ON THE PHYLLOSOMA OF MANDAPAM[1]

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INTRODUCTION

Several species of lobsters belonging to the families Palinuridae and Scyllaridae have been known to occur in Indian waters but the lack of information of their larvae is rather striking. This is perhaps because of the relative scarcity of these larvae in the plankton collections made in the inshore waters and probably also due to the difficulty in rearing them in captivity for a long time, for the duration of larval life is known to be long and may range from three to six or seven months. This long larval life is important in the life history of lobsters because this period covers the main dispersal phase of the species concerned and the distribution of the adult depends to a very large extent upon the duration of this larval life. Plankton investigators from various centres along the coasts of India have reported the occurrence of Phyllosoma in the inshore plankton and throughout they do not seem to be very common. No attempt has so far been made to classify the different types of Phyllosoma that occur in our waters and besides we know very little about the season of occurrence of these larvae at the various places. Alikunhi (1948) seems to have been able to study in detail the mechanism of larval and post-larval moults and the various stages in the development of two species of *Scyllarus* and a single species of *Panulirus*. According to him the Phyllosoma larvae form a conspicuous item, though not very common, of the macroplankton of the Madras coast particularly during March and that the early stages are remarkably few in the surface plankton, while the final pelagic stage predominates. He adds that the final pelagic larvae metamorphose into post-larvae overnight in the laboratory, the early larvae also moult into later stages and that the post-larval specimens thrive in aquaria and grow by regular moults. Unfortunately the results of his investigation are reported only in the form of a brief note and the details have not been published yet.

Three species of the family Palinuridae, *Panulirus ornatus* (Fabricius), *P. dasypus* (*Latreille*) and *P. fasciatus* (Fabricius) and one species of the family Scyllaridae *Thenus orientalis* (Rumph.) are commonly caught in this area. During 1950 to 1955 a number of Phyllosoma larvae, belonging to different types and stages of development, were obtained from the local plankton and it was thought that a study of these will be interesting and informative, particularly in view of our very meagre knowledge of these larvae. There is still a great deal of uncertainty about the identity of the different types of Phyllosomas and in many cases they have not been positively correlated with the adults. Similarly, in many species the number of stages through which the Phyllosomas pass before metamorphosing into the puerilla stage is also still mostly a matter of conjecture. Therefore, attempts were made to rear the larvae in the aquarium. It was possible to keep berried specimens of *P. ornatus* and *T. orientalis* in the aquarium until the eggs hatch and

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thus establish the identity of the first Phyllosoma, the characters of which are quite important in recognising the later stages. Efforts to keep the larvae in the aquarium to study the later larval history have, however, proved so far unsuccessful.

Descriptions of Phyllosoma

Panulirus ornatus (Fabricius)

A berried specimen was obtained on January 2, 1955. The eggs were almost spherical, 280μ in diameter and orange-red in colour at the time of capture. They gradually increased in size as development advanced and became 350μ when the embryos were practically fully developed. On February 16, the eggs hatched and the first Phyllosomas (Fig. 1A) were seen actively swimming about. The larvae had bright orange-red chromatophores distributed over the body and the appendages as shown in Fig. 1A. It has been reported by some of the earlier workers that there is a stage before the first Phyllosoma and that this stage lasts only for a few hours. Gilchrist (1913 and 1916 as quoted by Gurney, 1936) who recorded this for the first time in *Palinurus* (*Jasus*) *lalandii* gave the name "naupliosoma" to these larvae. He suggested that if the hatching takes place at night one may miss the naupliosoma and that this active stage is retained in order that the surface may be reached more rapidly than a normal Phyllosoma would be able to do. Von Bonde (1936) observed a pre-naupliosoma stage in this species which lasted for about eight hours before moulting into the naupliosoma. Sheard (1949) observed a naupliosoma stage in *Panulirus longipes*. He remarks that the naupliosoma is quickly followed by the first of a number of Phyllosoma stages and adds that the naupliosoma avoids light, creeping into rocks, cracks, etc., for protection. Gurney (1936) is of the opinion that the naupliosoma represents the prezoeal stage. Neither Lebour (1950) nor Lewis (1951), who made observations on *Panulirus argus*, have recorded these stages and according to them the eggs of *P. argus* hatch as first Phyllosomas. In the present instance also the authors have not noticed either a pre-naupliosoma or a naupliosoma stage. The first Phyllosoma stage was seen early in the morning and it is not unlikely that hatching took place at night and the naupliosoma stage escaped unnoticed. During the last few years several berried crabs, alpheids, etc., were kept under observation by the authors and it was their experience that hatching in most cases took place at night.

The first Phyllosoma of *P. ornatus* (Fig. 1A) measures 1.42 mm. in length (from the tip of the abdomen to the tip of the fore-body between the eyes) and 0.67 mm. across the widest part of the fore-body. The hind-body is slightly narrower than the fore-body. The eyes are thick stalked and are about as long as the first antennae or may be slightly shorter. First antenna is long and slender and is about one and a half times the length of the second antenna. There are three long terminal hairs and a short one. Towards the distal half there are a series of short hairs on either side. The second antenna is unsegmented with two short terminal hairs, two short ones on the outer side and a few on the inner side (Fig. 1B). Second maxilla is two jointed, the basal segment bears three short setae and the distal segment has four long plumose setae. The second maxillipede is five jointed and without an exopodite. The distal segment is prolonged into a spine and has two short hairs at the base of the spine. The penultimate segment bears four short setae (Fig. 1C). The third maxillipede has an exopodite. There are three pereiopods present of which only the first and second are biramous with well developed exopodite bearing natatory setae. The exopodite of the third pereiopod is visible as a rudiment. All the three pereiopods have prominent coxal spines (Fig. 1A). The abdomen is about half the length of the hind-body and the sides are almost

parallel. The tip of the abdomen is drawn out into points on either side, each side having three spines (Fig. 1D).

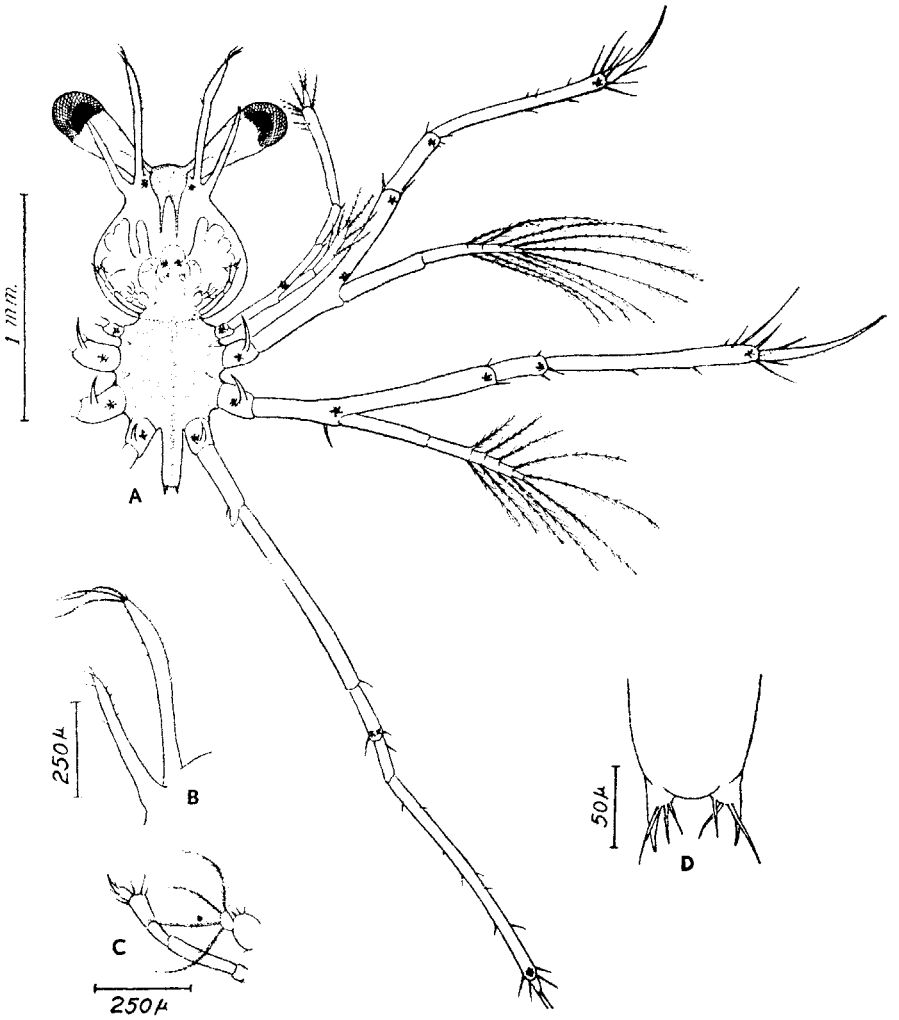


Figure 1. A. The first Phyllosoma of *Panulirus ornatus*. B. The first and second antennae. C. The second maxilla and the second maxillipede. D. The abdomen.

