STUDIES ON LARVAE OF CRABS OF THE FAMILY PINNOTHERIDAE.

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The material on which the original portion of this paper is based has been collected at Beaufort, North Carolina, during several summers.

All of the first zoeal stages originally described in this paper have been obtained by hatching them in the laboratory. Ovigerous females were collected and, if the form was abundant, those whose eggs were in an advanced stage of development selected. The stage of development may be determined readily by observing the depth of color of the yolk mass. In newly laid eggs the yolk is deeply colored and it becomes progressively lighter as the embryos develop. When the females have been selected they are placed in finger bowls filled with sea water. It is best to place not more than three females together and to have a bit of shell in each bowl. The crabs are less excited when they can hide. The eggs hatch at nightfall and the zoeas will live for about a week if the water is changed daily and the bowl kept in a cool place.

The second zoeal forms have been secured by collecting large numbers of the first zoeas from the tow and keeping them in finger bowls until a few have molted.

The writer wishes to express his appreciation of the courtesies extended to him by the Bureau of Fisheries and especially by Charles Hatsel, the acting director of the station. I also acknowledge with gratitude the assistance that has been given me unfailingly by Dr. Waldo L. Schmitt and Miss Mary J. Rathbun, of the United States National Museum.

THE PINNOTHERID ZOEA.

The zoeas of the Pinnotheridae do not form a well-defined, homogeneous group as in some other families. The only feature that is common to them all and serves to distinguish them from the zoeas of other families, is the minute size of the antenna. This is so small in *Pinnotheres ostreum* that it hardly can be discovered and is only 0.2 mm. long and quite slender in *P. maculatus* in which it is largest.

In other families the arrangement and size of the spines of the carapace form distinguishing features of the zoeas. Among the Pinnotherids there is no uniformity in this respect. In *P. holothuriae* there is not a vestige of any of the carapace spines (fig. 48) while in *Disso-*

dactylus mellitae all the spines are present and prominent (fig. 30). The telson while characteristic in some families, is variable in the Pinnotherids. *Dissodactylus* and *Pinnotheres maculatus* have the bicornuate telson that is commonly found in the Brachyuran zoea (figs. 28 and 37). In *Pinnixa chaetopterana* also the cornua are elongated and cylindrical but the telson bears a median deltoid process on its posterior margin (fig. 47). In all the other known zoeas (except that of *Pinnixa sayana* (fig. 62) the median process is present and the cornua are likewise reduced to short, thick processes (figs. 17, 18, 50, and 51).

KEY TO KNOWN ZOEAS.

a.[1] Telson bicornuate, without median process.
- *b.*[1] Fifth abdominal segment expanded and produced posteriorly as lappets *Pinnixa sayana.*
- *b.*[2] Fifth abdominal segment not expanded.
  - *c.*[1] Prominent dorsal tubercle on first abdominal segment *Dissodactylus mellitae.*
  - *c.*[2] No dorsal tubercle on first abdominal segment *Pinnotheres maculatus.*

a.[2] Telson bicornuate with median deltoid process.....*Pinnixa chaetopterana.*

a.[3] Telson not bicornuate, with three deltoid teeth posteriorly.
- *b.*[1] No spines on carapace or vestiges only.
  - *c.*[1] Pigment spot on second maxilliped.....*Pinnotheres ostreum.*
  - *c.*[2] No pigment on second maxilliped.....*Pinnotheres holothuriae.*
- *b.*[2] Dorsal spine only absent.....*Pinnotheres pisum.*
- *b.*[3] All spines present.....*Pinnotheres veterum.*

PIGMENTATION.

The pigmentation of the zoeas is constant for each species and is helpful in classification. In all the known species, the color of the pigment is light brown when fully expanded and black in contraction. The following table gives the pigmentation of the known forms. The notes on the pigmentation in the older descriptions probably are incomplete.

