing centre of Kayalpattinam near Tuticorin. The berried specimens were kept in the brood stock rearing tank till the eggs hatched out. Successful hatching of the eggs was obtained several times.

2. The controversial naupliosoma was observed during this study. The appendages and antennae of this form was folded and the eyes were drooping. The naupliosoma lasted for 5-6 hrs during which time it transformed to the Ist phyllosoma stage without any moulting. The point worthy of mentioning is that there is no moulting for the transformation of naupliosoma to first phyllosoma stage.

3. The rearing experiments were conducted in glass beakers of 5 litre capacity, 10 numbers of larvae being put in 4.5 litre of double filtered sea water treated with antibiotics. All the environmental parameters like salinity, pH etc of the rearing media were kept constant as those of the natural condition. The phyllosoma larvae were mostly fed on Artemia nauplii. In addition jellyfish, Sagitta etc collected

from plankton were also tried on occasions when they were found acceptable to the larvae especially the later stages.

4. The phyllosoma larvae moulted 5 times in the laboratory. The 5th moult correspond to the 4th stage. Till the 3rd stage there was only one moult for each stage. The 3rd stage moulted 2 times to become the 4th stage. Thus it was confirmed that more than one moult may occur between two stages. The intermoult period was found to vary between 6 to 12 days. The eggs, the naupliosoma and the larval stages obtained by rearing are described in detail with figures.

5. The major cause of the larval mortality seems to be lack of proper nutritive feed. Eventhough Artemia nauplii was accepted as one of the favourable food of the larvae, the size of at least the later stages would indicate lack of proper nutrition in the food supplied. This could also be inferred

from the fact that the size of the phyllosoma larval stages obtained by moulting in the laboratory was smaller than that of the same stage obtained from the plankton.

6. Experiments in triplicate were conducted to determine the influence of different environmental parameters such as salinity, pH, temperature and dissolved oxygen on moulting and survival rate of the phyllosoma stage. For each experiment 10 numbers of larvae were reared in 4.5 litres of experimental media after proper acclimation and using Artemia nauplii as feed. The results were statistically treated and optimal levels of the different parameters for maximum survival rate and moulting worked out.

7. In the case of salinity, experimental rearing was carried out in different grades of 26.0, 28.0, 30.0, 32.0, 34.0, 36.0 and 38.0 ppt. The best survival rate was obtained in 34.0 ppt and the best moulting in 36.0 ppt salinity.

8. The optimum level of pH, for survival and moulting of the larvae determined from a series of pH, namely 6.1, 6.5, 7, 7.5, 8, 8.6 and 9.2, ranged between 8 and 8.6.

9. Experiments in temperature series of $25^{\circ}C$, $27^{\circ}C$, $29^{\circ}C$, $31^{\circ}C$ and $33^{\circ}C$ showed that $31^{\circ}C$ was the suitable temperature for proper survival and moulting of the phyllosoma larvae.

10. Among dissolved oxygen levels 2.5, 3.0, 3.5 and 4 ml/litre in which the experiments were conducted, the optimum level for growth of the larvae was 4 ml/litre.

11. Samples of phyllosoma larvae sorted out from plankton collections made during the cruises of FORV Sagar Sampada in 1985 from the West coast of India were analysed. Different stages of phyllosoma belonging to various species were identified.

Phyllosoma stages 3-9 of Panulirus homarus stages 7,8,9, 10 of P.versicolor, stages 9, 10 & 11 of P.penicillatus stages, 6, 7 and 9 of P. polyphagus, stages 4 & 10 of P.ornatus and stage 9 of P.longipes were obtained in the collection and these are described in detail along with figures.

12. A collection of phyllosoma made during a cruise of R.V.Skipjack from east coast of India was also analysed and a short paper published on the taxonomy of the same is included.

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