Gurney (1936) has given the characters of the Phyllosoma of *Panulirus* as follows :

"Fore-body pear-shaped, sometimes very narrow. Hind-body wider, sometimes much wider than fore-body; generally concave behind. Abdomen small and narrow in early stages."

"Antenna slender. Maxillipedes 2 and 3 with exopod in later stages. Leg 5 without exopod."

He separated the material he had into two groups one form (Form A) in which the hind-body is not much wider than the fore-body, antenna in early stage

much longer than antennule, exopodite of the maxilla enlarging early and always with setae and the third maxillipede and the first pereiopod having coxal spines and Form B with hind-body much wider, antenna in early stage shorter than the peduncle of the antennule, exopodite enlarging late and without setae until last stage and no coxal spines on the third maxillipede and first pereiopod.

Gurney (1936) has also described a third type (Form D) which he thinks may be of *Panulirus*. These have the fore-body pear-shaped, narrow in front, narrower than hind-body and which is slightly hollowed behind in later stages. The antennule has segments two and three of peduncle nearly equal and about half the length of the first segment. Antenna is slender and longer than the antennule in the earliest stages. The maxillule is without palp and the exopodite of the maxilla is setose. The second maxillipede is without an exopodite in the early stages but has a setose exopodite later, whereas the third maxillipede has a setose exopodite from the earliest stage. Pereiopods have large ventral coxal spines and the second and third pereiopods have large dorsal coxal spines. The dactylus of the second pereiopod is elongated.

The characters of the Phyllosoma under discussion do not agree completely with those of either of the forms described by Gurney (1936). The present larvae differ from Form A in that the hind-body is slightly narrower than the fore-body, antennae are shorter than the antennules and the third maxillipede is without a coxal spine, while they differ from Form B in not having the hind-body much wider than the fore-body and the presence of coxal spines in the first pereiopod. There are also differences from Form D of Gurney, the identity of which he himself is not certain. It should, however, be pointed out that Gurney (1936) had no corresponding stage in his collection and unfortunately the present authors do not have later stages in their collection. The present Phyllosoma, it may be added, shows many characters which Gurney (1936) has described for the Phyllosoma of *Palinurus*. In fact it agrees more with the characters of *Palinurus* rather than *Panulirus* as given by Gurney. They are (1) fore-body about as wide as long at all stages and wider than hind-body, (2) hind-body not concave behind, (3) third maxillipede with setose exopodite from the first stage, (4) abdomen parallel sided, (5) the dactylus of the first and second pereiopods prolonged into very long spines, and (6) pereiopods with coxal spines. Here again Gurney had access only to comparatively late stage of larvae. The first Phyllosoma of *P. ornatus*, however, shows close resemblance to the corresponding stage *P. argus* (see Lebour, 1950 and Lewis, 1951) and to that of *P. interruptus* and *P. gracilis* (see Johnson, 1956). There is, however, no uncertainty about the identity of the Phyllosoma described above because these larvae hatched in the aquarium as mentioned earlier.

Thenus orientalis (Rumph.).

A berried specimen of *T. orientalis* was obtained on July 8, 1953 and eggs were in a fairly advanced stage of development. The eggs were dull yellowish-brown in colour and measure 830μ in diameter. The larvae hatched on July 20.

Phyllosoma I (Fig. 2A).

The larvae measure 2.95 mm. from the front margin of the carapace to the tip of the abdomen. The fore-body which is broader than long is much broader than the hind-body. The latter is almost circular and is 1.29 mm. wide. The former is 2.19 mm. at its widest part. The eyes have a fairly thick stalk and are slightly longer than the first antenna (Fig. 2A). The first antenna is long, slender and unsegmented with three terminal hairs. A little above the middle of the antenna there is a short spine. The second antenna is less than half the length of the first. It is unsegmented and bears two terminal setae (Fig. 2B). The second maxilla is single jointed with three plumose setae. The second maxillipede is without

an exopodite and consists of five segments of which the second is the longest. The terminal segment tapers to a point and has two short setae. The third and fourth segments carry one and five setae respectively (Fig. 2C). The third maxillipede is uniramous. Pereiopods one, two and three are biramous with the exopodite having well developed natatory setae. The dactylus of the first, second and third pereiopods are not very elongated. The fourth pereiopod is uniramous. Coxal spine is present on the maxillipede and the first four pereiopods. The fifth pereiopod is present as a rudiment. It is unsegmented and is about two-thirds the length of the abdomen (Fig. 2A). The abdomen is rather small and is about half the length of the hind-body. The corners of the abdomen are drawn out into points on either side with three bristles on either side (Fig. 2D).

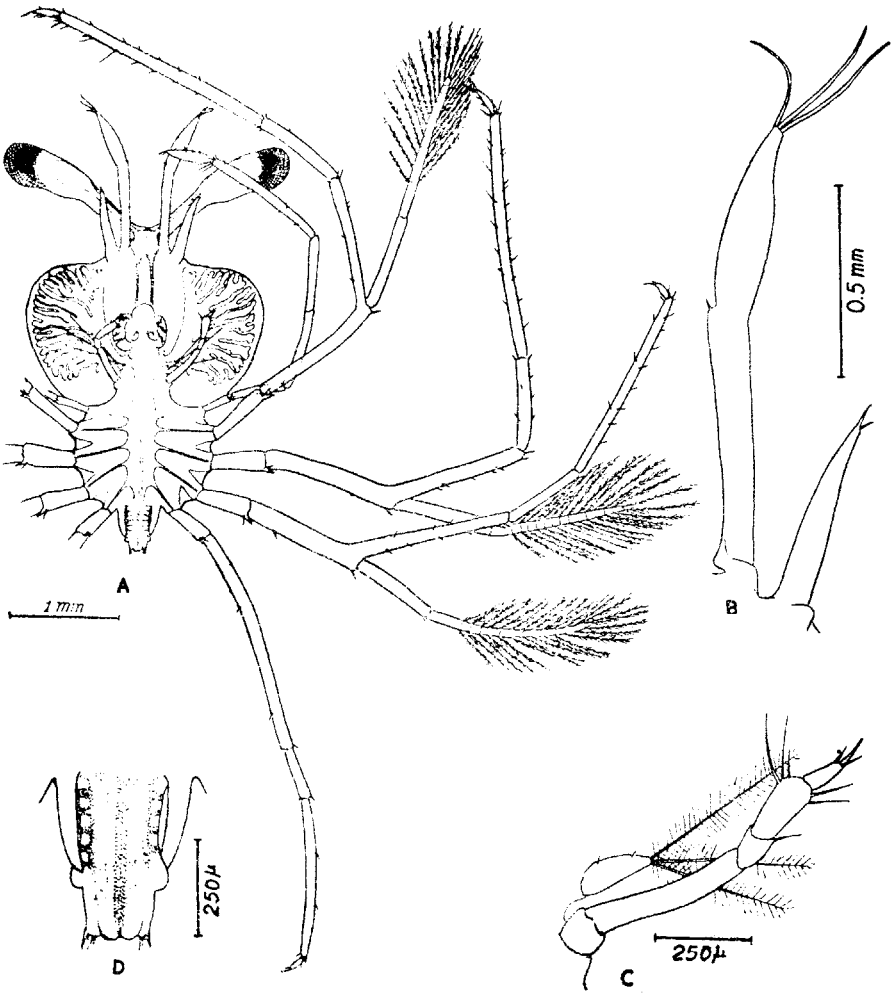


Figure 2. A. The first Phyllosoma of *Thenus orientalis*. B. The first and second antennae. C. The second maxilla and second maxillipede. D. The abdomen and the rudimentary fifth leg.

