THE EARLY DEVELOPMENTAL STAGES OF *SCYLLA SERRATA* FORSKAL* (CRUSTACEA PORTUNIDAE), REARED IN THE LABORATORY

by

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ABSTRACT

Scylla serrata Forskal has been reared successfully from the berried female to the crab-stages. Berried crabs hatch the eggs in laboratory glass tanks. The majority of the eggs hatch and are liberated in the first zoeal stage; only some are in the pre-soea stage. The incubation period is 12 days. The larval stages were reared in circular plastic basins and only *Artemia* nauplii were used for feeding. There are 5 zoeal stages, which require a minimum developmental period of 18 days at a salinity of 31 ± 2 p.p.t.; the megalopa takes a minimum of 7-8 days to change into the first crab-stage at a salinity of 24 ± 2 p.p.t. The zoeal and megalopa stages are described in detail. The low yield of the rearing experiments calls for further investigations if laboratory production of the early crab-stages as seed-stock for culture in ponds is to be achieved.

*Estampador (1949a, 1949b) proposed a revision of the genus *Scylla*, based on external morphology and gametogenesis, to include 3 species: *S. serrata* Forskal, *S. oceanica* Dana and *S. tranquebarica* Fabricius; and one new variety, *S. serrata var. paramamosain* Estampador. Serene (1951) described the 4 forms from Vietnam. Although the specimens of *Scylla* in Malaya can be divided into the 4 forms, the present author, subscribing to the view held by Stephenson and Campbell (1960, p. 113) that more work is required before the separation of *Scylla* can be regarded as justified, recognizes only one species: *S. serrata* Forskal.

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INTRODUCTION

Scylla serrata Forskal constitutes a very important crab fishery throughout the entire Indo-Pacific region. The meat is highly esteemed as food, and in Malaya quite large numbers of this crab are caught, mainly from mangrove swamps at high tide, when the crabs move in with the tidal water to the mangrove areas in search of food. In Malaya, *Scylla* fishing areas are mostly on the West Coast, where there are many brackish estuarine areas and mangrove swamps, e.g. in Kuala Kedah, Kuala Gula, Port Weld, Sungei Dindings and Pulau Ketam.

The high demand for *Scylla* is attested to by the high market price of the crab, which in Penang averages M$1.30/kg. for males, and M$2.40/kg. for females with well-developed ovaries. The latter are particularly relished by consumers; the ovaries are generally served with the well-known shark-fin soup in Chinese restaurants. Intensive and indiscriminate fishing for this crab and the absence of any regulatory measure almost certainly have resulted in diminishing the crab population, as many fishermen claim. Investigations have therefore been initiated in the Fisheries Research Institute, Penang, Malaysia, since early 1963 on the life history of this crab and the possibility of its culture on a commercial scale from the stage of the berried female.

Preliminary studies on the life history of *Scylla* have been made by Arriola (1940) and Raja Bai Naidu (1955), but the larval development from the first zoea into the crab-stages has not described. The present paper is based on the successful rearing of all early stages of the crab from eggs carried by berried crabs. Only the zoeal stages and the megalopa are described; the crab-stages will be described in a subsequent paper.

MATERIALS AND METHODS

Berried *Scylla* specimens were purchased from drift-net fishermen in Batu Maung, Penang and brought in sea water to the laboratory, where the crabs were placed singly in aquaria measuring 90 cm x 45 cm x 50 cm, filled to a depth of 25-30 cm of sea water. The sea water had a salinity of 31 ± 2 p.p.t. and had been filtered through a sand-charcoal filter. Each aquarium was provided with 2 aerators, and the crabs were fed with pieces of shrimp, cockle or squid; excess food was removed to prevent pollution of the water. The aquaria were cleaned daily.

The larvae hatched in the aquarium were scooped up gently with a bowl, and placed into a number of receptables for rearing. Thick-walled circular plastic basins, in diameters of 18 cm, 24 cm and 28 cm, filled with 5 cm of filtered sea water, were used. At the initial stage, each basin contained about 200-300 larvae, but with the high mortality of the larvae, the number became less in the later stages. In the megalopa stage onwards, the specimens were either kept singly, or a few in one container, provided with coral or shells for shelter. The basins were not supplied with aerators; they were exposed to drafts which kept the water sufficiently aerated. The water temperature in the rearing containers had an average daily range from 24.5°C to 31.5°C. No apparatus was available to keep the temperature in the rearing containers constant.

