The calculated weights for *L. splendens* are shown in Table 3 and these give, as shown in Figure 6, a good fit to the class means of the observed weights. It is seen that the weight of *L. splendens* increases at a rate slightly greater than the cube of the length.

SUMMARY

The silver belly, *Leiognathus splendens*, forms an important fishery of Thangachimadam on the Rameswaram Island, the annual catch being 500 tons, bringing a value of nearly Rs. 2,00,000 to the fishermen. The principal gear used commercially for the capture of the silver belly is a bag-net (locally known as *Mada valai*) having a mesh of ½ inch. The net is operated from the boat catamarans. The fishing is done in depths from 3 to 6 fathoms.

L. splendens matures at an average standard length of 60 millimeters and spawns from March till September, the peaks of the spawning period being in April and August. The mature eggs are spherical, translucent, contain a single oil globule and measure from 0.51 to 0.77 mm in diameter. Each fish matures rapidly and spawns more than once in a season. An ovary contains an average of 7,566 eggs. The larger fish may contain up to 11,000 eggs. The length-frequency distributions for the months for which data were available show that *L. splendens* attains an average standard length of 60 mm at the end of the first year and 72 mm at the end of the second year of its life. No fish was observed to attain a standard length of more than 85 mm. The weight of the fish increases at a rate slightly greater than the cube of the length. The correct formula for the length-weight relationship was found to be $W = .000015\ (L)^{3.2}$, where W = weight in grams, and L = length in millimeters.

5

THE LIFE HISTORY AND BIONOMICS OF AN INDIAN PENAEID PRAWN *METAPENAEUS DOBSONI*, MIERS

by

M. Krishna Menon*

ABSTRACT

This paper embodies the results of an investigation on the life history and bionomics of *Metapenaeus dobsoni*, one of the most important of the commercial species of penaeid prawns of the south-west coast of India.

MATERIAL AND METHODS

The life history was traced mainly by securing eggs and larvae from plankton collected at the surface and near the bottom from places ranging in depth from 2 to 13 fathoms, with nets made of organdy and ordinary mull. In addition to inshore hauls, offshore samples collected once a week from December 1949 to the end of May 1950 at places approximately 20 fathoms deep have also been examined. Nauplii and Protozoeae were obtained by hatching eggs and rearing the early larvae in small glass vessels and were compared with corresponding stages isolated from plankton. Late larval stages were secured both from plankton and by getting the immediately preceding stage to moult in the laboratory. Numerous individuals of the earliest post-larva obtained from plankton as well as from the last zoea (Mysis) were reared for varying lengths of time in order to establish specific identity and growth rate.

Adult and adolescent prawns have been collected from numerous brackish water localities such as Ennur and Pulicat near Madras, the mouth of the Adyar river in the same place, the backwaters along the Kerala coast and the mouths of some streams in the neighbourhood of Calicut. Samples from commercial catches were studied frequently. Valuable material was also available from the regular bi-weekly catches of fish made for the laboratory from the foreshore waters at West Hill, Calicut, up to a depth of 4 fathoms. Three types of nets are being used for this purpose, namely the gill net, the cast net and the boat seine locally called 'paithuvala' and these collections proved invaluable, especially in the study of the bionomics of the species.

*Prawns Research Officer, Central Marine Fisheries Research Station, Calicut.

The writer wishes to express his thanks to Dr. N. K. Panikkar for his helpful suggestions in the preparation of this paper.
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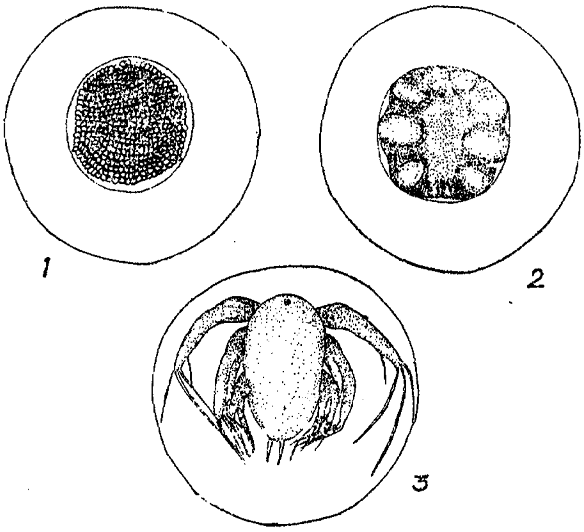
LIFE HISTORY

The life histories of a number of penaeids are fully known from the work of Gurney, Hudinaga, Dakin, Pearson and Mme Heldt. But none of the species are from Indian seas. The only published account of the larvae of an Indian form is that of *Penaeus indicus* given by the present writer (1937). Only the Protozoea and Zoea stages have been described, since the series was incomplete in the collection. So far as the genus *Metapenaeus* is concerned larvae of only one species are known, namely those of *M. stebbingi* described by Gurney (1927) from the Suez Canal. It will be evident from the following account that the course of development of the Indian species follows on closely parallel lines, having the same number of stages with numerous characters in common.



FIGS. 1–3. Ova of *Metapenaeus dobsoni*:
1. segmentation completed;
2. embryo with appendage buds;
3. fully developed nauplius.

Eggs. Figs 1-3. Eggs were obtained only from plankton, for there were no facilities for keeping mature females alive until they shed their eggs. Though penaeid eggs are believed to be demersal, large numbers of them belonging to *M. dobsoni* were found in plankton collections on several days made near the bottom as well as at the surface. They are buoyant and are easily stirred up by disturbances caused by currents or waves. These eggs have large perivitelline spaces like those of *Trachypenaeus constrictus* (Pearson 1939) rendering them much lighter than those of some other species and this peculiarity may account for their presence in surface samples.

With few exceptions the eggs obtained were in later stages of development. Two of them have been figured. One seems to be immediately after completion of segmentation, and the other with the rudiments of the 3 pairs of naupliar appendages developed as buds bent over the ventral surface of the embryo. Each egg measures 0.44mm in diameter and is perfectly spherical. In a few samples there were some slightly smaller, being only 0.35 mm in diameter. On hatching, the latter naturally gave rise to nauplii which were smaller, though the difference is too little to attract notice in a collection of both. Detailed study of the appendages failed to bring out any marked difference between the two sets of larvae either in this or the two subsequent stages. It seems fairly certain therefore that both sets of eggs belong to the same species. The eggs of *M. stebbingi* also are reported by Gurney to vary from 0.32–0.41 mm in diameter.

Both the early embryos and the fully developed nauplii do not fill the eggs completely, a wide space, the perivitelline space, being left around them. The embryo is closely invested by a thin embryonic membrane which ruptures later and the nauplius comes to lie within the egg membrane with the appendages partly straightened out so as to occupy the entire space inside. Eggs transferred to clean sea water in finger bowls or other glass containers kept cool by being stood in water, hatched invariably in the course of a few hours, the time varying, of course, with the state of development of the contained embryos. Some of the earliest batches of eggs secured in plankton behaved, however, in an entirely different manner. On 2 or 3 days in the month of September 1949, when the inshore water was extremely turbid due to rains and stormy weather, it was noticed that while some of the eggs kept overnight hatched normally, many did not hatch at all. In the latter set, however, the embryos continued to develop and in the course of the day had changed into protozoeae that were alive and showing movements though still enclosed within the embryonic membranes. They continued to live for a few hours, but later died, having failed to break the egg membranes. Though eggs were plentiful, larvae were surprisingly few in plankton on those days, showing thereby that either the vast majority of eggs perished without hatching or that the nauplii into which they hatched died soon afterwards.

As in *M. stebbingi*, there are only 3 naupliar stages, though in species of *Penaeus*, *Trachypenaeus* and *Sicyonia* several more stages have been observed by Hudinaga (1935), Mme Heldt (1938) and Pearson (1939). Nauplii hatched out early in the morning were found to have passed into the first protozoea stage by next morning or a few hours later so that this phase in the life history apparently lasts only from 24 to 36 hours.

Stage I.—Figs. 4-5. Length from anterior to posterior end excluding caudal setae 0.26-0.28 mm.