*Phyllosoma II**

This and the subsequent stages of Phyllosoma have been obtained from the plankton of the Mandapam area.

The Phyllosoma (Fig. 3) now measure 3.29 mm. in length. This stage does not show many striking differences from the first stage. The fore-body is little more than one and a half times the width of the hind-body. The eyes have become slightly longer and the eye-stalk more slender. The first antenna shows indications of segmentation at the place where the short spine is present. The exopodite is present in the fourth pereiopod as an unsegmented rudiment. The fifth pereiopod is still short and unsegmented and is about two-thirds the length of the abdomen. The base of the abdomen has become slightly broader.

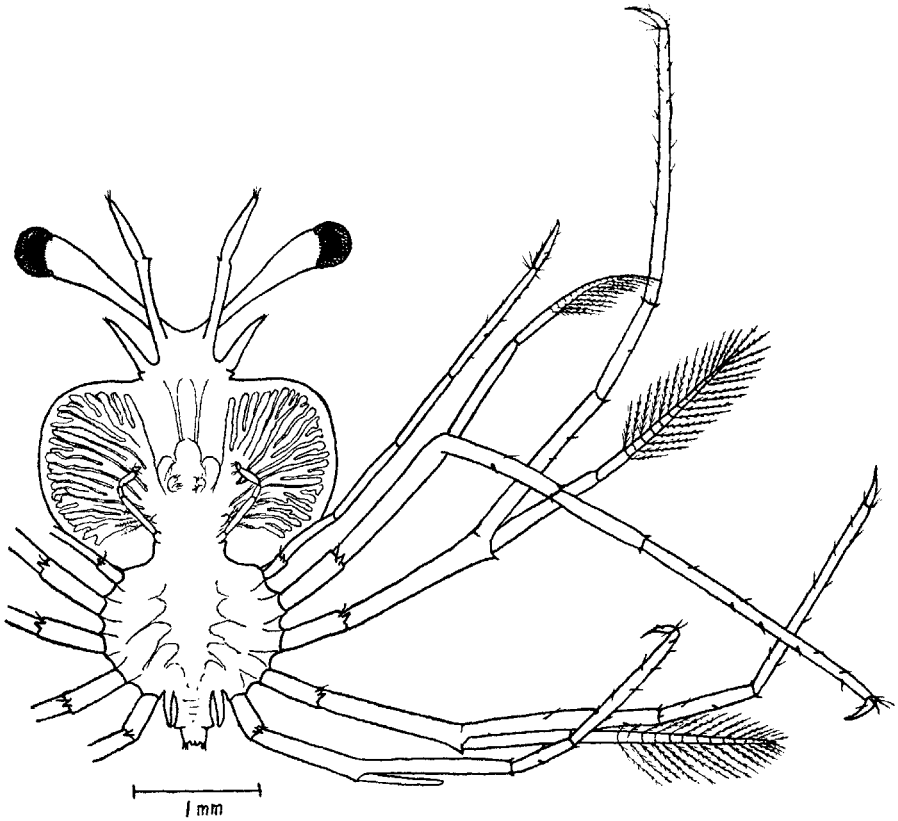


Figure 3. Phyllosoma II of *Thenus orientalis*.

Phyllosoma III (Fig. 4A)

The larvae measure 5.8 mm. in length. The fore-body has become very broad, almost twice as broad as the hind-body. The eye-stalk now shows two distinct segments, the long, cylindrical, proximal part connected by articulation

*The numbers do not refer to the actual stages in the development as the number of Phyllosoma stages in the development of the species is not known.

with the distal, conical part. It is now much longer than the first antenna. In the first antenna the short spine has become greatly enlarged and appears like a diverticulum. It is still unsegmented. In addition to the terminal setae it has developed four rows of sensory setae. The second antenna now appears bifurcate, somewhat longer being nearly two-thirds in length of the first antenna (Fig. 4B). The second maxilla has lost its plumose setae and also slightly changed in its shape. The first maxillipede has appeared as a small protuberance between the second maxilla and the second maxillipede. The second maxillipede (Fig. 4C) remains essentially the same as in the previous stage. There is no change in the third maxillipede as well as in the first, second and third pereiopods. The exopodite of the fourth pereiopod has become jointed and possesses natatory setae. The fifth pereiopod is present and is nearly double the length of the abdomen. The abdomen has increased in width, the rudimentary uropods are distinctly indicated and are bifid. The telson has two short spines at the corners (Fig. 4D).

The nature of developmental changes that have taken place in Phylosoma III compared to the previous stage described here, suggests that what is described here as Phyllosoma III may actually represent the fourth stage in development and that stage III is not represented in the collection.

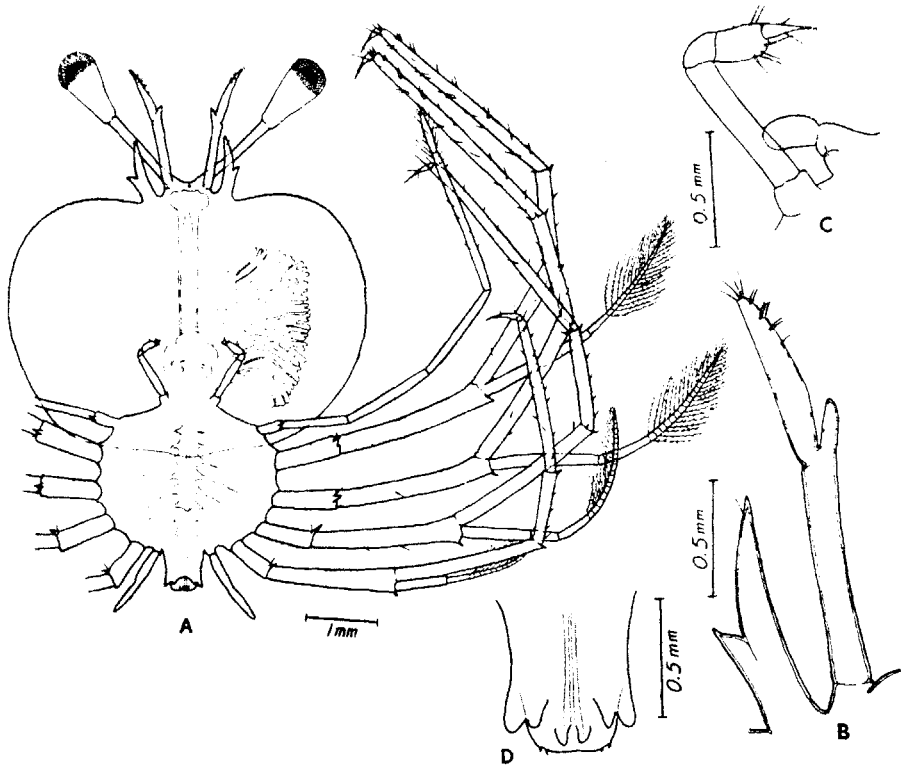


Figure 4. A. Phyllosoma III of *T. orientalis*. (Drawn from a whole mount). B. First and second antennae. C. The maxilla, the rudiment of the first maxillipede and the second maxillipede. D. Abdomen showing the rudimentary bifid uropods.

Phyllosoma IV

The next stage available is relatively very much advanced where the larvae measure 17.8 mm. in length (Fig. 5A). The fore-body has become very broad (13.6 mm.) while the hind-body measures only 7.2 mm. The first antenna is five jointed with a three jointed peduncle. The inner process at the end of the peduncle (the inner flagellum) is distinctly articulated at its base and it possesses a few marginal hairs. The outer process which becomes the outer flagellum has developed many more sensory setae. Both these segments are nearly of equal length. The second antenna has become broad and leaf-like with a strong process on the outer side and is almost as long as the first antenna. It shows signs of segmentation and the margin at the distal part as well as the margin of the lateral process are serrated (Fig. 5B). The second maxilla has the exopodite expanded but without setae. The first maxillipede is still a finger-like protuberance but with the indication of an epidopite (Fig. 5C). The second and third maxillipedes are with rudimentary exopodites without setae (Figs. 5A and C). The fifth pereiopod is longer than the abdomen and has six distinct segments. Gills are present on the third maxillipede and the first four pereiopods. The abdomen has become very much longer and there are indications of segmentation. These are especially distinct in the middle region of the abdomen but does not extend out to the sides. The uropods almost resemble those of the adults. All the pleopods are present as small protuberances. The telson shows two short lateral spines (Fig. 5D).