Daily, either the living zoeae were transferred by a large-bore pipette (aperture diameter 8 mm) into clean basins containing the required volume of sea-water, or the dead larvae were removed to prevent contamination of the sea water. Where the salinity exceeded 31 ± 2 p.p.t. due to evaporation, appropriate amounts of distilled water were added. Freshly hatched *Artemia* nauplii and also viable *Artemia* eggs, which would hatch in a few hours, were added to the basins daily for feeding the zoeae. The megalopae were fed with larger *Artemia* nauplii and pieces of shrimp.

The rearing receptacles were observed daily for successive developmental stages, moulting larvae, and exuvia. The members of a new stage were then kept together in separate containers from the preceding stage, and specimens for morphological study preserved in 5% neutral formalin. The frequency of moulting and the number of moults were recorded.

Morphological studies were made by dissection under the binocular dissecting microscope of both fresh and preserved specimens, including the exuvia, and the drawings made with the aid of camera lucida.

OBSERVATIONS AND RESULTS

Yield of experiments

The best yield, out of 5 successful rearing experiments conducted so far, was 400 megalopae but only 60 crabs from the larvae of one hatching. Highest mortality occurred in the first and second zoeal stages. Unsuccessful moulting, pollution of the water by dead larvae, and infiltration of ciliates into moulting and soft larvae probably account largely for the mortality. Another important reason is the failure to supply natural food for feeding the zoeae; *Artemia* nauplii probably are too fast and big for the majority of the early zoeae. From the megalops stage onwards, death was mainly caused by cannibalism.

Incubation and hatching

Three crabs spawned in the laboratory and the incubation period was found to be 12 days. In the beginning the egg-mass appeared completely yellow and compact. As development proceeded, with the development of the chromatophores and the eyes, the egg-mass darkened to a greyish-yellow and finally to a brownish-black colour. The berried crab made occasional swimming movements in the tank by means of the paddle-like fifth pair of legs, but more often it stood on the pereiopods, with the egg-mass held above the substratum. As development continued further, the egg-mass became loosened and the abdomen tilted dorsally. The abdomen frequently made jerking movements in quick succession while the walking-legs lightly jabbed at the egg-mass.

A short while before all the eggs hatched, the crab, by the frequent contraction of the abdomen, released some larvae. These were in the pre-zoea stage, which within about half an hour burst through the embryonic cuticle to become the first zoeal stage. The majority of the eggs hatched from the berry directly into the first zoeal stage. The larvae were liberated continuously over a period of 3-5 hours, but the main mass of eggs hatched within about half an hour, when the crab was in a very excited stage. At this time, the contraction of the abdomen and the pleopods was incessant, throwing out large numbers of larvae in the first zoeal stage. Also, the swimming legs fanned in repid succession, while the 2nd-4th pairs of pereiopods repeatedly jabbed into the egg-mass. A comparatively small portion of eggs, some still attached to the ovigorous setae, dropped to the substratum; nearly all of some 2 million eggs would successfully hatch.

Moulting and Development

There are 5 zoeal stages, passing through 5 moults to reach the megalopa stage. Moulting in the zoea and megalopa takes place by a split at the dorsal boundary between the cephalothorax and the abdomen. The latter bends ventrally and the dorsal arch thus formed emerges first through this split, followed by the rest of the abdomen. The soft abdomen now curves anteriorly and the telson repeatedly tears at the cast abdomen which is still attached at the anterior end, to loosen the exuvium of the cephalothorax. Finally, the cephalothorax with all the appendages of the new stage emerges through the dorsal split to complete the moult.