It agrees closely with that of *M. stebbingi.* The body is opaque, pear-shaped and unsegmented and has a pair of short setae at the posterior end. A prominent hump-like elevation is present on the dorsal surface. Ventrally there is the labrum, which in this stage is in the form of an approximately conical process with no free flap extending backwards. A median nauplius eye is visible in front of several individuals. The usual 3 pairs of appendages namely antennules, antennae and mandibles are present, the two latter being biramous.

Antennules—Uniramous, unjointed with 5 setae at the extremity, 2 of which are longer than the rest.

Antennae—Biramous ; both rami unjointed. Exopodite with 5 setae along inner margin and tip ; endopodite with 3-4.

Mandibles—Biramous ; branches short, each with 3 terminal setae. No masticatory process.

The larva does not feed, nutriment being provided by the yolk material inside the body making it opaque. As it grows this is gradually used up with the result that the last stage is somewhat semi-transparent.

Stage II.—Figs 6-9. Length 0.33 mm

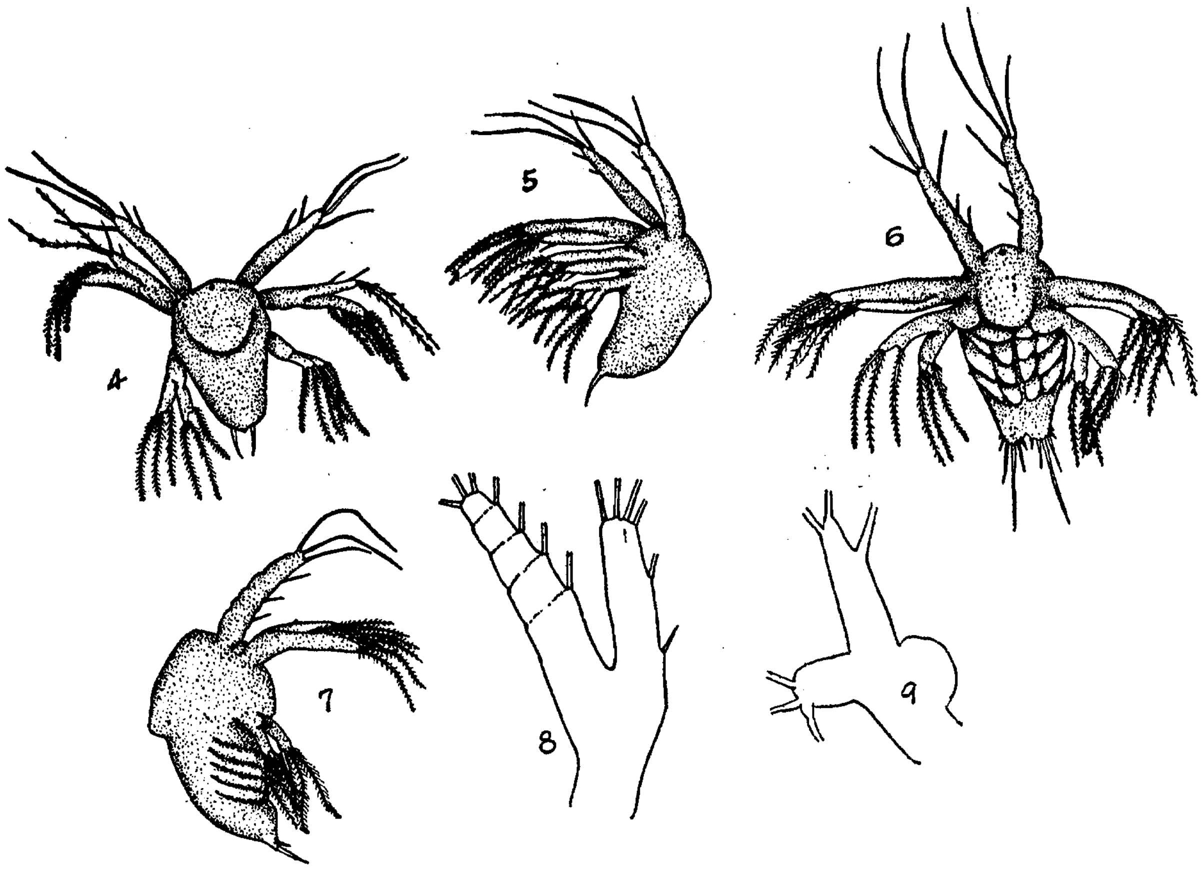
On the dorsal side a shell fold is plainly visible, its posterior margin being almost on a level with the base of the first pair of maxillae. Nauplius eye present in all. Posterior end of body, which carried anal setae in the previous stage, has elongated to become a short broad bilobed telson, each lobe carrying 6 setae, 2 on the outer margin and 1 inside being little more than points. Labrum is now free.

Antennules—Faintly segmented.

Antennae—Endopod with 4 terminal and 2 inner setae ; exopod with 4 faintly marked joints distally and 7 setae on inner margin and tip.

Mandible—A prominent hemispherical masticatory process at the base ; the 2 rami unchanged.

Rudiments of the 2 pairs of maxillae and first 2 pairs of maxillipeds have developed and are visible through the transparent cuticle.



FIGS. 4-5. Nauplius stage I:
(4) ventral view ; (5) side view.

FIGS. 6-9. Nauplius stage II:
(6) ventral view ; (7) side view ; (8) antenna ; (9) mandible.

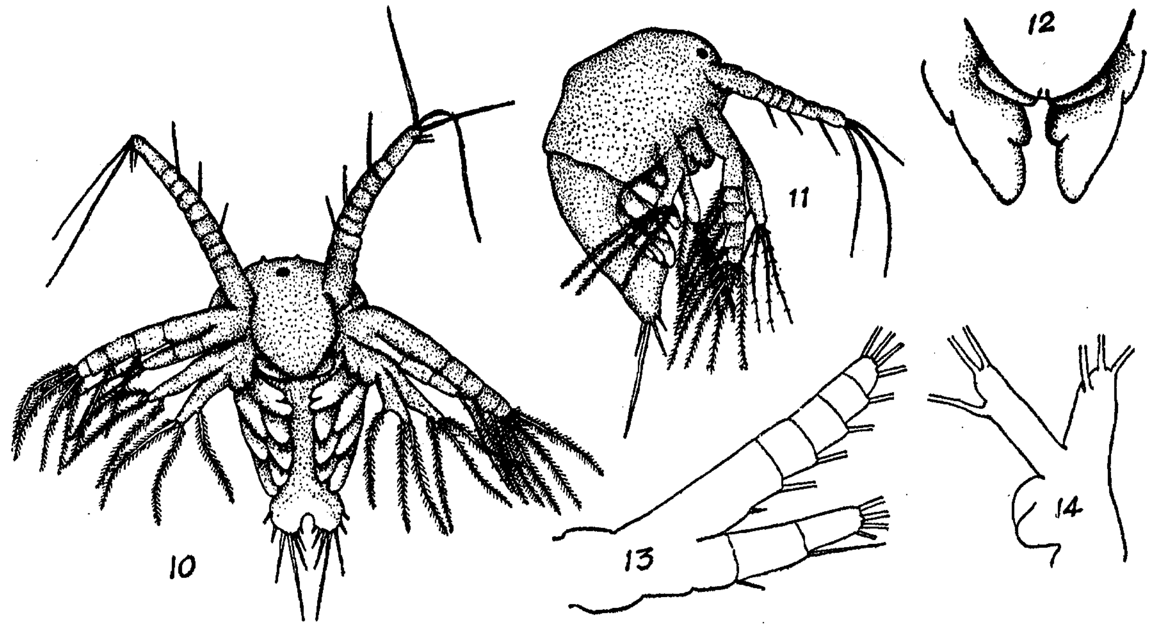
Stage III.—Figs. 10-14. Length 0.36-0.39 mm

This is the last nauplius. The body appears more slender than in the last stage. The shell fold extends backwards to include the somite of second maxilla and the telson has elongated further so as to form a conspicuous part of the posterior region of the body, the median notch of which has deepened. Its spine formula remains the same, but in older forms a minute point-like additional spine may be seen on the inner margin of each lobe. A pair of minute frontal organs are visible at the anterior end.

Antennule—Distinctly jointed with a few setae on the inner margin as in previous stage.

mass without pigment which later on becomes the stalked eye. In older larvae belonging to the same stage a patch of pigment develops at their outer extremities. The frontal organs are quite prominent and are slender and pointed. Such pointed frontal organs, as remarked by Gurney (1943), are present only in one other genus of Penaeinae, viz. *Parapenaeus*. All thoracic segments are well differentiated and the first abdominal somite is also faintly marked out.

