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The Larval Stages of the Calanoid Copepod *Eurytemora hirundoides* (Nordquist)

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THE LARVAL STAGES OF THE CALANOID COPEPOD *EURYTEMORA HIRUNDOIDES* (NORDQUIST)

CHARLES C. DAVIS

INTRODUCTION

The study of the larval stages of the Copepoda is a rather neglected field, there having appeared very few publications carefully describing all the larval stages. However, it has been well known for a long time that most Copepoda pass through, first, a series of nauplius stages, and then through a series of copepodid stages (or cyclops stages), in which the general form of the adult is assumed. It is unfortunate that more has not been done, for there is considerable value to be gained from a detailed knowledge of the many stages. In the first place, the differentiation between the larvae of the various copepod species to be found in the plankton, both marine and fresh water, greatly augments the value and accuracy of quantitative and qualitative plankton analyses, because many species spend a large portion of their life span in an immature condition. In the second place, the taxonomy of the Copepoda is admittedly not completely satisfactory (as indicated, for instance, by the discussion in Gurney, 1931, pp. 22-25), and the few publications that have so far appeared concerning the larval structure indicate that a thorough exploration of this field will bring to light many relationships between the various copepod genera that are obscured in the adult forms. Conversely, further study will undoubtedly show that some genera now considered closely related are actually widely separated phylogenetically.

Eurytemora hirundoides was first described in 1888 by Nordquist as *Temorella affinis* var. *hirundoides,* and was raised to specific status by G. O. Sars (1903), pg. 102. The species, however, is very closely related to *E. affinis* Poppe, and the minor differences to be found in the adult stage are probably undetectable in the larvae. *E. hirundoides* (Nordquist) was originally found along the coasts of Finland, but subsequently has been reported widely in the North Atlantic region (Norwegian coast, Zuider Zee, France, British waters, Nova Scotia, Narragansett Bay, Woods Hole region and Chesapeake Bay). It has also been reported from two

localities on the Pacific Coast of North America, namely San Francisco Bay and the Vancouver Island region. In all of these localities the species is characteristic of brackish to fresh waters.

The species has heretofore been reported from the Chesapeake Bay by Wilson (1932), whose investigations had previously been summarized by Cowles (1930). Wilson found it to be largely confined to the inner regions of the Bay, though it was also found sparingly in the lower Bay. This is the distribution to be expected of a brackish water species. In the upper Chesapeake Bay the species is subordinate in importance in the plankton only to the very numerous *Acartia* and *Oithona* species, and it may occur in abundance at all times of the year.

In connection with the present studies it was observed to breed very prolifically in widely varying environments in the Chesapeake Bay region. For example, in a plankton tow taken at Howell Point, at the mouth of the Sassafras River on August 27, 1942, the species was very common. Of the adult females, 80 per cent carried either developing eggs or spermatophores. At Howell Point on this date the temperature of the water was 24.0° C. and the chlorinity was only 1.0 per mille. On the other hand, at Point Patience, near the mouth of the Patuxent River, on March 5, 1943, 64 per cent of the adult females bore either developing eggs or spermatophores. Here the temperature of the water was 2.5° C. and the chlorinity was 6.0 per mille. The great fertility of the animals is indicated by the fact that frequently those females carrying egg masses (these egg masses vary in size from a few eggs to sixty or seventy) contain other well developed eggs in their ovaries, ready to be laid. In all cases where ovigerous females were kept under observation in the laboratory, the eggs hatched within three to four days, but no other evidence was obtained concerning the frequency of spawning. That fertilization of the eggs is not a problem is indicated by the number of adult males present along with the females, and by the fact that it is not unusual to find females carrying as many as eleven spermatophores at one time.

HISTORICAL

Probably the first observation of the relation between the nauplius and the adult copepod was made by Anthony van Leeuwenhoek (Leeuwenhoek, 1699-1719), who observed the hatching of the eggs of ovigerous specimens of *Cyclops* and described the resulting nauplii. However, it was not until much later that any serious study of copepod metamorphosis was undertaken, although the nauplii of several species were

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described (as, for instance, by Jurine in 1797 and again in 1820). The larval history was outlined by Ramdohr in 1805.