	P. ostreum.	*P. holothuriae.*	*P. pisum.*	*P. veterum.*	*P. maculatus.*	*P. chaetopterana.*	*P. sayana.*	*D. mellitae.*
Anterior rostral base	×	×			×	×		×
Posterior rostral base						×		×
Interorbital	×				×	×	×	
Supracardiac	×	×	×			×	×	×
Subcardiac	×				×		×	×
Lateral to stomach	×				×			×
Lateral to first abdominal segment	×	×						
Postero-ventral lobe	×	×			×	×	×	×
Labrum	×	×			×	×		
Mandible	×	××			×	×		×
Basipodite first maxilliped	×				×	×		×
Basipodite second maxilliped	×							
Dorso-lateral first abdominal segment					×	×		×
Ventral first abdominal segment	×							
Ventro-lateral second abdominal segment	×	×			×	×		×
Ventro-lateral third abdominal segment	×	×		×	×	×		×
Ventro-lateral fourth abdominal segment	×	×		×	×	×	×	×
Ventro-lateral fifth abdominal segment	×	×		×	×	×	×	×
Telson	×	×	×					×

METAMORPHOSIS.

The complete history of metamorphosis has not been followed in any species. The present paper carries the description of the first two zoeal stages of *P. ostreum* while Smith describes the transformation of the last zoeal stage into a megalops in *P. chaetopterana* and Faxon the transformation of the last zoeal stage directly into the young crab in *P. sayana*. When these observations are considered together, it seems probable that the Pinnotherids have at least three—probably four—zoeal stages followed either by a megalops and then the young crab or else by the crab stages directly. This generalisation must be put forward with considerable reserve as it is known that, among the Crustacea, closely related species of the same genus may present developmental histories that are quite different.

PINNOTHERES OSTREUM Say.

The zoeas of this species are among the most abundant in towings taken at Beaufort. They are recognised at once by the absence of the spines of the carapace. They are comparatively small and are active and rapid swimmers. When they come into contact with other bodies, the abdomen is flexed under the cephalothorax and the larva forms an almost perfect sphere. All of the appendages are covered except the maxillipeds.

Cephalothorax.—The dorsal and lateral spines of the carapace are wanting and the rostral spine is reduced to an exceedingly minute tubercle (fig. 1). The eyes are large and well-developed.

Cephalic appendages.—The antennules are very minute and are carried folded under the anterior border of the carapace so that usually only the terminal hairs are seen (fig. 5). The antennae are still more minute. They may be discovered after careful dissection. The mandibles, maxillules, and maxillae are of the usual brachyuran type (figs. 7, 9, 11).

Thoracic appendages.—The endopodite of the first maxilliped is composed of five segments. The sensory hair on its terminal segment is very small and is not plumose. The endopodite of the second maxilliped has two segments (figs. 13 and 15).

Abdomen.—The segments of the abdomen are progressively flattened and broadened as they approach the broad, plate-like telson. The posterior border of the telson is produced into three deltoid teeth. The marginal spines lie between the median and lateral spines (fig. 17).

FIRST ZOEA.

The first zoea has been described by Birge in a brief note. He gives accurate outline drawings of the zoea and its appendages. This stage is readily distinguished by the four swimming hairs at

the tips of the exopodites of the first and second maxillipeds. The larva is 1.3 mm. long and 0.5 mm. through the carapace (figs. 1 and 2).

SECOND ZOEA.

The second zoea is distinguished most readily from the first by the presence of six swimming hairs on the maxillipeds (figs. 4, 14, and 16). The length of the larva is now 1.6 mm. and its width 0.6 mm. The increase in size is largely in the cephalothorax (figs. 3 and 4). The maxillule (fig. 10) bears an epipodital hair. The epipodital process of the maxilla has begun its transformation and is now tripartite (fig. 12). On the abdomen the telson alone is slightly changed. Its median tooth is relatively larger (fig. 18).

PINNOTHERES HOLOTHURIAE Semper.

The description of this zoea here given is from Semper who gives a figure (fig. 48) and a very brief note in his book.

The first zoea resembles that of *P. ostreum* very closely indeed. There is not even a vestige of any of the spines of the carapace. The only other distinction between the two species is the absence of certain pigment spots in *P. holothuriae*. As Semper's figure was published in 1881 it is possible that he did not record all of the pigment spots.

PINNOTHERES PISUM Latreille.

This was the first of the Pinnotherid larvae to be described. Thompson has an interesting paper on the natural history of peacrabs and gives two figures and a few meagre notes on the larvae.

The dorsal spine of the carapace is wanting but the rostral and lateral spines are well developed (figs. 49 and 50). This peculiar condition is vouched for by Bell. As far as can be determined from Thompson's rude figures, the appendages offer no peculiarities. The abdomen expands into a flattened plate posteriorly as in *P. ostreum*. The telson resembles that of *P. ostreum* closely. Its distal border is produced into three deltoid teeth between which lie three spines on each side.