Colouration.—A pair of branching reddish brown chromatophores at the posterior margin of the telson and one at the base of each second maxilliped; otherwise the larva is more or less transparent.



FIGS. 10-14. Nauplius stage III: (10) ventral view; (11) side view; (12) labrum, paragnatha and maxilla 1; (13) antenna; (14) mandible.

Antennae—Exopod with 8 setae and a spinelike rudiment proximally; endopod two-jointed, but with the same number of setae.

Mandible—Masticatory process larger and two-lobed. Rami in older larvae appeared to be quite empty as noted by Gurney also.

Labrum and paragnatha quite prominent and behind them rudiments of the following 4 pairs of appendages are free and biramous with minute setae in larvae approaching the moult into the protozoea stage.

PROTOZOEA

Stage I.—Figs. 15-21. Length 0.67-0.74 mm

The moult from the last nauplius to the first protozoea brings about striking changes in the appearance of the larva. The anterior part of the body is now covered over by a flat and approximately oval carapace extending up to the second segment of the thorax. The nauplius eye persists and on either side of it there is a cellular

Antennule—Not quite half as long as body; 5 segments marked out proximally beyond which 2 long joints; 2 long but unequal setae and 3 aesthetes at tip and a few setae on the inner and outer sides.

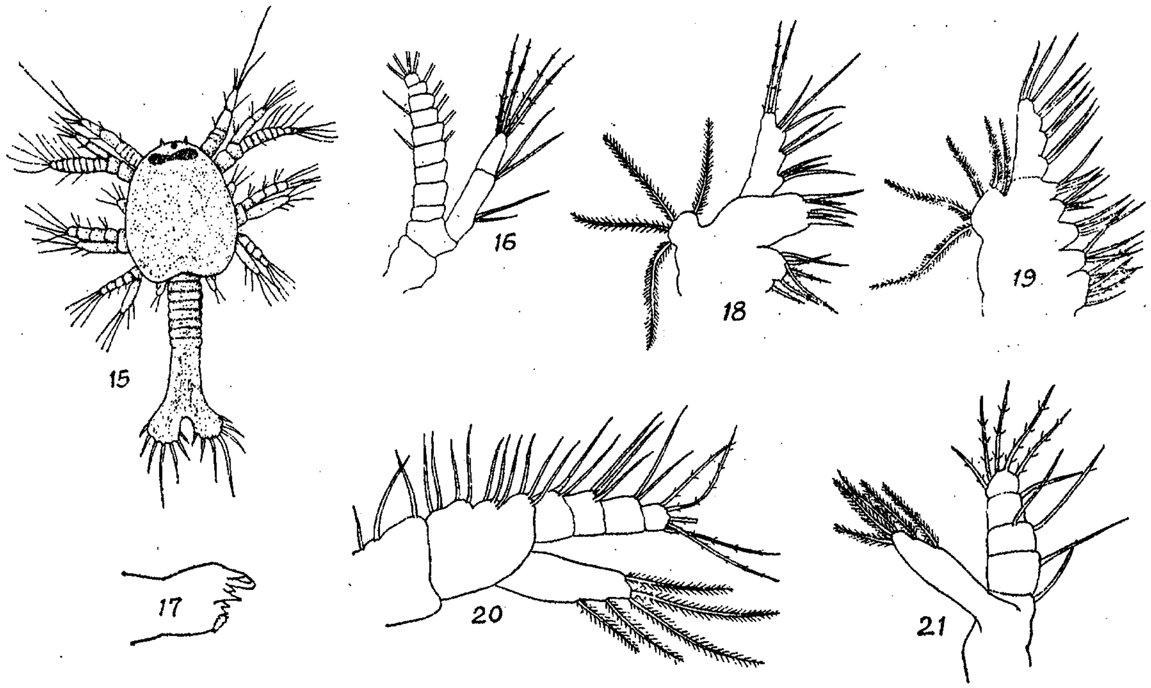
Antenna—A two-jointed protopodite, flagellum and exopodite present. Flagellum shorter, two-jointed and with 4 setae at tip and 2 pairs proximally. Scale with 9 segments; 9 plumose setae along inner margin and tip and 2 on outer margin on segments 4 and 6.

Mandible—Consists only of masticatory portion, the 2 rami having disappeared during the moult.

Labrum is prominent and bears a small forwardly directed spine.

Maxilla 1.—Consists of a basal portion produced into 2 endites, each with a number of short setae, a papilla-like exopod carrying 4 plumose setae and a faintly three-jointed endopod.

Maxilla 2.—Protopodite produced inwards into 5 endites, each armed with several setae. Exopod similar to that of maxilla I and carries 5 plumose setae; endopod four-jointed, each joint having 2-3 setae.



FIGS. 15-21. Protozoea stage 1:
15. dorsal view; 16. antenna; 17. mandible; 18. maxilla 1; 19. maxilla 2; 20. maxilliped 1; 21. maxilliped 2.

Maxilliped 1.—Fully developed and biramous, protopodite having several setae along inner margin. Exopodite shorter than endopodite with 3 terminal and 2 outer setae; endopodite four-jointed.

Maxilliped 2.—Similar to the first, but with much fewer setae on proto and endopodites.

Maxilliped 3.—Small, biramous rudiment with 2 setae at the tip of outer branch.

No other appendages are present.

Telson has 2 lobes, separated by a wide notch, each lobe having 7 setae, 4th from the outer side being the longest.

Unlike the nauplius, the protozoea feeds actively. In the laboratory they thrived well on diatoms and other forms of phyto-plankton mixed with microscopic animal forms which could not be separated.

Stage II.—Fig. 22. Length 0.81-0.98 mm

One of the most important advances which this stage shows over the first is the presence of well developed movable stalked eyes completely free from the carapace. Between them the median eye is still clearly visible. The anterior portion of the carapace is prolonged forwards between the eyes into a broad process which abruptly narrows into a short pointed rostrum. In older larvae there is a pair of small supraorbital spines, which in others are easily missed. Behind the thorax all abdominal somites except the last, are distinctly marked out. The telson remains unchanged with the same spine formula, namely 7 + 7. The appendages do not show much difference from those of the first except for the addition of one or more setae in some, as for example in the exopodites of the first and second maxillipeds which have now 7 and 6 setae respectively. Both branches of maxilliped 3 are approximately equal in length, the inner of which is unjointed and unarmed and the outer tipped with 3 setae. Small knoblike rudiments of the remaining 5 pairs of thoracic appendages are also present.

Colouration.—In addition to those noted in Stage I similar chromatophores have developed on the posterior surface of the ocular penduncles, labrum and ventrally in the region of the maxillipeds.

Stage III.—Figs. 23-25. Length 1.6 mm

The sixth abdominal segment is now cut off from the telson and the uropods have developed. The first 5 have small median spines dorsally and the fifth has a pair of lateral spines as well. The sixth segment has 2 pairs of lateral spines, a small dorsolateral pair and a slightly larger ventrolateral pair. Telson is unchanged with the same spine formula namely 7 + 7. In ***Penaeus***, ***Penaeopsis***, ***Parapenaeus*** and ***Trachypenaeus*** the spine formula is 8 + 8 so that in this respect ***Metapenaeus*** differs from the other genera of the Penaeinae. Nauplius eye is still visible and both the rostrum and supraorbital spines have grown.

Colouration.—Most of the chromatophores noted in stage II have grown larger and become branched, especially those on the telson. New ones have appeared in the middle of each abdominal somite and the exopodites of the uropods.

Antennule—Basal segmentation is hardly visible so that the appendage seems 3-jointed.

Antennae, mandibles and the 2 pairs of maxillae much as they were in the previous stage.