At a salinity of 31 ± 2 p.p.t., development from zoea I to megalopa required a minimum of 18 days; each zoeal stage takes a minimum period of 3-4 days before it moults into the next stage. This rate of development is probably normal. The megalopa takes 11-12 days at the above salinity before it moults into the first crab-stage; at lower salinities in the range of 21-27 p.p.t., this period is reduced to 7-8 days. The faster rate of development of the megalopa in a reduced salinity indicates that the megalopa in nature moves shorewards into brackish water.

Habits of the developmental stages

Zoeae of all stages swim by means of the exopodites of the first and second pairs of maxillipeds, with the dorsal spine usually directed anteriorly and the rostral spine ventrally. Whilst they can swim straight forwards, very often they swim in circles. The flexure of the abdomen helps in locomotion. The zoeae are photopositive, swimming towards the source of light. Food is caught aided with the curvature of the abdomen, which presses the food to the mouth-parts. The strong mandibles smash up the food.

The megalopa swims by means of the 5 pairs of pleopods, which are now functional for the first time. But more often, the megalopa rests at the bottom, usually on its back, and then occasionally swims round close to the bottom in circles. Less frequently, the megalopa swims straight upwards, and may stay suspended while the chelipeds and pereiopods attach to the surface film. The megalopa is also capable of progression on the sub-stratum, by walking with the pereiopods. The chelipeds are used to catch swimming prey or bits of dead food. From this stage onwards, the cannibalistic tendency is clearly manifest.

Morphology of the early developmental stages

Zoeal stages

The zoeae are of typical brachygnath type, with long rostral and dorsal spines, and short lateral spines on the carapace. There is a single hair on either side of the dorsal spine, at about two-fifths the distance from the dorsal spine to the lateral. Similar to many other brachyuran zoeae, the abdomen in all stages has lateral knobs on pleomeres 2 and 3; the knobs on pleomere 2 are larger and directed anteriorly, while those on pleomere 3 are smaller and directed posteriorly.

First Zoea (Figs.1-9)

Body length 1.15 mm; rostal spine 0.35 mm; dorsal spine 0.48 mm; lateral spine 0.19 mm. Eyes sessile. Antenna (Fig. 2) unsegmented and bears apically a short seta and three long aethetes. Antenna (Fig. 3) has a long spiniform process, which bears two rows of about 16 spinules each. Exopodite of antenna tipped by a short spine, and a long seta. Mandible (Fig. 4) is a broad, relatively hard structure, with 2 large teeth and serrated edges. Maxillule (Fig. 5) has a two-segmented endopodite, segment 1 with 1 seta, segmen 2 with 6 setae, 4 of which are terminal and 2 subterminal; protopodite is made up of two endites, coxal endite bears 6 setae, basal endite 5. Mixilla (Fig. 6) with an unsegmented endopodite which bears 4 terminal setae and 2 sub-terminal ones; the two endites of the protopodite are markedly bilobed, coxal endite has 7 setae, the basal 5. Scaphognathite with 4 plumose setae.

The first and second maxillipeds (Figs. 7 & 8) both bear 4 natatory setae on the exopodites. Endopodite of first maxilliped is made up of 5 segments, with 2-2-0-2-7 setae, counting from the proximal to the distal segments. Endopodite of second maxilliped has 3 segments with 1-1-5 setae.

The abdomen (Fig. 9) is made up of 5 pleomeres. On pleomeres 2-5, there is a pair of minute setae on the dorsal surface. Pleomeres 3-5 have short lateral spines. The telson (Fig. 9) bears a pair of long dorsolateral spines, close behind which are a pair of small spines. In addition to these, there is a pair of posteriorly-directed dorsal spines. The long dorso-lateral spines and the posteriorly-directed dorsal spines persist in the later zoeal stages. Between the long telson furca are 3 pairs of setae, the innermost pair have 8-10 exceptionally long setules on the inner border.

Second Zoea (Figs.10-13)

Body length 1.51 mm; rostal spine 0.39 mm; dorsal spine 0.54 mm; lateral spine 0.20 mm. Eyes now stalked. Antennule bears 4 aesthetes, and 2 short setae of unequal length. Antenna is as in in zoea I, except in size. Endopodite of maxillule (Fig. 11) is as in zoea I, but coxal and basal endites now bear 7 and 8 setae. There is a plumose seta on the outer margin of the protopodite. Coxal and basal bilobed endites of maxilla (Fig. 12) bear (3 + 4) and (5 + 4) setae, while scaphognathite now has 8 plumose setae. Exopodites of both maxillipeds bear 6 natatory setae. Pleomeres 3-5 have more distinct lateral spines (Fig. 13). The telson (Fig. 13) has developed a pair of small setae at the inner margins of the furca.