PINNOTHERES VETERUM Bosc.

The zoeas of this form as well as of a *Pinnotheres* taken from *Ascidia mentula* were hatched by Gourret. No description was given and only one figure, that of the telson (fig. 51). The abdomen is only slightly broadened as is the telson also. The three teeth are longer and narrower than in *P. ostreum* and are more like the cornua of other brachyuran telsons.

PINNOTHERES MACULATUS Say.

This form is common in the tow at Beaufort, occurring throughout the summer. It is strikingly different from the other known larvae of *Pinnotheres* and would hardly be referred to the genus unless

actually secured by hatching. The spines and telson both differ strikingly from those of the other known forms.

Cephalothorax.—All of the spines of the carapace are present and are well developed. The dorsal and rostral spines are very long, measuring 0.6 mm. (fig. 19). The lateral spines are smaller, 0.35 mm. (fig. 20). The relative lengths of the dorsal and lateral spines are helpful in distinguishing this zoea from that of *Dissodactylus mellitae*. In the latter the dorsal spine is smaller and the lateral spine larger than in *P. maculatus*.

Appendages.—These are typically brachyuran (figs. 21–27). The antennae are quite small and consist of a single ramus. They are larger, however, than those of any other known zoea of *Pinnotheres*.

Abdomen.—The abdomen is cylindrical and very different from those of other larvae of *Pinnotheres*. The telson is typically bicornuate and carries the usual six spines along its posterior border (fig. 28). This departure from the typical form of the *Pinnotheres* larva was mentioned by Faxon in a footnote. He secured his information from tracings sent to him by Smith. A telson corresponding exactly with this form is figured by Fritz Müller and assigned to a *Pinnotheres*.

DISSODACTYLUS MELLITAE Rathbun.

This zoea is common enough in the tow at Beaufort. It is large and robust, not suggesting the tiny adult crab. The zoea resembles that of *Pinnotheres maculatus* rather closely but may be distinguished by the dorsal protuberance on the first abdominal segment as well as by the shorter dorsal spine (figs. 29 and 30).

Cephalothorax.—All of the carapace spines are present and are well developed. The lateral spines especially are large and stout.

Appendages.—There is nothing peculiar about the appendages (figs. 31–36). The antennae are minute and uniramous. The sensory hair on the terminal segment of the endopodite of the first maxilliped is plumose.

Abdomen.—The abdomen resembles that of *P. maculatus* very closely. The horns of the telson are almost parallel with each other (fig. 37).

PINNIXA CHAETOPTERANA Stimpson.

The first zoea of this species has been described by Faxon and by Smith. The following description is based on material taken at Beaufort. The description corresponds with those formerly given. The pigmentation is given in the table on page 2.

The zoea is distinguished by its comparatively small spines and, especially, by the enlarged fifth abdominal segment and median process of the telson. The transformation of the last zoea into a megalops is given by Smith but he does not give description of either.

FIRST ZOEA.

The first zoea is distinguished from later stages by the four swimming hairs on the maxillipeds (figs. 39 and 45).

Cephalothorax.—All three carapace spines are present but they are small and slender, measuring only 0.3 mm. (figs. 38 and 39). The eyes are rather small.

Appendages.—All of the cephalic appendages except the mandibles are rather small. The antennules and antennae (figs. 40 and 41) are especially minute and slender.

Abdomen.—The first four segments are cylindrical but the fifth segment is expanded laterally into wings that extend backward, overlapping the telson. This feature is characteristic of the known zoeas of the Pinnixas. The telson has the bicornuate condition so often found in brachyuran larvae but is distinguished in this species by the presence of a large deltoid tooth projecting medially from its posterior border (fig. 47).

MEGALOPS.

This was reared from the last zoeal stage by Smith, but he gives neither description nor figure of either. Smith was unable to rear the megalops to the crab stage.

PINNIXA SAYANA Stimpson.

The early stages of this species have not been recorded, but the last zoeal stages of a *Pinnixa* commonly found off the New England coast have been referred to this species by Smith and Faxon. The last zoea passes directly into the crab stage. The descriptions given here are taken from Faxon, as are the figures.

The carapace is armed with long frontal, dorsal, and lateral spines. The natatory feet are very short in proportion to the size of the body, the inner branch of the second pair rudimentary, as usual with Brachyuran zoeae (fig. 53). The third pair of maxillipeds and the five following pairs of thoracic feet are folded under the carapace. On dissecting them out from the body, they are seen to be quite perfectly formed, as shown by Figure 57. The third maxillipeds (fig. 56) possess their three constituent parts and a gill at their base.