Subsequent stages are not available but it is likely that this may represent a fairly advanced stage and that there may be only two or three more stages before the Phyllosoma metamorphoses into the puerilla stage.

Stephensen (1923) has described the Phyllosoma of what he believes to be of *T. orientalis* from a single specimen. According to his description the carapace of the head is pear-shaped, somewhat longer than broad and the thorax nearly as long as broad with a notch in the posterior margin in which the short abdomen is set. The oral parts, according to him, resemble those of *Scyllarus arctus* at the same stage. Gurney (1936) has described six stages, stages IV to IX of Phyllosoma of *Thenus* and according to him the general characters are "Fore-body pear-shaped narrow in front in early stages, about 1½ times as wide as long; wider than hind-body. Hind-body deeply concave behind. Abdomen small and narrow."

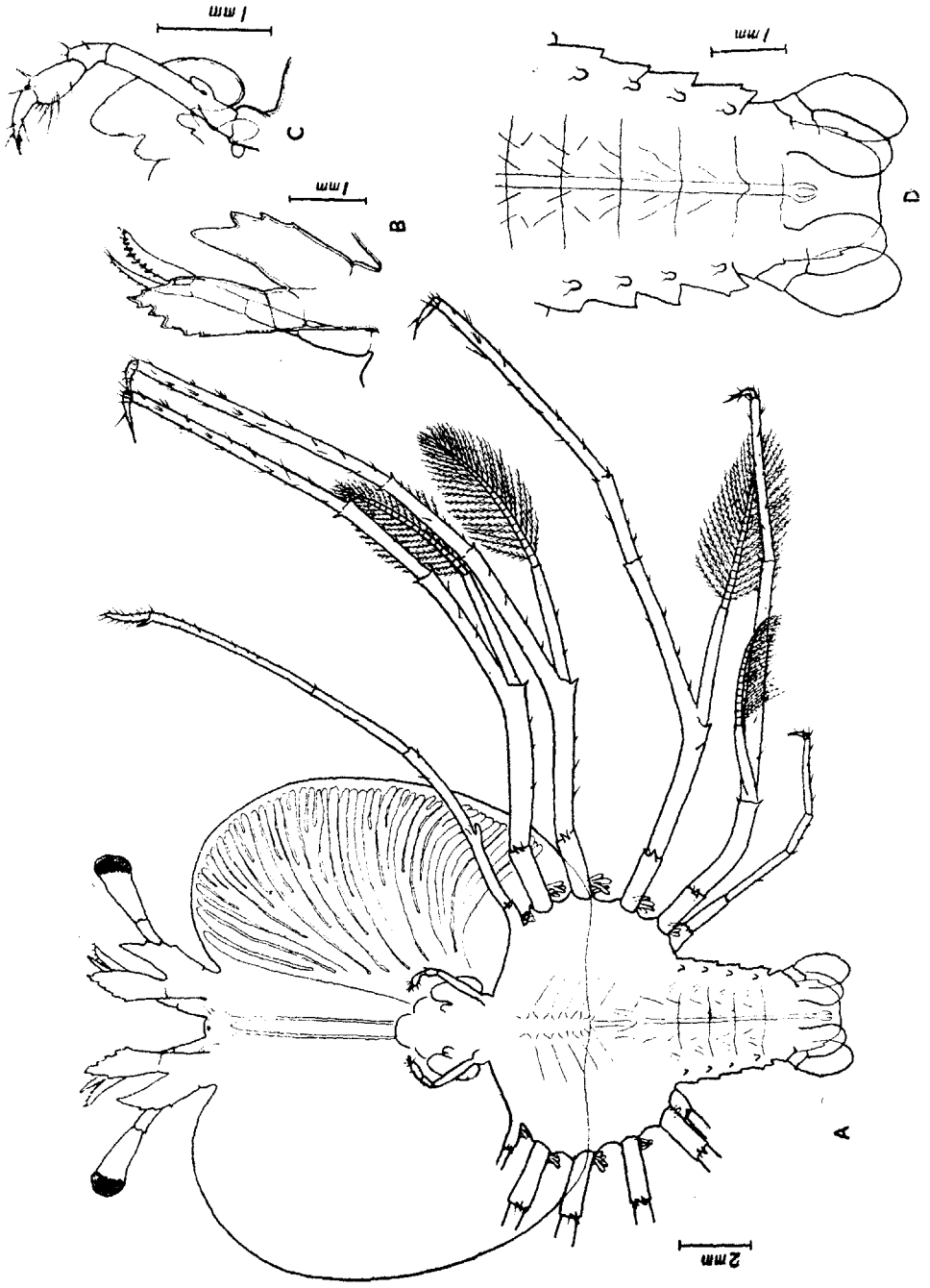
"Antennule with segments 2 and 3 equal, not much shorter than segment 1. Antenna short and stout, with strong pointed process on outer side of segment 2 of peduncle, segment 3 very much narrower than segment 2 in late stages."

"Maxillule without palp. Maxilla without setae on exopod. Maxillipedes 2 and 3 without functional exopods. Legs without coxal spines. Leg 3 with propodus dilated at end. Leg 5 without exopod, but with small rudiment of it in late stages."

It will be seen that the characters of the larvae of *T. orientalis* described here differ from those described by Stephensen (1923), the most significant difference being the shape of the fore- and hind-body and that of the abdomen. Similarly, the striking differences from the Phyllosoma of *Thenus* described by Gurney (1936) are the shape of the fore- and hind-body and the presence of coxal spines. However, the identity of the present series, at least that of the first Phyllosoma, is definitely known as the larvae hatched from a berried specimen kept in the aquarium and as the other three stages of Phyllosoma described here agree in all characters with the first Phyllosoma of *T. orientalis*, they seem to belong unquestionably to the same species.

Scyllarus sp.

A third type of Phyllosoma was obtained from the plankton of the Mandapam area and in the entire collection there were seven distinct stages of development.


1mm
C
1mm
B
1mm
D
A
2mm

From the general characters these undoubtedly appear to belong to the genus *Scyllarus*. The general characters of the Phyllosoma of the genus *Scyllarus* have been given by Gurney (1936) as founded on the description of *S. arctus*, based on the accounts given by Dohrn (1870 as quoted by Gurney) and Hornell (1894 as quoted by Gurney) both of whom described the first stage of *S. arctus* hatched from eggs and also by Stephensen (1923) who described the complete series of nine stages. The fore-body is much wider than long and much wider than the hind-body. Hind-body is not concave behind. Abdomen, in later stages, is very broad at the base and forms a direct continuation of the hind-body. Antenna is at first very much shorter than the antennule, later becoming broad at the base and with large outer pointed process; flagellum short and broad. Maxillule without palp. Exopodite of the maxilla with setae in the first stage but without setae in late stages. Second maxillipede without exopodite, or with exopodite rudimentary. Third maxillipede without exopodite. The dactylus of the second pereiopod not greatly elongated. The fifth pereiopod is without an exopodite and the pereiopods are with coxal spines. Pleopods in the last stage are very narrow and without appendix interna. The telson is with a large spine on either side.

Phyllosoma I (Fig. 6A)

The larvae measure 1.35 mm. in length. Stephensen (1923) has mentioned that the first Phyllosoma of *S. arctus* measures 1.5 mm. The fore-body is wider than long and much wider than the hind-body. The fore-body measures 0.54 mm. The eyes are thick stalked. The first antenna is longer than the eyes and at the commencement of the extreme third of its length there is a thin, long process. There are four terminal hairs one of which is much shorter than the other three. The second antenna is only about one-third the length of the first antenna. Both the first and the second antennae are unsegmented (Fig. 6B). The second maxilla consists of two joints, a long basal one and a small apical one which bears four plumose setae. The second maxillipede consists of five segments (Fig. 6C) and in general it resembles the second maxillipede of *Panulirus* and *Thenus*. The third maxillipede is without an exopodite. The first, second and third pereiopods are present of which the first two are biramous with a well developed exopodite bearing natatory setae. The third pereiopod has no exopodite but the second joint has at its distal end a short, thick process which may be the rudimentary exopodite. In the first Phyllosoma of *S. arctus* Stephensen (1923) has recorded a similar process. The rudiments of the fourth pair of pereiopods are seen as small rounded protuberances. All the pereiopods have coxal spines. The abdomen is short, slightly broader at the base and the corners are drawn out into a fairly long point on either side each with three setae (Fig. 6D).