Third Zoea (Figs. 14-17)

Body length 1.93 mm; rostral spine 0.52 mm; dorsal spine 0.63 mm; lateral spine 0.24 mm. Antennule is as in zoea II but larger. Antenna has developed a small bud, which is the beginning of the flagellum. Coxal endite of maxillule (Fig. 15) has 8 setae, basal endite 9; outer margin of protopodite has developed another seta, in addition to the plumose seta. Coxal and basal endites of maxilla (Fig. 16) bear (3 + 4) and (5 + 5) setae respectively. Scaphognathite with 15-17 plumose setae. Exepodite of first maxilliped bears 8 natatory setae while that of second maxilliped 9. Rudiments of the remaining thoracic appendages are distinct beneath the carapace (Fig. 14). Lateral spines on pleomeres 3-5 longer and the abdomen (Fig. 17) now has 6 somites. The telson (Fig. 17) has lost the pair of small spines close behind the pair of long dorse-lateral spines.

Fourth Zoea (Figs.18-23)

Body length 2.40 mm; rostal spine 0.72 mm; dorsal spine 0.86 mm; lateral spine 0.28 mm. Antennule (Fig. 19) bears aesthetes in a terminal group and a sub-terminal group. The former comprises 4 long aesthetes and one seta and the latter 2 long aesthetes and 2 setae. Antenna (Fig. 20) has the flagellum or endopodite elongated to about one-fifth the length of the spiniform process. Maxillule (Fig, 21) bears 12 setae on coxal endite and 14 setae on basal endite. Maxilla (Fig. 22) has 25-27 plumose setae on the scaphognathite; coxal endite bears (6 + 4) setae, basal endite (6 + 6). First maxilliped bears 10 natatory setae on the exopodite, and a setation of 2-2-1-2-6 on the endopodite. Exopodite of second maxilliped bears 10 long setae, and 1 or 2 shorter ones. The rudiments of all the remaining thoracic appendages are larger, and those of the third maxilliped and the cheliped are bifid. Setae are found round the posterior and lateral margins of the carapace. Abdomen (Fig. 23) with buds of pleopods on pleomeres 2-6. Three seatae on the posterior dorsal surface of the first pleomers. Lateral spines on pleomeres 3-5 further elongated. The telson (Fig. 23) grows an additional seta between the innermost pair of setae.

Fifth Zoea (Figs. 24-32)

Body length 3.43 mm; rostal spine 1.07 mm; dorsal spine 1.31 mm; lateral spine 0.32 mm. Antennule (Fig. 25) bears aesthetes in 3 tiers, and the endopodite is present as a bud. Endopodite of antenna (Fig. 26) has elongated to approximately four-fifths the length of the spiniform process. Maxillule (Fig. 27) with about 15 and 20 setae on the coxal and basal endites respectively. Maxilla

(Fig. 28) has 45-50 plumose setae on the scaphognathite. Exopodite of first maxilliped (Fig. 29) bears 11 long setae, and 1-4 short setae. Exopodite of second maxilliped (Fig. 30) bears 12 long setae and 2-3 short setae. Third maxilliped (Fig. 31) may or may not bear a few setae. All the pereiopods are elongate and show signs of segmentation. Pleopod buds on pleomeres 2-6 are well-developed and the exopodites may bear a few setae. Lateral spines of pleomere 3 extend posteriorly to reach to about one-third the anterior part of pleomere 5, those of pleomere 4 are as long as the length of pleomere 5. Between the telson furca (Fig. 32) there are now 5 pairs of setae.