The abdomen (fig. 62) is short, its penultimate segment expanded into two lobes, which extend backward on each side of the terminal segment. The terminal segment is ovate, produced posteriorly into a long spine on either side. Between the lateral spines and a small median sinus are three short, finely feathered setae on each side.

There are four pairs of simple abdominal appendages.

There is a black pigment spot at the base of the dorsal spine, one near the base of each lateral spine, and several on the abdominal somites.

From tip of frontal spine to posterior border of carapace, 2.5 mm. From tip to tip of lateral spines, 2 mm. Length of frontal spine, 1 mm.

FIRST CRAB.

In the first crab stage (figs. 63 and 64), which immediately follows the last zoea stage just described, the carapace measures less than 1 mm. in length by 1.5 mm. in breadth. The front is nearly straight, the branchial regions expanded laterally so as to form a

prominent shoulder at the point where they meet the hepatic areas. A row of small irregularly disposed spines on the sides of the carapace. The second and third pairs of maxillipeds (figs. 70 and 71) have the same structure as in adult Pinnixae, the terminal segment of the inner limb being articulated with the penultimate segment near the proximal end of the latter, in such fashion as to form a sort of didactyle claw.

The chelae are didactyle, the dactylus closing against a long process of the antecedent segment. The following pairs of ambulatory appendages are extremely long, the last pair being much smaller than the rest, as in the adults of this genus.

The abdomen is small, closely folded against the sternum, and is not used as a swimming organ. It carries four pairs of appendages (fig. 65), which consist of a basal segment which supports two branches. The outer branch is much larger than the inner, and bears about nine setae on its border. The telson is broader than long, its posterior margin regularly convex and fringed with setae.

Blotches of dark pigment, of dendritic forms, occur on the carapace, sternum, and abdomen, arranged as represented in Figures 63 and 64.

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EXPLANATIONS OF PLATES.

Plate 1.

Figs. 1–10. Zoeas of *Pinnotheres ostreum*.
- Fig. 1. Lateral view of first zoea.
- 2. Frontal view of first zoea.
- 3. Frontal view of second zoea.
- 4. Lateral view of second zoea.
- 5. Antennule, first zoea.
- 6. Antennule, second zoea.
- 7. Mandible, first zoea.
- 8. Mandible, second zoea.
- 9. Maxillule, first zoea.
- 10. Maxillule, second zoea.

Plate 2.

Figs. 11–18. Zoeas of *Pinnotheres ostreum*.
- Fig. 11. Maxilla, first zoea.
- 12. Maxilla, second zoea.
- 13. First maxilliped, first zoea.
- 14. First maxilliped, second zoea.
- 15. Second maxilliped, first zoea.
- 16. Second maxilliped, second zoea.
- 17. Abdomen and telson, first zoea.
- 18. Abdomen and telson, second zoea.

Figs. 19 and 20. Zoeas of *Pinnotheres maculatus*.
- Fig. 19. Lateral view of first zoea.
- 20. Frontal view of first zoea.

Plate 3.

Figs. 21–28. First zoea of *Pinnotheres maculatus*.
- Fig. 21. Antennule.
- 22. Antenna.
- 23. Mandible.
- 24. Maxillule.
- 25. Maxilla.
- 26. First maxilliped.
- 27. Second maxilliped.
- 28. Abdomen and telson.

Figs. 29–37. First zoea of *Dissodactylus mellitae*.
- Fig. 29. Lateral view of zoea.
- 30. Frontal view of zoea.
- 31. Antennule.
- 32. Antenna.
- 33. Mandible.
- 34. Maxilule.
- 35. Maxilla.
- 36. First and second maxillipeds.
- 37. Abdomen and telson.

PLATE 4.