EXPLANATION OF THE FIGURE 5.

Figure 5. A. Phyllosoma IV of *T. orientalis* (Drawn from a whole mount). B. The first and second antennae. C. The second maxilla and the second and third maxillipedes. D. The abdomen.

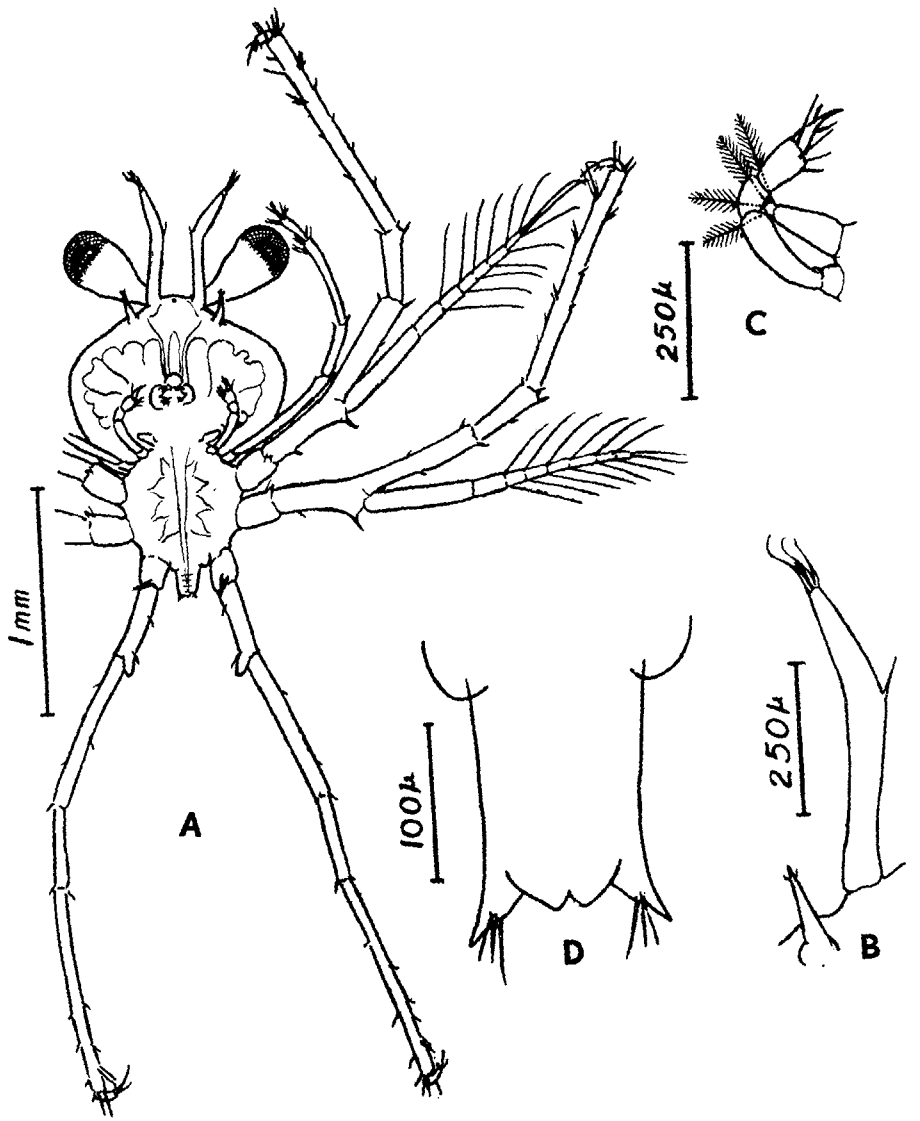


Figure 6. A. Phyllosoma I of *Scyllarus* sp. B. The first and second antennae. C. The second maxilla and the second maxillipede. D. The abdomen.

Phyllosoma II (Fig. 7A)

The larvae measure 1.83 mm. in length. There is a slight change in the shape of the fore-body which has now become more or less as long as it is broad. The eye-stalk has become thinner with a proximal cylindrical part and a distal somewhat conical part and the eyes are longer than the first antennae. Towards the tip of the first antenna a row of sensory setae has developed and except for this it resembles that of the previous stage (Fig. 7B). The second maxilla and the second maxillipede remain essentially the same as in the previous stage (Fig. 7C). The third pereiopod has an unsegmented exopodite. The rudiments of the fourth pair of pereiopods have appeared and they are longer than the abdomen. The tip of the abdomen shows very little change from that of the earlier stage (Fig. 7D).

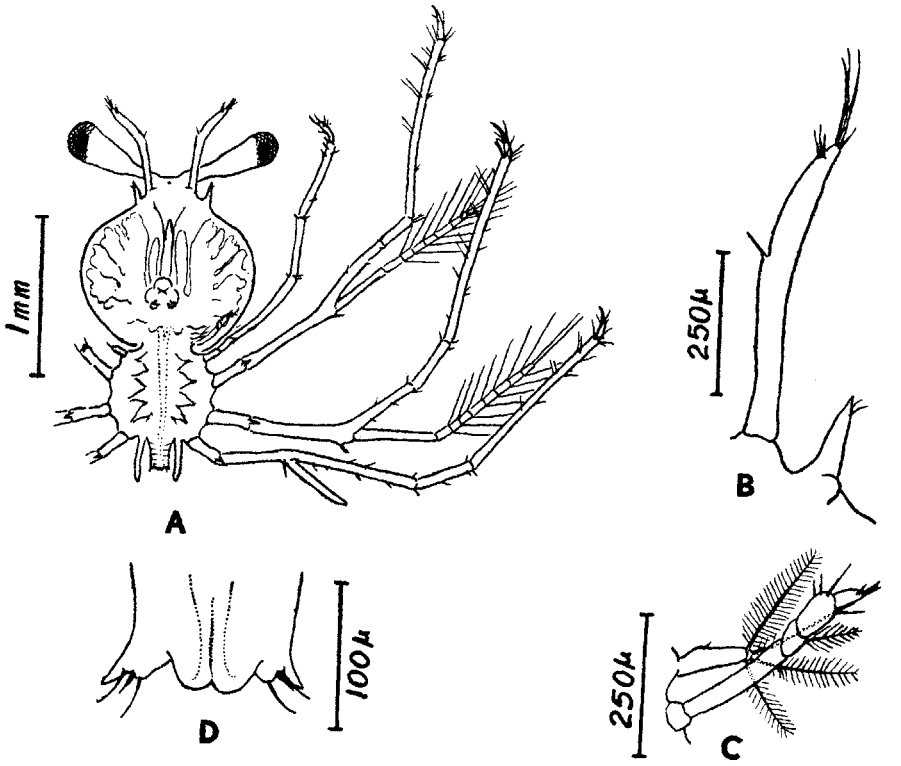


Figure 7. A. Phyllosoma II of *Scyllarus* sp. B. The first and second antennae. C. The second maxilla and the second maxillipede. D. The abdomen.

Phyllosoma III (Fig. 8A)

The larvae measure 2.65 mm. in length. The fore-body is a little longer than broad. The eyes are longer than the first antennae and the eye-stalk now consists of a distinct narrow, proximal, cylindrical part articulated with the distal, conical part. More sensory setae have developed on the first antenna. The process which was present at the commencement of the extreme third of the first antenna has now greatly thickened. The second antenna has slightly increased in length (Fig. 8B). The second maxilla and second maxillipede remain essentially the same as in the previous stage (Fig. 8C). The exopodite of the third pereiopod is fully developed with natatory setae. The fourth pereiopod has grown longer and the exopodite is present as a small protuberance. The tip of the abdomen shows no change from that of Phyllosoma II.