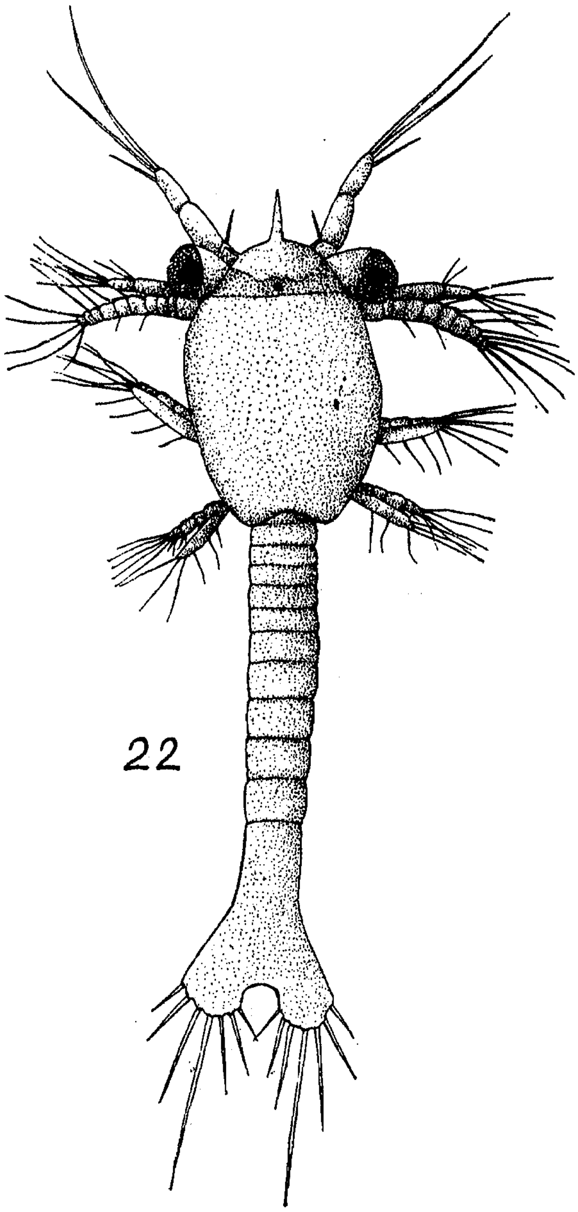


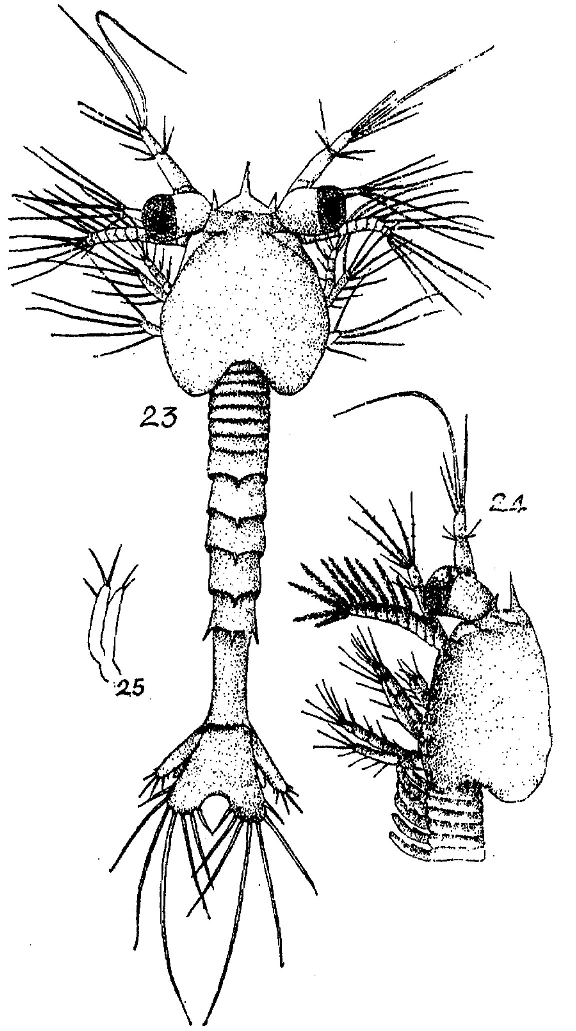
Fig. 22. Protozoea stage II.

Maxillipeds also unchanged except the third pair in which the endopod also tipped with a couple of setae.

Rudiments of the remaining 5 pairs of thoracic appendages are quite prominent and biramous, but unjointed and not functional.

Pleopods absent.

Uropods well developed and biramous; exopod slightly longer than endopod, with 6 short setae at extremity, the outermost and innermost of which are almost spinelike.



Figs. 23-25. Protozoea stage III :
23. dorsal view; 24. side view; 25. maxilliped 3.

ZOEA (Mysis).

While discussing the nomenclature of the different stages in the larval development of Decapoda, Gurney (1942) has pointed out the inappropriateness of the term Mysis. He has remarked that " it is an unfortunate term, implying a false relationship and it is not easily definable. Referring as it does to a stage with biramous legs, it cannot legitimately be applied to a stage with no exopods, although that stage is precisely equivalent to a Mysis stage in other forms. Furthermore, if the term is really used, as it has been, to imply a phylogenetic meaning, it should be applied to a stage in which the thoracic legs are free from the carapace, since thia is a much more fundamental feature of the Mysidacea than the possession of exopods ". He has suggested the term zoea instead and it is used here.

The moult from the last protozoea to the zoea brings about a striking change in the shape of the larva which now assumes that of the adult prawn. Besides the change in shape, the functional development of the exopodites of all the 5 pairs of walking legs and the appearance of the pleopods (in the later stages) are the other important advances of the zoea over the protozoea.

Colouration.—The colouration is similar to that of protozoea III. The pigment spots on the abdominal segments have begun to branch and in the later stages appear like vertically arranged plates forming one of the distinguishing features of the species.

Stage I.—Figs. 26-33. Length 1.8-2.3 mm

The rostrum reaches to the middle of the cornea of the eyes and bears no teeth; a short distance behind its base there is a small median papilla. A small antennal spine and a much larger pterygostomian spine behind the base of the antenna are present. Abdominal segments 5 and 6 have small median dorsal spines, an anal spine arises close to the margin of the last segment. Labral spine and the nauplius eye are still present.

Maxilliped 1 and 2.—Hardly any change from those of Protozoea III.

Maxilliped 3.—Endopodite 5-jointed; exopodite with setae at tip and functional.

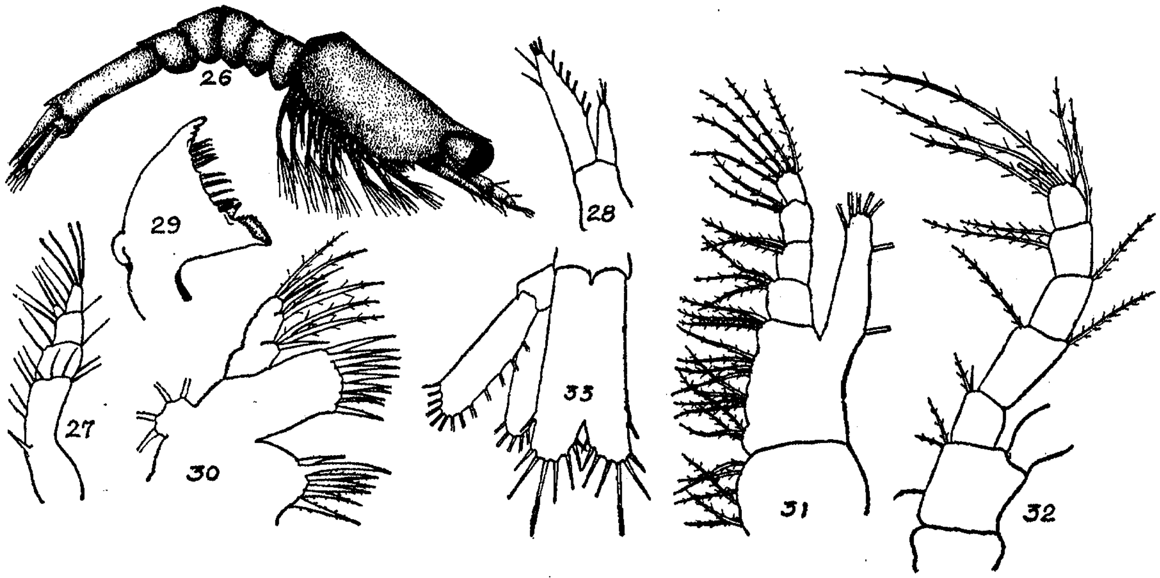
Legs 1-5.—Small and indistinctly segmented with functional exopodites.

A small gill present at the base of each of the first 4 legs. The development of gills at this stage seems rather precocious when compared to the Suez Canal larvae in which they develop only in the last zoea. Pleopods absent.