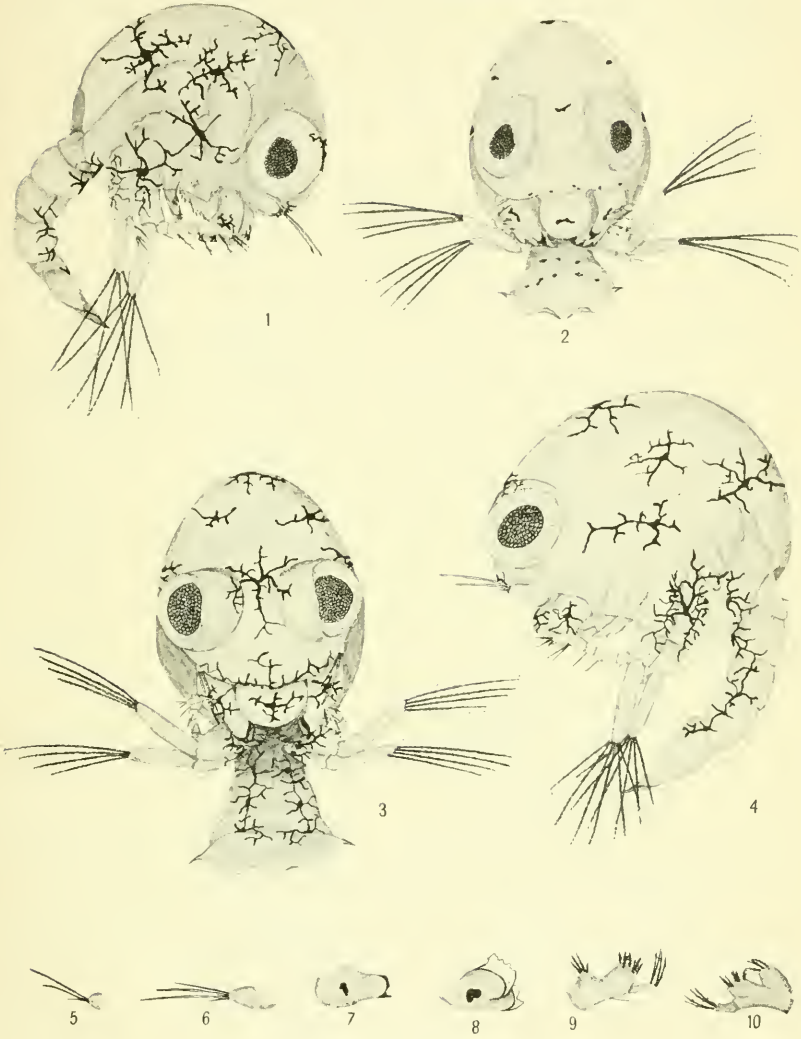
FIGS. 38–47. First zoea of *Pinnixa chaetopterana*.
FIG. 38. Frontal view of zoea.
39. Lateral view of zoea.
40. Antennule.
41. Antenna.
42. Mandible.
43. Maxillule.
44. Maxilla
45. First maxilliped.
46. Second maxilliped.
47. Abdomen and telson.

PLATE 5.

FIG. 48. Lateral view of first zoea of *Pinnotheres holothuriae* (from Semper).
FIGS. 49 and 50. First zoeas of *Pinnotheres pisum* (from Thompson).
FIG. 49. Lateral view of zoea.
50. Frontal view of zoea.
FIG. 51. Terminal segments of abdomen and telson of first zoea of *Pinnotheres veterum* (from Gourret).
FIGS. 52–58. Last zoeas of *Pinnixa sayana* (from Faxon).
FIG. 52. First maxilliped.
53. Second maxilliped.
54. Frontal view of zoea.
55. Posterior view of zoea.
56. Third maxilliped.
57. Third maxilliped, cheliped, and ambulatory appendages.
58. Maxilla.

PLATE 6.

FIGS. 59–62. Last zoeas of *Pinnixa sayana* (from Faxon).
FIG. 59. Maxillule.
60. Antennule, *a*, and antenna, *b*.
61. Labium.
62. Terminal segments of abdomen and telson.
FIGS. 63-71. First crab stage of *Pinnixa sayana* (from Faxon)
FIG. 63. Dorsal view of crab.
64. Ventral view of crab.
65. Ventral view of abdomen.
66. Antennule.
67. First maxilliped.
68. Left chela of adult male of *P. chaetopterana*.
69. Right chela of adult female of *P. chaetopterana*.
70. Second maxilliped.
71. Third maxilliped.



LARVAE OF CRABS.