<u>Megalopa</u> (Figs. 33-41)

There is a single megalopa stage. Carapace length (excluding rostral spine) 2.18 mm; carapace breadth 1.52; abdomen length 1.87 mm; total body length (excluding rostral spine) 4.1 mm; rostral spine 0.5 mm; sternal spine 0.77 mm. The megalopa is very similar to that of other portunids. It has a rostral spine, and a pair of long, slightly curved spines directed caudally from the fourth thoracic sternite.

Antennule (Fig. 34) comprises a peduncle of 3 large segments, of which the basal one is the largest, and two flagella. One flagellum is made up of a single segment while the other of 5 segments; numerous aesthetes, arranged in 4 tiers, arise from the terminal 4 segments of the longer flagellum. Antenna (Fig. 35) is elongate and made up of 11 segments. Mandible (Fig. 36) is a hard cup-shaped structure bordered at one edge with a tooth, and bears a two-jointed palp, with 16 stiff setae on the distal segment. Maxillule (Fig. 37) with 2 short spines on the distal segment of the endopodite, the setae on the coxal and basal endites have increased in number. Maxilla (Fig. 38) bears about 70 plumose setae on the scaphognathite, and 5 on the endopodite. The deeply bilobed coxal and basal endites have (14 + 6) and (10 + 12) setae respectively.

The maxillipeds differ much from the zoeal stages. The first maxilliped (Fig. 39) has a well-developed epipodite, which arises from the coxopodite, and bears many long, non-plumose setae. The expanded and bilobed protopodite, which serves for mastication, bears numerous stiff setae. The exopodite bears 5 plumose setae on the distal segment terminally. The endopodite is flat, unsegmented, bearing 4 setae on the distal margin. The second maxilliped (Fig. 40) has many stiff setae on the last 2 segments of the endopodite. The exopodite has 6 terminal setae. The epipodite is small, with a single apical seta. A gill is also present on the coxopodite. The third maxilliped (Fig. 41) is very well-developed. The endopodite bears numerous stout setae on all the segments. The coxopodite bears a gill and a well-developed epipodite, which bears at the distal portion 14 long non-plumose setae. The exopodite is similar to that of the first two maxillipeds.

The cheliped has a curved spine on the ventral surface of the ischiopodite; the other segments are non-spinous. The second pereiopod has a straight spine on the ventral surface of the basipodite. A straight spine is also present on the sternum, in the middle across the first two pairs of pereiopods. The fifth pereiopod has a slightly flattened dactylus, fringed with 7-9 long setae on the outer margin, 3-5 setae on the inner margin at the proximal protein, and 6-8 long, hooked, and non-plumose setae at the distal portion. Two of the hooked setae are invariably toothed like a saw in the curved portion.

The abdomen bears 5 pairs of pleopods, on the second to the last (sixth) pleomeres; pleomere 1 is apodous. Each pleopod consists of a small endopodite, except in the last pleopods (uropods), and a large exopodite, fringed with many plumose setae. The setae are 23-24, 24-26, 23, 17-20, and 11-14 in number, counting from pleopods 2 to 6. The telson has 3 small setae at the medial posterior border.

DISCUSSION

Brachyuran zoeae have been reared successfully by a few workers for life-history studies. Lebour (1928), with a plunger-jar set-up, used larvae of *Ostrea*, *Teredo* and *Pomatoceras* for feeding. As none of these can be produced in quantity in our laboratory, other food had to be found. The popular food in laboratory culture, *Artemia*, which had been proved to be an excellent food for carid larvae in our laboratory (Ling, 1961), was successfully tried out for feeding *Scylla* larvae. Later, it was found that *Artemia* nauplii had earlier been used for rearing crab larvae, by Costlow and Bookhout (1959) who used *Arbacia* eggs in addition.