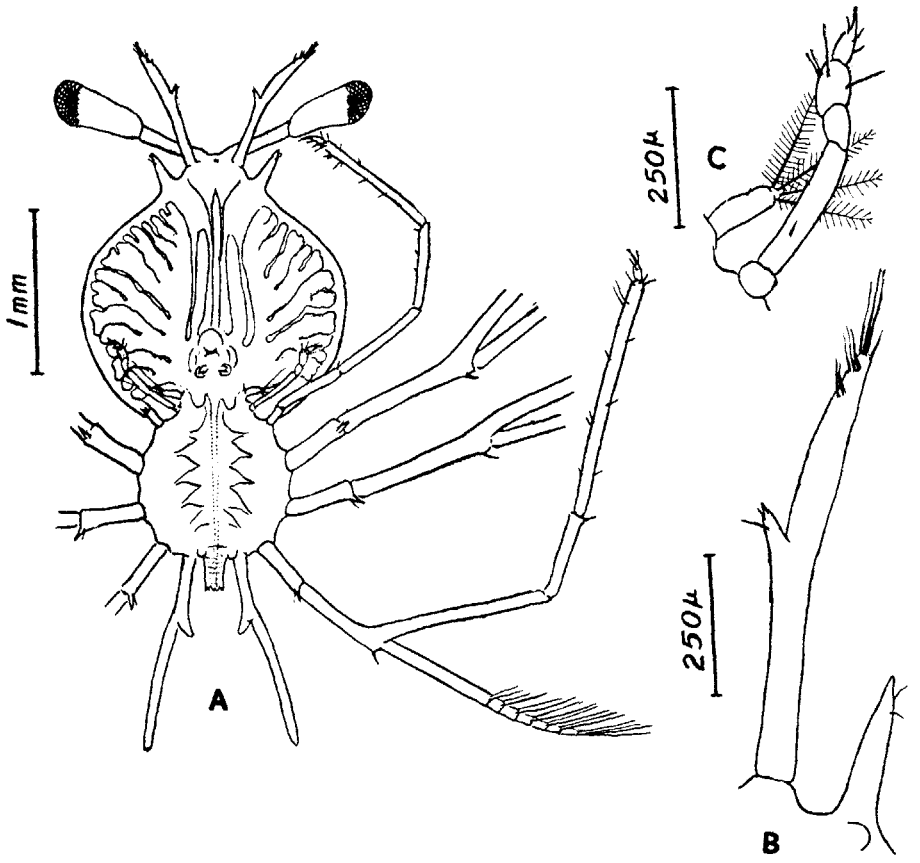


Figure 8. A. Phyllosoma III of *Scyllarus* sp. B. The first and second antennae. C. The second maxilla and the second maxillipede.

Phyllosoma IV

The next stage available in the series is the larvae measuring 2.97 mm. (Fig. 9A). In general appearance they resemble very closely the Phyllosoma of the previous stage described. The fourth pereiopod has increased in length and segmentations are clearly visible. The most important change is in the abdomen. The base of the abdomen has become much broader and the rudiments of the uropods are distinctly seen as a pair of protuberances (Fig. 9B).

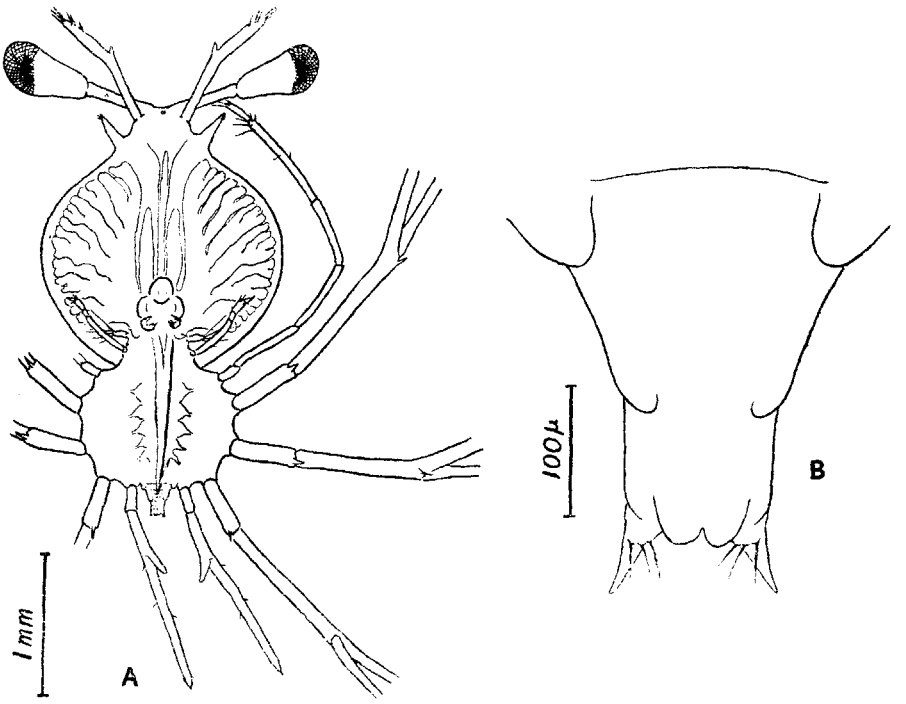


Figure 9. A. Phyllosoma IV of *Scyllarus* sp. B. The abdomen.

Phyllosoma V (Fig. 10A)

The larvae measure 3.31 mm. in length. The eyes are a great deal longer. The first antenna shows more sensory setae and also indications of segmentation. The inner process has now grown bigger. The second antenna is longer and is very nearly half the length of the first antenna (Fig. 10B). The second maxilla and the second maxillipede remain unchanged (Fig. 10C). The fourth pereiopod has increased very much in length, the segmentations are clearly indicated and the exopodite has become longer but without natatory setae. The rudiments of the fifth pereiopods are clearly indicated. The abdomen does not show any marked differences from that of Phyllosoma IV except that the rudiments of the uropods have become more prominent (Fig. 10D).