FOR EXPLANATION OF PLATE SEE PAGE 8

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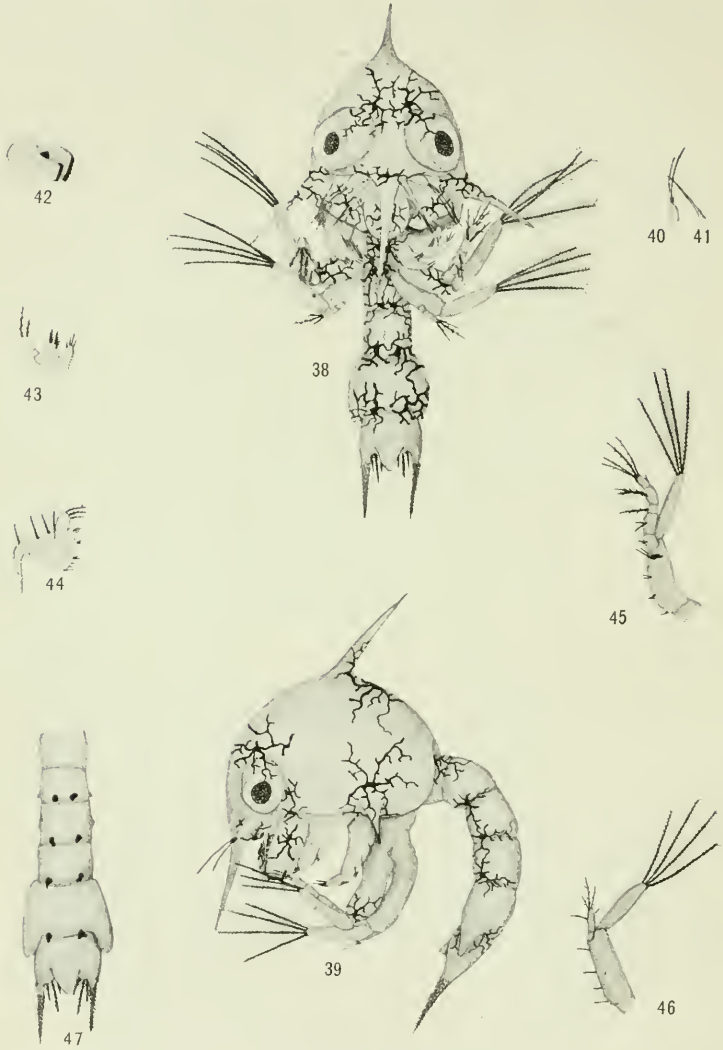

LARVAE OF CRABS.

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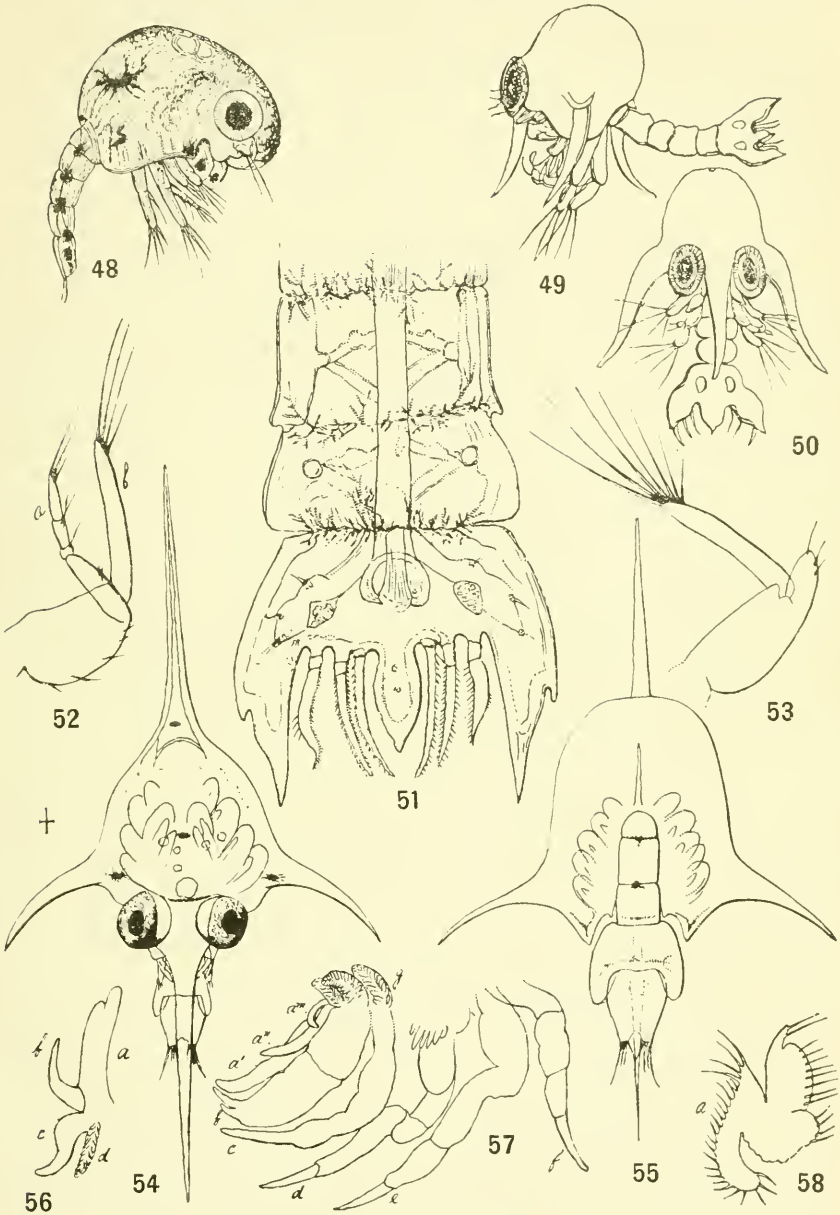