Telson and Uropods—Telson roughly parallel-sided with the posterior margin deeply cleft; spine formula 8+8, one on each side being on the outer margin. Basal segment of uropod with a small, curved outer spine. Exopodite and endopodite both setose, but without spine on the outer margin of the former.

Stage II.—Figs. 34-36. Length 2.4-2.8 mm

Rostrum has 1 tooth dorsally. Antennal and pterygostomian spines as well as spines on abdominal somites



FIGS. 26-33. Zoea stage I:
26. side view; 27. antennule; 28. antenna; 29. mandible; 30. maxilla 1; 31. maxilliped 1; 32. maxilliped 3; 33. uropod and telson.

Antennule—A peduncle consisting of 3 clearly marked segments and 2 unjointed flagella, the inner of which is small and knoblike. A prominent spine present on the inner side of the basal segment. No statocyst.

Antenna—Flagellum unjointed and about half as long as scale with 2-3 short setae at tip. Scale has 9 setae along inner margin and extremity, but no spine; 2 setae on its outer margin.

Mandible—Slightly asymmetrical, the number of serrated spines on one side being more. A rudimentary palp present.

Maxilla 1.—Similar to that of the last protozoea.

Maxilla 2.—Similar to that of protozoea III but number of setae, especially on exopodite, more.

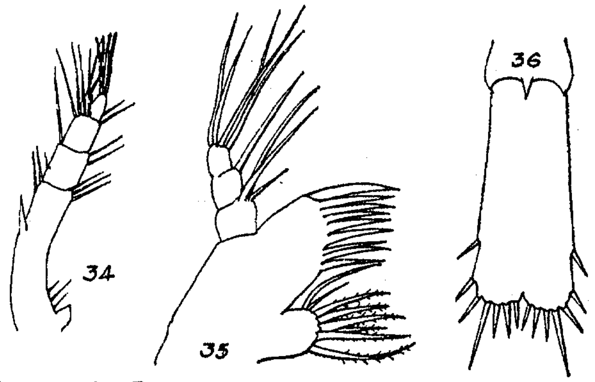
5 and 6 present as in previous stage. Small hepatic spine and pleopod rudiments have developed. Nauplius eye persists.

Antennule—A rudiment of the stylocerite in the form of a thin triangular process present; but the statocyst has not developed. Flagella equal in length to the third joint of peduncle and unjointed.

Antenna—Flagellum still unjointed and about half as long as scale; the latter with 15 setae along inner margin and tip and a spine.

Mandible—Palp slightly larger.

Maxilla 1.—Exopodite completely absent; but endopodite still jointed.



FIGS. 34-36. Zoea stage II:
34. antennule; 35. maxilla 1; 36. telson.

Maxilla 2.—Scale has 12-13 plumose setae.

Maxillipeds 1-3.—Similar to those of stage I.

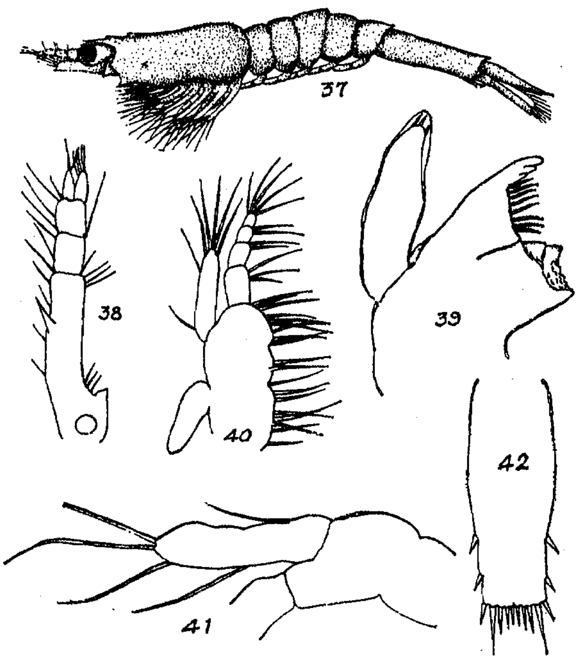
Legs 1-5.—First 3 minutely chelate.

No additional gill.

Telson and uropods.—Median cleft on posterior margin of telson quite small; only 7 spines on each side, 2 of which are on outer margin. Uropods not much changed.

Stage III.—Figs. 37-42. Length 3.3 mm

Rostrum has 2 dorsal teeth, one of which is some distance behind orbit, the other level with it. All other



GS. 37-42. Zoea stage III:
37. side view; 38. antennule; 39, mandible; 40. maxilliped 1; 41. leg 1; 42. telson.

spines on carapace and abdominal somites of previous stage still present. Nauplius eye persists. Pleopods are large and jointed, but uniramous and without setae.

Antennule—A well developed statocyst at the base of the peduncle. Flagella still unjointed.

Antenna—Flagellum with one segment at base and another at tip.

Mandible—Palp grown fully, but not jointed.

Maxillae 1 and 2—Show little change.

Maxilliped 1—A fairly large epipodite has developed.

Maxillipeds 2 and 3—Practically unchanged.

Legs 1-5—Large and jointed.

Number of gills remains the same.

Pleopods—Large, bent forwards and distinctly segmented, but not functional.

Telson—Shape of telson slightly different from that of stage II and this shape is retained in the early post-larval stages. Cleft on the posterior margin hardly visible. Two pairs of spines on lateral margins and 10 posteriorly.

Uropods.—Exopodite with a spine and 16-17 setae; endopodite also has an equal number.

POST-LARVAE

Stage I.—Figs. 43-50. Length 3-3.5 mm

The moult at the close of the zoea stage brings about two striking changes in the organization of the animal, namely the loss of exopodites from the thoracic appendages and the development of setae on the pleopods so as to make them functional and the chief natatory organs of the young prawn. According to Burkenroad this is usual in the subfamilies Penaeinae and Sicyoninae. In this species they do not completely disappear, degenerated stumps persisting in some individuals.

Rostrum has the same number of teeth as in the last zoea; in older individuals an extremely minute tooth also in front of the other two. A small somewhat triangular antennal spine is present; but the anterolateral angle of the carapace is not produced into a distinct pterygostomian spine. Hepatic spine quite conspicuous. Median dorsal spine only on the last abdominal somite, anal spine absent. Spine on labrum also absent; but on ventral surface of seventh thoracic somite a large forwardly bent spine has developed. Pleopods, though uniramous, are setose and functional.

Antennule—Differs but little from that of last zoea.

Antenna—A small spine on protopodite. Flagellum almost as long as scale, 4-jointed. Scale with 24-25 setae and a spine.

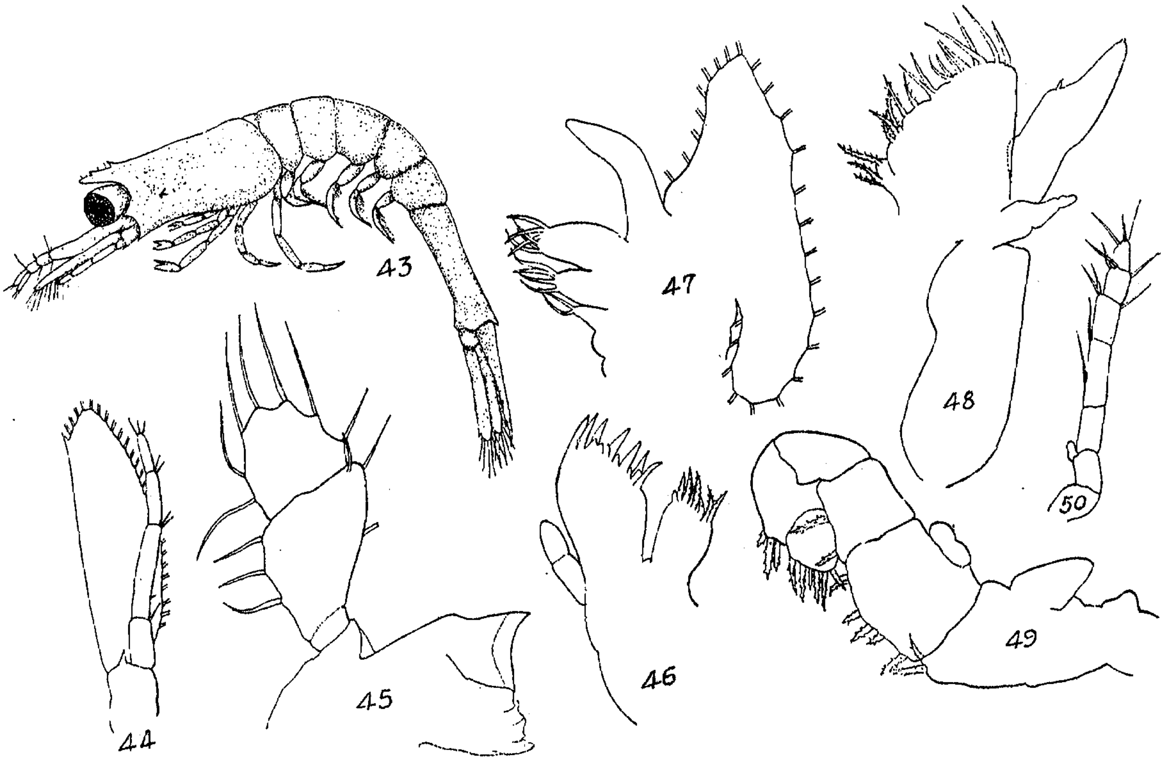
Mandible—Palp well developed, jointed and fringed with setae.