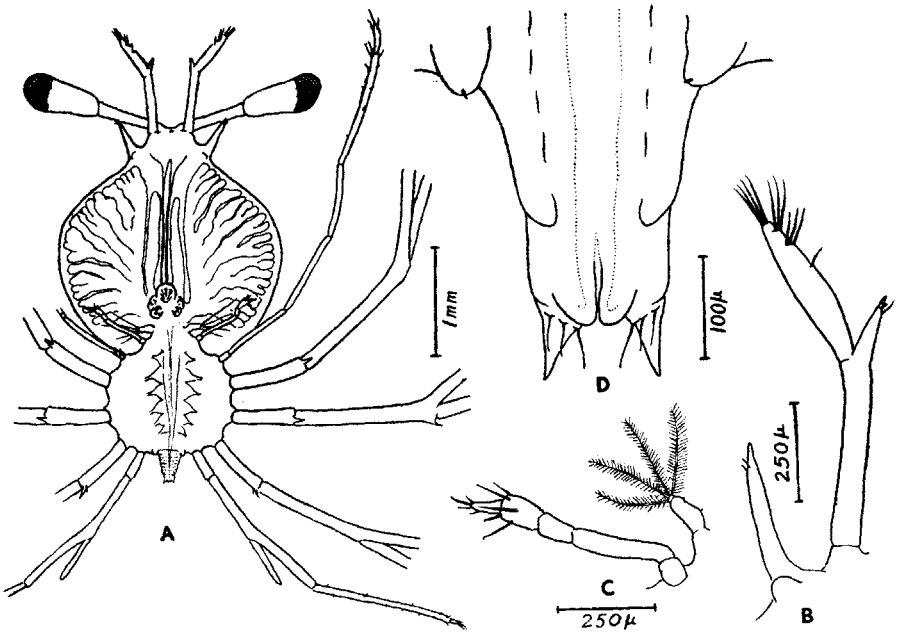


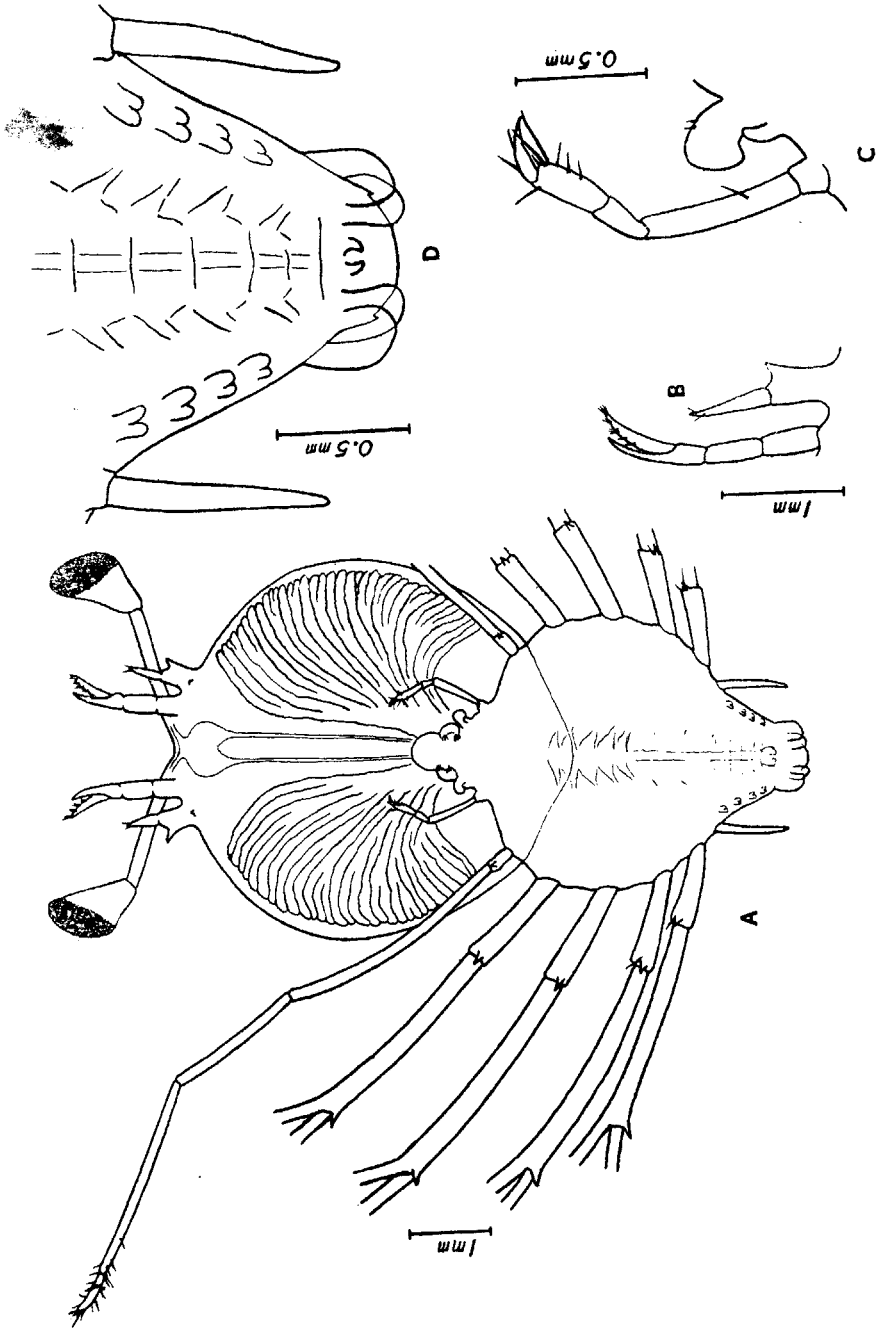
Figure 10. A. Phyllosoma V of *Scyllarus* sp. B. The first and second antennae. C. The second maxilla and the second maxillipede. D. The abdomen.

Phyllosoma VI

The Phyllosoma available in the next stage of development measures 8.02 mm. (Fig. 11A). The eyes have become very much longer. The peduncle of the first antenna is three jointed and the first antenna has many more sensory setae. The second antenna has become longer and broader and is distinctly two segmented. The distal segment is somewhat conical and the basal segment has developed a process on the outer side (Fig. 11B). The second maxilla has changed markedly. It has become broad and leaf-like and has lost its small apical joint and the plumose setae. The first maxillipede has now appeared and is in the form of a finger-like process. The second maxillipede remains essentially similar to that of the earlier stages (Fig. 11C). The exopodite of the fourth pereiopod is fully developed and has the natatory setae. The fifth pereiopod is rudimentary but is almost as long as the abdomen. The base of the abdomen has become very much broader and forms a direct continuation of the hind-body. The uropods have increased in length and are deeply cleft. The telson is clearly marked off now and it has two short spines on either side. The pleopods are indicated as bifid processes. The abdomen shows faint indications of segmentation in the middle (Fig. 11D).

EXPLANATION OF THE FIGURE 11.

Figure 11. A. Phyllosoma VI of *Scyllarus* sp. B. The first and second antennae. C. The second maxilla, the rudiment of the first maxillipede and the second maxillipede. D. The abdomen.


A
1mm
B
1mm
C
0.5mm
D
0.5mm

Phyllosoma VII

The last stage in the series of Phyllosomas belonging to this type measures 14.30 mm. The fore-body has slightly changed its shape. The eyes have become still longer (Fig. 12A). The first antenna has a peduncle of three segments. The process which is to become the inner flagellum has developed a few hairs. It is still not articulated at its base. The second antenna has become broader at the base and is longer. The distal segment, which was conical, has become flat and leaf-like, the upper half of the inner margin having serrations. The lateral process on the second antenna has also increased in size (Fig. 12B). The second maxilla has a large exopodite. The first maxillipede remains as a finger-like process but with an epipodite. The second maxillipede has a rudimentary exopodite (Fig. 12C). The fifth pereiopod is five jointed and is almost as long as the abdomen. Stephensen (1923) has noticed in *S. arctus* that in most specimens corresponding to this stage the fifth pereiopod has only four joints but in some specimens there are five, the dactylus forming a segment by itself. The abdomen has grown considerably. There are clear indications of segmentation particularly in the middle region of the abdomen. The uropods have become larger and the exopodite is distinctly articulated. The two short spines on the telson are still present. The pleopods are much longer and deeply cleft (Fig. 12D).

The characters of the seven stages of Phyllosoma described above show close agreement with the larvae of *S. arctus* described by Stephensen (1923). According to him there are nine Phyllosoma stages in all but in some, however, the difference between the previous and succeeding stages is only slight. The stage of development of the fourth and fifth pereiopods and the abdomen with corresponding pleopods and uropods seems to give the best means of distinguishing the stages because the eyes, antennae and oral parts do not seem to afford quite such good characters for determining the age, as these do not altogether keep pace in regard to development with the pereiopods and the abdomen. On this basis the present collection consists of seven distinct stages. Phyllosomas I to V correspond to stages I to V of *S. arctus* described by Stephensen, whereas Phyllosoma VI and VII in the series seem to correspond to stages VII and VIII of Stephensen. Phyllosma VIII is fairly advanced and it is likely that in this species of *Scyllarus* also there are only nine stages in all, as in *S. arctus* in which case stages VI and IX alone are missing.