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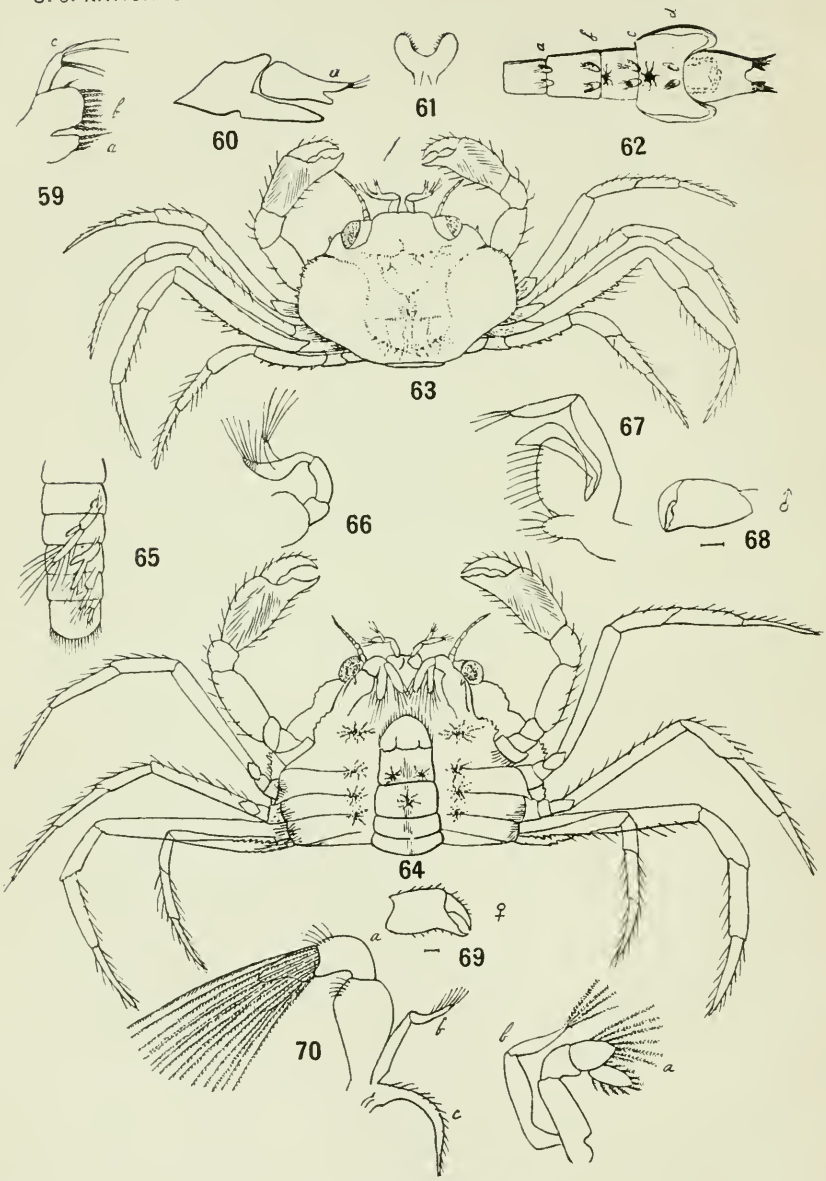

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