Maxilla 1—Endopodite considerably reduced in size, but faintly segmented and without setae.

Maxilla 2—Only 3 functional endites, the proximal endite of the zoea persisting as a degenerate lobe without setae. Palp unjointed and unarmed. Scale with numerous plumose setae.

Maxilliped 2—Epipodite and a small gill rudiment have appeared. Endopodite bent as in the adult.

Maxilliped 3—Neither epipod nor gill visible.



FIGS. 43-53. Post-larva stage I :
43. side view; 44. antenna; 45. mandible; 46. Maxilla 1;
47. maxilla 2; 48. maxilliped 1; 49. maxilliped 2;
50. maxilliped 3.

Legs 1-5—All jointed and functional. None with epipods; only 4 pleurobranchs as in zoea stages. Minute spines have developed on basipodites of first 3 pairs.

Pleopods—Exopodites fringed with numerous setae; endopodites absent.

Telson—Changed very little.

Post-larvae, older than the one described, were absent from plankton, although a large number of samples collected from close to the shore up to 12-13 fathoms were examined in the course of over an year. This contrasts markedly with the corresponding stages of *P. carinatus* and *P. indicus* which are frequently captured in the tow-net not only from the sea, but also from estuaries and backwaters connected with the sea. Presumably they go down soon after the moult into the second stage and adopt the bottom living habit.

In order to trace the successive changes brought about by each following moult on some of the structures which differ markedly from those of the adult like the rostrum, pleopods and telson, a few first stage post-larvae were reared separately in finger bowls and at every moult the shed skin was removed and examined. The moulting always happened at night so that the skins could be examined only the next morning. This method was adopted because of the difficulty of rearing a large number of specimens in order that one or two may be killed and examined at each moult. Despite its imperfection the method yielded a fairly good picture of their gradual development until they acquired the adult form.

These observations were started on 22-6-50 with 4 individuals obtained on that day from the last zoea stage. Moulting occurred at intervals of 2 days at first, but subsequently the periods became somewhat irregular. The dates on which one of the specimens moulted are given below :

1950, June 23, 25, 27 July 2, 5, 9, 11, 20

This specimen died shortly after the last moult. Another individual which had passed into the same stage on 21-7-50 moulted on 25-7-50, 28-7-50, 2-8-50, 4-8-50, 9-8-50 and 13-8-50. As the parts mentioned above had acquired the adult characteristics at this stage no attempt was made to follow the moults regularly thereafter. Their gradual development during this period of approximately a month and 3 weeks is briefly summarised below :

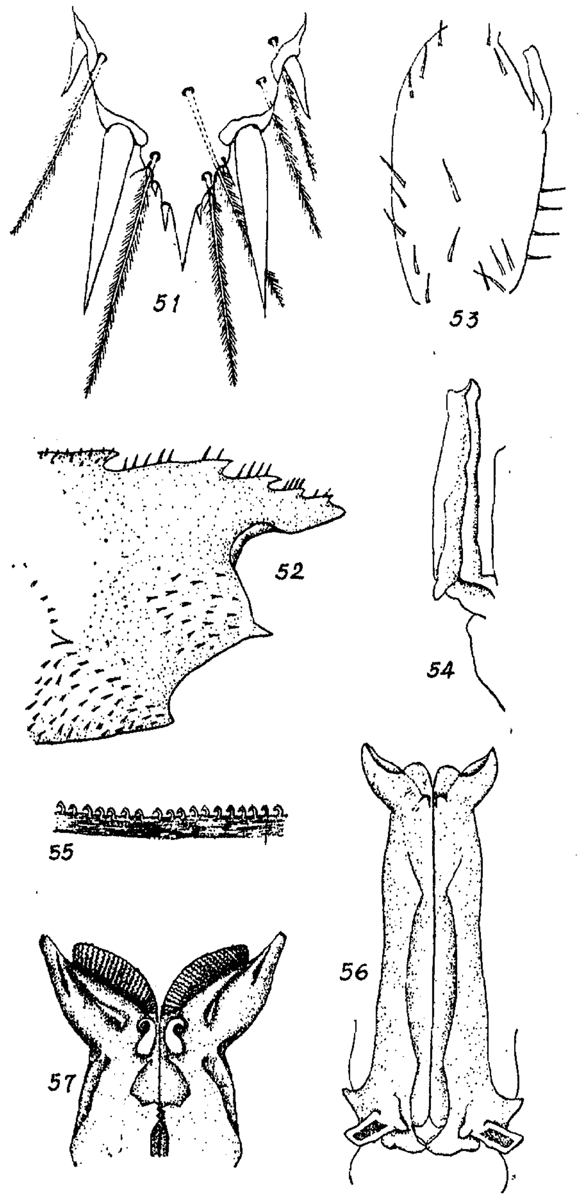
Post-larva II—A minute third tooth on rostrum; pleopods and telson unchanged.

Post-larva III—3 well developed teeth on rostrum; pleopods and telson unchanged.

Post-larva IV—Rostrum broken; pleopods unchanged; telson considerably narrower posteriorly; spines on its posterior margin between the large ones at the angles quite small.

Post-larva V—Rostrum missing; pleopods unchanged; telson as in stage IV.

Post-larva VI—Rostrum with 4 large and 1 minute teeth; pleopods unchanged; between large spines of telson a pointed triangular process has developed, on either side of which the remaining spines have become considerably reduced.



FIGS. 51-52. Post larva VII:

51. extremity of telson; 52. anterior portion of carapace.

FIGS. 53-57. Development of petasma:

53. rudiment of petasma developing on protopodite of pleopod 1;

54. the same has become grooved; 55. hooks on anterior margin;

56. lobes of petasma united; 57. extremity of adult petasma, anterior view.

Post-larva VII—Figs. 51-52. Rostrum with 5 teeth and the dorsal crest characteristic of the adult just developed; minute knoblike endopodites with setae on pleopods 2-5; posteromedian process of telson larger.

Post-larva VIII—Rostrum with a point-like 6th tooth; endopodites of pleopods as fingerlike processes; posteromedian process of telson reaches almost to extremity of large spines, the smaller ones reduced to mere points. Antennal flagellum about two and a half times as long as scale.

Post-larva IX—Rostrum with 6 fully developed teeth, endopodites of posterior pleopods about half of exopods; posteromedian process of telson just projects beyond tips of large spines; antennal flagellum about four times as long as scale.

Post-larva X—Rostrum with a pointlike 7th tooth; endopodites of pleopods prominent and fringed with several setae; posteromedian process of telson much the same as in last stage; antennal flagellum stretches backwards up to the middle of telson.

Post-larva XI—Rostrum with 7 teeth; pleopods as in last stage; posteromedian process of telson longer and the two large spines of previous stages reduced; a small thin process has developed on the protopodite of the first pleopod, which is the rudiment of the petasma.

Post-larva XII—Rostrum with a minute 8th tooth; large spines on either side of the median process of telson hardly larger than anterior lateral teeth; antennal flagella stretch considerably beyond tip of telson; rudiment of petasma larger.