In the crustacea, economic shrimps and lobsters have attracted many research workers to explore the possibility of their culture, but crabs have been neglected in this respect, although the cultivation of *Scylla* in ponds from young crab-stages collected from the natural habitat is practised in some countries, e.g. Taiwan and Philippines. As this crab is of such great demand, the possibility of its propagation on an economic scale to supply the seed-stocks for culture in ponds, deserves investigation. Although *Scylla* zoeae have been reared to the crab-stages, the experiments conducted so far are yet, unfortunately, of little commercial value because of the low yield, resulting from the high mortality of the larvae from improperly understood causes, and the cannibalism of the megalopa stage onwards in the small containers used. Further experiments need to be made in an attempt to reduce the larval mortality rate. If sufficiently large numbers of the megalopa stage could be produced, it would be worthwhile to stock a brackish-water pond, which had been screened of predators, with the megalopae immediately after their metamorphosis from the fifth zoeae, in addition to trying to keep them to crab-stages in laboratory containers. The pond would furnish better shelter and more space for the dispersion of the megalopae and the subsequent crab-stages, and thus curtail mortality due to cannibalism.

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EXPLANATION OF FIGURES

Figs. 1-9. *Scylla serrata* Forskal. First Zoea: Fig. 1. Lateral view. Fig. 2. Antennule. Fig. 3. Antenna. Fig. 4. Mandible. Fig. 5. Maxillule. Fig. 6. Maxilla. Fig. 7. First maxilliped. Fig. 8. Second maxilliped. Fig. 9. Abdomen and telson.

Figs.10-17. *Scylla serrata* Forskal. Second Zoea: Fig. 10. Lateral view. Fig. 11. Maxillule. Fig. 12. Maxilla. Fig. 13. Abdomen and telson. Third Zoea: Fig. 14. Lateral view. Fig. 15. Maxillule. Fig. 16. Maxilla. Fig. 17. Abdomen and telson.

Figs.18-24. *Scylla serrata* Forskal. Fourth Zoea: Fig. 18. Lateral view. Fig. 19. Antennule. Fig. 20. Antenna. Fig. 21. Maxillule. Fig. 22. Maxilla. Fig. 23. Abdomen and telson. Fifth Zoea: Fig. 24. Lateral view.

Figs.25-32. *Scylla serrata* Forskal. Fifth Zoea: Fig. 25. Antennule. Fig. 26. Antenna. Fig. 27. Maxillule. Fig. 28. Maxilla. Fig. 29. First Maxilliped. Fig. 30. Second maxilliped. Fig. 31. Third maxilliped. Fig. 32. Telson.

Figs.33-41. *Scylla serrata* Forskal. Megalopa: Fig. 33. Dorsal view. Fig. 34. Antennule. Fig. 35. Antenna. Fig. 36. Mandible. Fig. 37. Maxillule. Fig. 38. Maxilla. Fig. 39. First maxilliped. Fig. 40. Second maxilliped. Fig. 41. Third maxilliped.