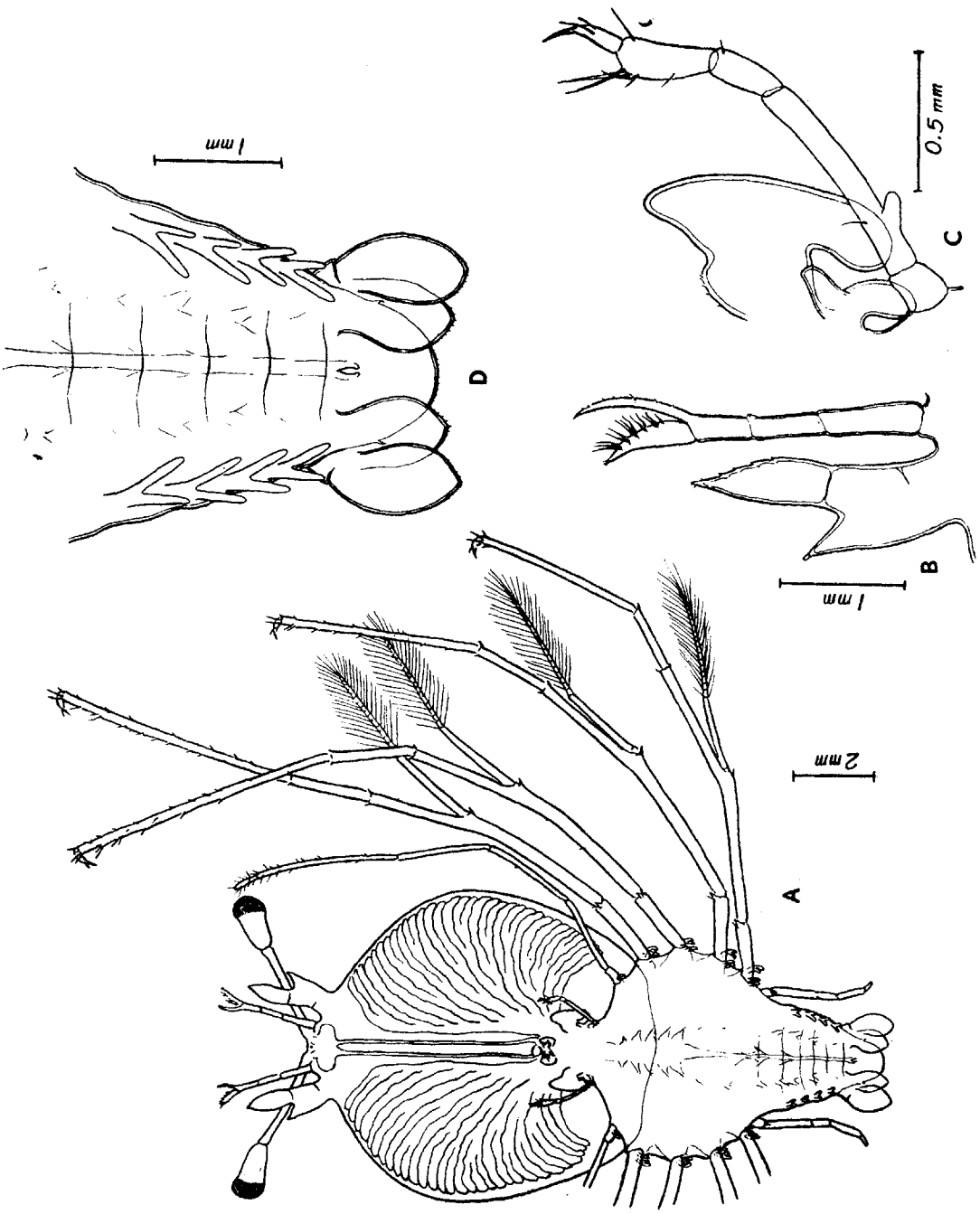
Specimens of *Scyllarus* have not been obtained so far in this area but *S. orientalis* (Spence Bate) has been recorded from the Bay of Bengal and the Arabian Sea and *S. arctus* var. *paradoxus* Miers from the Indian Ocean (Ramadan, 1938). Since *S. orientalis* is common both in the Bay of Bengal and the Arabian Sea the Phyllosoma described here may, in all probability, belong to this species.

Seasonal Distribution of Phyllosoma in the Plankton

Plankton studies at many centres along the coasts of India have shown that Phyllosoma larvae are relatively scarce in the inshore plankton. Aiyar, Menon and Menon (1936) have reported their occurrence in the Madras plankton during December to February. Menon (1945) observed Phyllosoma at intervals during November to March in small numbers off Trivandrum but in January 1939 he noticed swarms of these. Alikunhi (1948) has remarked that these larvae, though not very common, form a conspicuous item of the macroplankton of the Madras

Explanation of the figure 12.

Figure 12. A. Phyllosoma VII of *Scyllarus* sp. B. The first and second antennae. C. The second maxilla, the rudimentary first maxillipede and the second maxillipede. D. The abdomen.


0.5 mm
C
1 mm
D
1 mm
B
2 mm
A

coast particularly during March. In the waters around the Krusadai Island, Chacko (1950) recorded them as occurring during October to February. Bal and Pradhan (1952) recorded their occurrence in Bombay waters during December to April and off Calicut George (1953) observed that they are generally rare except for stray specimens during January to March. Prasad (1954) reported that Phyllosoma were generally found in the plankton of the Mandapam area during February to March and occasionally in June.

In spite of the scarcity of the Phyllosoma larvae in the inshore plankton it is interesting to note that the period of occurrence reported by the various investigators, both along the east and west coasts of India, is almost the same i.e., from December to March or April with the maximum number probably during January to March. Most of the early stages available to the present authors were obtained during January to March and the late stages during June to September. As mentioned earlier an ovigerous *P. ornatus* was obtained in January. A single specimen of *P. fasciatus*, caught on August 31, 1956, moulted in the aquarium on December 26 and on January 30, 1957 it became berried. The berried specimen of *T. orientalis* was, however, caught early in July and the larvae hatched in the aquarium in the third week of July. This may be an instance of off-season spawning which is not uncommon among the decapod crustacea. It seems probable, therefore, that breeding takes place generally from December to March or April and the occurrence of late stages during June to September suggests that the larval life may extend up to about six months. Sheard (1949) observed in Western Australia that in *Panulirus longipes* hatching of eggs takes place from December to February with some isolated cases in November and March while the puerilla and the first juvenile lobsters were seen from June to October and that the duration of larval life in different species ranges from about three to perhaps six or seven months.

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Summary

The first Phyllosoma of *Panulirus ornatus* and *Thenus orientalis* has been described based on larvae hatched in the aquarium. Attempts to rear the larvae in the aquarium to study the complete larval history proved unsuccessful. Descriptions of three more stages of Phyllosoma of *T. orientalis* and seven stages of Phyllosoma of a species of *Scyllarus*, persumably *S. orientalis*, obtained from the local plankton, have been given. From the available data the occurrence of Phyllosoma in the Indian coastal waters appears to be during December to April which gives some indication of the breeding season. The larval life seems to be protracted and may extend up to about six months.

References

Aiyar, R. G., Menon, K. S., and Menon, M. G. K. (1936). Plankton records for the years 1929 and 1930. *J. Univ. Madras*, **8**, 97–139.

Alikunhi, K. H. (1948). Note on the metamorphosis of Phyllosoma larvae from the Madras plankton. *Proc. 35th Indian Sci. Congress, Pt. III, Abstracts*, 193.

Bal, D. V., and Pradhan, L. B. (1952). Records of zooplankton in Bombay waters during 1944–47. *J. Univ. Bombay*, **20**, 75–80.

Chacko, P. I. (1950). Marine plankton from waters around the Krusadai Island. *Proc. Indian Acad. Sci.*, **31**, Sec. B, 162–174.

George, P. C. (1953). The marine plankton of the coastal waters of Calicut with observations on the hydrological conditions. *J. Zool. Soc. India*, **5**, 76–107.

Gurney, R. (1936). Larvae of decapod crustacea Pt. III.—Phyllosoma. *Discovery Repts.*, **12**, 400–440.

Johnson, M. W. (1956). The larval development of the California spiny lobster, *Panulirus interruptus* (Randall), with a note on *Panulirus gracilis* Streets. *Proc. California Acad. Sci., Ser.* 4, **29**, 1–19.

Lebour, M. V. (1950). Notes on some larvae Decapods (Crustacea) from Bermuda. *Proc. Zool. Soc. London*, **20**, 369–379.

Lewis, J. B. (1951). The Phyllosoma larvae of the spiny lobster *Panulirus argus*. *Bull. Mar. Sci. Gulf. & Caribbean.*, **1**, 89-103.

Menon, M. A. S. (1945). Observations on the seasonal distribution of the plankton of the Trivandrum coast. *Proc. Indian Acad. Sci.*, **22**, Sec. B, 31–62.

Prasad, R. R. (1954). Observations on the distribution and fluctuations of planktonic larvae off Mandapam. Symposium on marine and freshwater plankton in the Indo-Pacific, 1954. *Proc. Indo-Pacific Fish. Council Symposium*, 21–34.

Ramadan, M. (1938). The Astacura and Palinura. The John Murray Exped., 1933-34. *Sci. Repts.*, **5**, 123–145.

Sheard, K. (1949). The marine crayfishes (Spiny lobsters), Family Palinuridae, of Western Australia with particular reference to the fishery on the Western Australian crayfish. (*Panulirus longipes*). *Commonwealth Sci. Indus. Res. Organisation, Australia, Bull.*, No. 247, 1–45.

Stephensen, K. (1923). Decapoda-Macrura excluding Sergestidae. *Rept. Danish. Ocean. Exped.* 1908–10, **2**, Biology, D, 3, 1–85.

Von Bonde, C. (1936). The reproduction, embryology and metamorphosis of the Cape crawfish *Jasus lalandii* (Milne Edwards) Ortman. Union S. Africa, Dept. Comm. Industr., Fish & Mar. Biol. Surv. Div., Invest. Rep., No. 6, 1–25.

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