Post-larva XIII—Rostrum with 8 fully developed teeth; endopodites of pleopods and petasmal rudiments have grown slightly; lateral teeth of telson hardly visible.

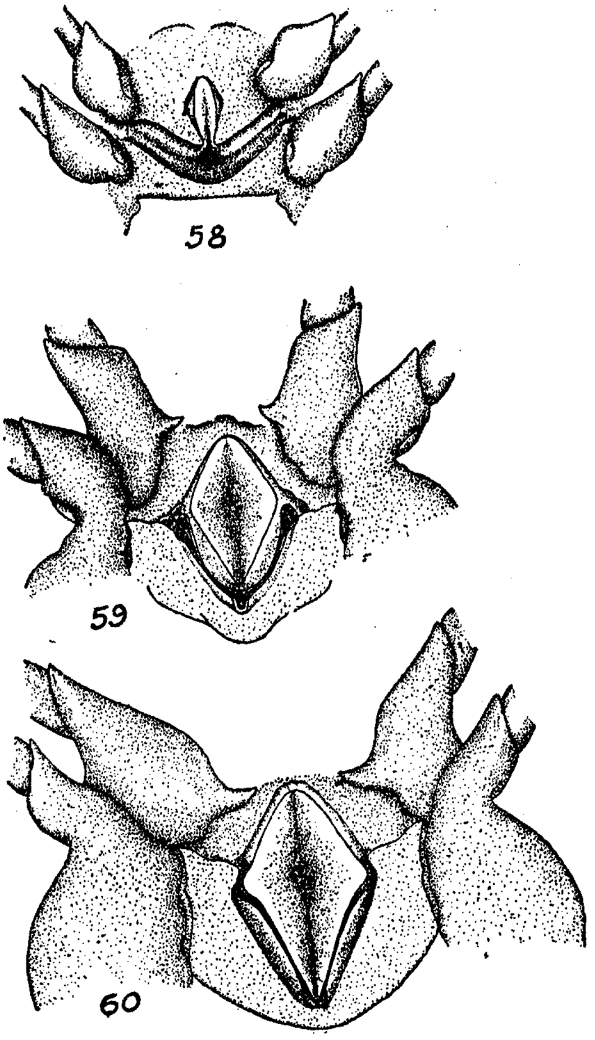
The number of teeth on the adult rostrum is never more than 8. Starting with 2 in the first post-larva, the full number is therefore established in the course of a succession of 12 moults.

DEVELOPMENT OF EXTERNAL SEXUAL ORGANS

The petasma or andricum and the thelycum (receptaculum seminis) of the male and female respectively afford easily recognizable characters of taxonomic value and a brief account of their development is therefore added below:

Petasma.—Figs. 53-57. It is made up of 2 halves, each borne by the protopodite of the first pleopod. As noted already it develops as a short thin foliaceous process from about the middle of the protopodite in the 11th post-larval stage when the animal is slightly over 15 mm in length. It gradually grows during succeeding moults and at the same time its margins turn inwards so as to form an open groove. The outer part of its tip is gradually produced into a spout-shaped process called the distolateral lobe by Burkenroad (1934 b). At the same time the anterior margin of each half develops minute hooks all along its length. At first the hooks are arranged in a single row, those towards the extremity being separated by wide intervals. As growth proceeds additional rows are developed in the proximal part while those situated distally are closely arranged. These interlock and give rise to an incomplete tube open behind through the space left between their posterior margins. The distolateral lobes are also open. This happens usually when the young prawn is 50-60 mm. Some time before this the anterior margin of the spout develops a small flap or lobe at the inner end. It gradually extends along a good part of the length of the spout and the surface becomes corrugated. The space inside each spout, which was open, is closed by the growth of its posterior margin. Two pairs of papillae are developed at the base of the spouts, one pair anterior and the other posterior in position. The former are stout with curled-up tips, the latter thin and leaflike. In prawns of about 65 mm the petasma is completely developed.

Thelycum.—Figs. 58-60. The earliest stage in development was not obtained, but in a specimen measuring approximately 25 mm there is a broad roughly crescentic groove running transversely across



FIGS. 58-60. Three developmental stages of thelycum: 58. groove on sternum XIV just formed; 59. hood growing from its posterior margin; 60. hood practically covers up the groove.

the anterior part of the sternum of the last (XIV) thoracic segment. Laterally it stretches up to the base of the last two pairs of legs. On the sternum of the penultimate segment (XIII) there is a median elongated process, its lateral margins posteriorly becoming continuous with the front margin of the groove. This is the 'median tongue' referred to by Alcock (1906) and gives rise to the median plate of the adult thelycum. From its position it appears to be formed by the enlargement of the median spine noticeable in early post-larvae. Later it broadens out ventrally into a conspicuous, approximately quadrilateral plate with the concave surface connected with the sternum by a narrow dorsal part. At the same time the posterior margin of the groove grows and forms a flap or hood enclosing its cavity. It extends on each side from the middle line and gradually overlaps the lateral portions of the posterior half of the median plate, its anterior ends being partly concealed under the lateral margins of the front half of the latter. This is the 'salient horse-shoe shaped process' described by Alcock as ensheathing posteriorly the 'Median tongue'. The inner ends of the two hoods eventually meet along the median line so that there is hardly any gap left between them and the median plate as in *M. brevicornis* Burkenroad (1934b), through which spermatophores could be inserted at the time of copulation. In the fully developed thelycum seen in prawns of approximately 60 mm in length the anterior opening of the groove on each side is blocked in front at the level of the front end of the median plate by a short stout spine arising from the coax of the fourth leg. No part of the cavity of the groove is dilated as in other genera though the front end of each side is wide and the lateral portions are continuous in the middle line.

BIONOMICS

Breeding.

(*a*) *Place*

Penaeid prawns, with the exception of *M. stebbingi* and *M. monoceros*, breed, as far as is known, only in the sea. *M. stebbingi* has been observed to breed in the Bitter Lakes of the Suez Canal and *M. monoceros* in the shallow coastal lakes of New South Wales (Dakin, 1946). So far as present observations go, *M. dobsoni* seems to breed mainly in the sea. In discussing the habits of the species of Metapenaeus living in the Chilka lake Kemp (1915) states: 'I think it improbable that any of them breed in the lake'.

Eggs and larvae have been so far collected only in the sea though early post-larvae attributed to *Metapenaeus monoceros* have been recorded from brackish-water (Panikkar & Aiyyar 1939). Further, samples of plankton collected from brackish water areas where the adults are found throughout the year, for example the backwaters of Adyar and Kerala, have failed to show any larvae or eggs. These two facts strongly suggest the sea as the breeding place of this species.

Study of adult prawns has also yielded reliable evidence in its support. While mature males with well developed spermatophores have been frequently collected from brackish water, no female, either impregnated or with ripe ovary, has so far been obtained from the same areas. Sexual union and ripening of the female gonad seem to take place only in the sea. Adult females from the sea have invariably the fifth pair of legs reduced to stumps. Kemp noted that in every female obtained from the Chilka lake these legs were of normal length. Commenting on this he remarks: 'It appears to me highly probable, as has already been suggested by Nobili, that the degeneration of these limbs is in some way connected with reproduction and, if this should prove to be the case, the condition of the Chilka specimens lends support to the view, based on other evidence, that this species at any rate does not breed in the lake'. However, the possibility of some of them breeding in environments similar to those in which *M. monoceros* is reported to breed cannot be ruled out altogether.

(b) Period

The breeding period seems to be fairly long as evidenced by the presence of larvae in plankton from September to April. The maximum number was obtained from November to March. Eggs occurred in plankton in fair numbers from September to the middle of January, after which the number dropped abruptly, none being obtained on several days. Plankton samples up to January contained mostly larvae of this species and in all probability therefore most of the eggs also should belong to the same. From both sets of observations it would seem that the period September to December or January forms the peak of the spawning season.