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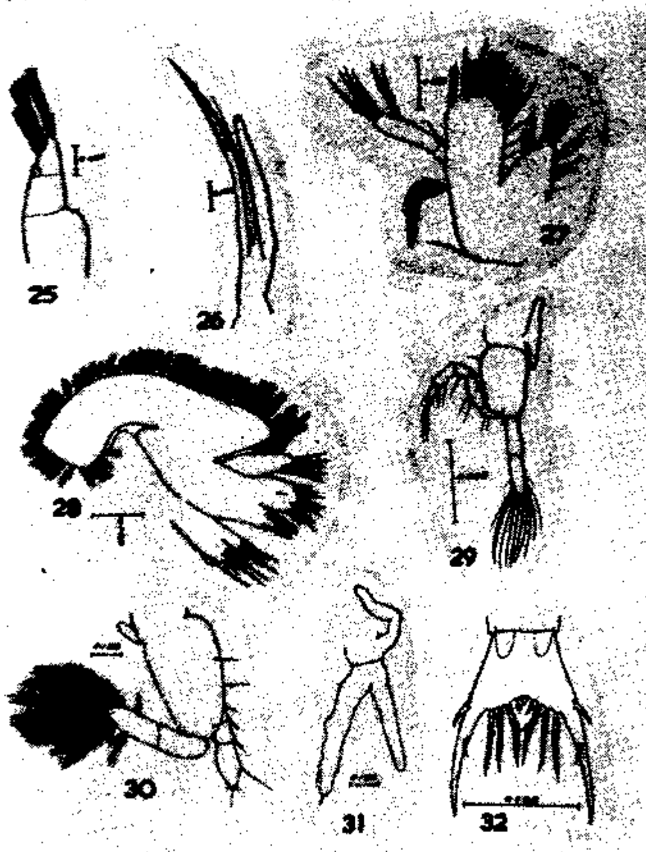
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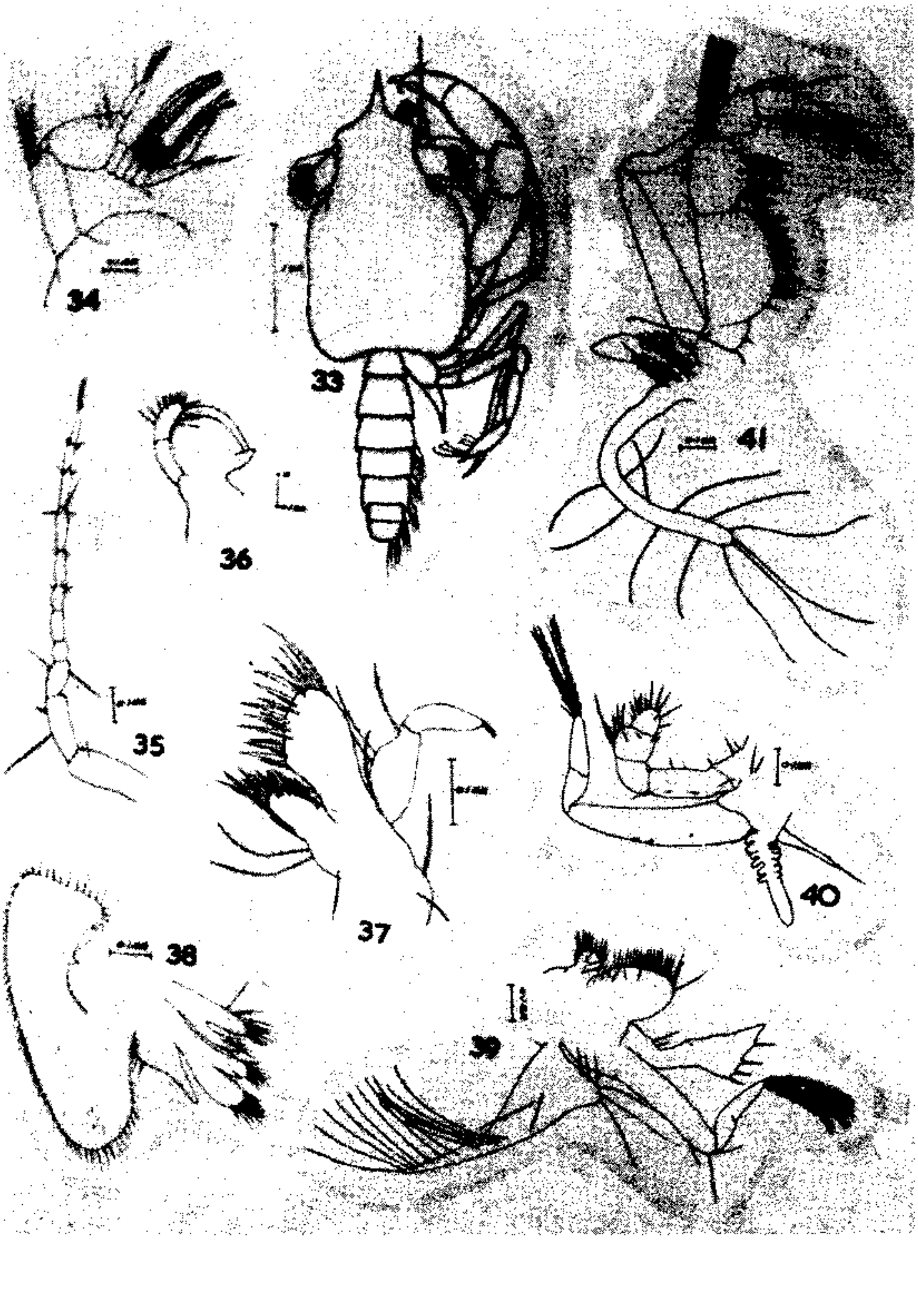
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