(c) Area

Details of the localities and method of making plankton collections have been already given. The offshore collections, contained very few penaeid larvae and practically no eggs. None has been made between this and the 12-13 fathoms region so that their distribution in this area is unknown at present. Basing our conclusions on the data available it may be stated that a good number of breeding females liberate their eggs in the inshore waters up to or slightly beyond the 12-13 fathoms line. In making this statement the effect of currents on the distribution of eggs and larvae has been left out of consideration owing to the lack of any information regarding them. Judging from the known distribution of planktonic eggs and larvae Pearson (1939) and Anderson and co-workers (1949) conclude that spawning of *P. setiferus* is done usually in offshore areas of the South Atlantic and Gulf Coasts of the United States of America. Dakin (1938) has stated that *P. plebejus* of Australia breeds in ocean water well out of the estuaries. The Indian species apparently differs from them inasmuch as it spawns in the comparatively shallow inshore waters.

Sexual union.

Impregnated females have been obtained practically throughout the year, the largest number being in the months of August to January and this period roughly coincides with the peak of the breeding season. Females, soon after sexual union, can be easily recognized because of the pair of prominent white pads that cover the surface of the thelycum. Each pad is completely formed in the vas deferens and can be found together with the spermatophore (occasionally 2 spermatophores, one being smaller) in the terminal dilatation of the vas deferens situated at the base of the last leg. Burkenroad (1934b) has accepted the suggestion of Kishinoye that these pads are 'perhaps rudimentary homologues of the appendages of the spermatophore of Penaeus' the function of which is stated to be 'for attachment of the exposed spermatophores in Penaeids with open thelycum'. The smallest impregnated female measured just over 65 mm.

Food.

The food of the larvae has been already described. The statement of Alcock regarding the feeding habits of adult prawns that 'they are scavengers, but many are carnivorous in a better sense and several species prey upon marine larvae and microscopic algae' is true of young ones as well. Small post-larvae thrived well on plankton containing a good proportion of algal constituents. Later on small quantities of finely minced clam or fish muscles were given in addition to plankton. Examination of the stomach contents of numerous individuals varying in length from 21-88 mm has been carried out in order to discover the food constituents in the natural habitat of these prawns and the variations, if any, in the proportion of these constituents at different stages of growth. The food in general consists of varying amounts of organic matter mixed with sand and mud. Fragments or entire bodies of small animals and algae including diatoms compose the organic matter, of which the proportion of vegetable constituents has been found to be less in the larger individuals. In some specimens measuring 21-45 mm in length examined on 22-11-49 and 6-12-49 the stomachs were practically full of fragments of the alga *Cladophora* mixed with mud and some diatoms, no recognizable animal remains being present. Individuals measuring 65-75 mm contained only a few fragments of the same alga. The animal matter largely consists of entire or partly digested bodies of the following groups (No attempt was made to determin their identities more exactly) :

Foraminifera, Copepoda, Nematoda, Amphipoda and Gastropoda.

Besides Cladophora a number of genera of diatoms also were frequently present. The more common of them are *Fragilaria, Coscinodiscus, Pleurosigma, Navicula* and *Cyclotella.**

Rate of Growth.

Observations on the rate of growth were carried out by rearing post-larvae in suitable glass vessels. The method adopted for rearing the earliest post-larvae has been described above. After a few days the animals were transferred into glass troughs measuring 8″ x 4½″ and finally into a large one 10″ in diameter, but of the same height. Four sets of these observations were continued long enough to make them really useful. In the first 2 post-larvae obtained from the last zoea were reared for a period of 2 months and 20 days. The bottom of the trough was covered with a thin layer of sand mixed with a little mud and some sea weed also was put in. They were fed regularly with clam meat, for which they showed a great liking. Both of them were males and measured 47 and 41 mm respectively. The initial size was approximately 3.5 mm so that the increase in length was 43.5 and 37.5 mm

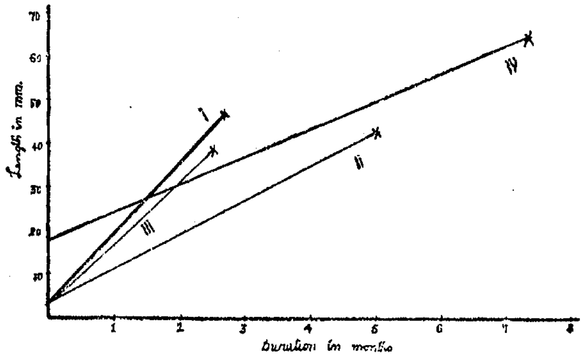


FIG. 61. Graph showing growth rates of 4 individuals in the rearing experiment.

In the 3 other experiments which were carried out at Calicut only one individual was put in each vessel. Sand and sea weeds were put in at first, but were removed later as the water was fouled quickly. The food given was finely minced fish muscle as clams were not available. Two of them were post-larvae in the first stage and the other was a young prawn measuring approximately 18 mm. In all the experiments the water was changed at least once a week. The periods through which they were reared and final size to which they grew are given below :

	Initial size.	*Period.*	*Final size.*	*Increase.*
(ii)	3.5 mm	5 mths.	43 mm	39.5 mm
(iii)	3.5 mm	2½ ,,	38 mm	34.5 mm
(iv)	18 mm	7 ,,	65 mm	47 mm

Reviewing the results of these experiments it becomes apparent that the average rate of growth has been most rapid in the first, presumably because of the optimum conditions of life provided. That in the third is comparable to the first notwithstanding some differences in environment. Taking into consideration the much longer period during which the other two specimens were reared, the average is much less. Apart from food and other factors governing growth, it is very likely that the limited space available in the vessel may retard growth markedly after a certain size is reached. Measurements of the moulted skin in the last experiment showed that in the course of the last 40 days the increase in length was only from 60 to 65 mm. Pearson (1939) also noticed ' that a limitation in maximum growth occurred quite independently of the period of confinement or the total amount of food consumed '.

Measurements of several hundreds of prawns from the commercial catches and those made for the laboratory at Calicut during the course of over an year have revealed that the dominant size groups are those between 60 and 80 mm which could not therefore be older than 7 or 8 months. During the breeding period females of 50-70 mm were found with fully ripe ovaries so that sexual maturity may also be attained at about this age.

Migration.

The observations regarding the life history recorded in the foregoing pages would make it clear that the life cycle of each individual is completed in two types of environments, namely the brackish water of estuaries and lakes connected with the sea and the sea itself. The entire course of larval development and the earliest post-larval phase are passed through in the open sea. It is not possible to state definitely where or at what size migration inwards commences. Panikkar (1937) has stated that post-larval penaeids enter backwaters when 1-2 cm in length. As has been mentioned already all available evidence goes to show that soon after the moult from the first post-larval stage the young ones cease to be pelagic. The smallest captured from brackish water at various localities are 15-25 mm in length. Prawns of this size were caught in fair numbers from the foreshore waters at West

* I am indebted to my colleague, Dr. R. Subrahmanyan, for their identification.

Hill, Calicut, up to a depth of 4 fathoms in November and December. Later there was a fall in number, but they continued to appear in the catches up to the end of April. It is quite probable that migration from the sea takes place when the young have reached this size and that successive batches pass out of the sea during the greater part of the breeding period (see also Panikkar 1937). The maximum size of prawns collected from backwaters and estuaries, as stated already, does not exceed 80 mm. Kemp records that specimens from the Chilka lake examined by him did not exceed 75 mm. The backward migration into the sea may take place soon after the monsoon rains start, the prawns being carried in the current flowing into the sea. As the largest individuals measure as much as 120 mm and have been found only in the sea they do not seem to leave the sea afterwards and re-enter their former habitat. Kemp also has arrived at the same conclusion in regard to the penaeids of the Chilka lake. It may be of interest to mention here that the investigation on the osmotic regulation in *M. monoceros* has demonstrated its high adaptability to water of varying salinity (Panikkar and Viswanathan 1948). Presumably this power is shared by *M. dobsoni* and other migratory penaeids.

SUMMARY

The larval development of *M. dobsoni* resembles closely that of *M. stebbingi* having the same number of stages and numerous common characters. Rostrum, telson and pleopods have been observed to acquire approximately adult character in the course of 12 moults. The species breeds mainly in the sea in comparatively shallow inshore waters and the period is fairly long, extending over 5-6 months. The food of larvae and early post-larvae consists chiefly of plankton; they later become bottom-feeding in habit, their stomach contents showing a good proportion of mud and sand. Considerable quantities of algae are consumed when available. Sexual maturity may be reached in 7-8 months. Like some other species of penaeids, *M. dobsoni* also migrates into estuaries and brackish water areas early in life and after a period of growth returns to the sea.

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