The first really serious studies of the problem were published by the eminent carcinologist C. Claus (1858a, 1858b, 1862, 1868, 1875, 1876, 1893a, 1893b), who described the larval forms of both free living and parasitic species. Other authors who also made valuable contributions to the field during this same period were Hoek (1877-1878), Grobben (1881), Rehberg (1882), Canu (1892), and Maupas (1892). None of these authors, however, carefully detailed all of the minute changes that occur following each molt of the nauplius and copepodid stages, nor, with one exception, did they determine the number of molts that occur, although Maupas (1892) determined that in *Belisaurius viguieri* and *Canthocamptus staphilinus* there were six nauplius and six copepodid stages. Also, none of these authors realized that it would be possible to recognize generic and specific differences in the nauplii of the Copepoda, and this limited, to a certain extent, the value of their work. As Manfredi (1923) said concerning C. Claus, the most eminent of the authors in question:

> " . . . et, bien qu'il observât et figurât des *nauplius* de différentes espèces, il ne s'occupa guère de la possibilité de les reconnaître, des le premiere stade de *nauplius.*"

It was not until the work of Oberg (1903) on free living Copepoda, and that of Wilson (1905, 1907a, 1907b, 1907c, 1911a, 1911b, 1915) on parasitic forms, that a basic knowledge of the number of molts involved and the minute changes occurring in the body and appendage structure was obtained. Oberg described and figured the nauplius larvae and the first copepodid stages of *Centropages hamatus, Temora longicornis, Acartia bifilosa, A. longiremis,* and *Oithona similis,* and described and figured some of the stages in *Pseudocalanus minutus* and *Eurytemora hirundo.* He found that there were six nauplius and six copepodid stages, the last of which was the adult. Grandori (1912) described larval stages of *Diaptomus vulgaris* and *Acartia clausi,* and also found six stages of nauplius and copepodid. These observations of Oberg and Grandori, as well as of Maupas, were then accepted as a generality by the greatest of the early authorities on the Copepoda, W. Giesbrecht (see Giesbrecht, 1913).

With (1915) described the copepodid stages of a number of species of the sub-order Calanoida. Pugliesi (1914) described the larvae of

Harpacticus gracilis, while Dietrich (1915) described the nauplius and first copepodid stages of *Diaptomus vulgaris,* and in addition, those of *Cyclops strenuus* and *Canthocamptus staphylinus.* It was discovered that many, but not all, of the Harpacticoida had only five nauplius stages instead of six as in Calanoida. Dietrich gave a historical summary of most of the publications that had appeared in the field of the metamorphosis of the Copepoda up to his time.

In 1916 Lebour, working at the Plymouth laboratory, reported on the developmental stages of *Calanus finmarchicus,* as reared experimentally in the laboratory, while Currie (1919) and Gibbons (1933) also reported on this same species. The Soviet marine biologist Bogorov (1933) gave a careful report of the weight and length characteristics of the six copepodid stages of *C. finmarchicus.*

Chappius (1916a, 1916b) described the nauplius stages of the Harpacticoids *Viguierella coeca, Phyllognathopus viguieri, Moraria varica* and *Maraenobiotus vejdovskyi.* Brian (1919, 1921, 1922) studied certain species of Harpacticoids, reporting on the nauplii and copepodid stages of *Alteutha depressa, Harpacticus uniremis, Laophonte brevirostris, L. cornuta,* and *Psamathe longicauda.* The larvae of two other fresh water Harpacticoids, namely *Moraria schmeili* and *Epactophanes richardi* were described by the Soviet worker Borutsky (1925), working at the limnological station at Kossino.

An investigation of the larvae of fresh water Cyclopoids was also published from the Soviet limnological station at Kossino in 1927 by Amelina. Other investigators of the Cyclopoida have been Byrnes (1921), Walter (1921), Murphy (1923), Manfredi (1923, 1925), Zeigelmayer (1925), Lucks (1927), Ewers (1930), and Pine (1934), but the last named obviously missed at least two stages of the nauplius and one of the copepodid. Most of these authors dealt with fresh water species of *Cyclops,* but Murphy (1923) dealt with experimentally reared specimens of the marine form, *Oithona nana.*

Grandori (1925) discussed the larvae of the Calanoid *Centropages typicus.* Rylov (1928) repeated for the Soviet-Siberian species, *Epischura chankensis* Rylov, a discussion of the interesting development of the male fifth legs, such as had some time previously been described by Marsh (1900) for the American species *E. lacustris.* Mitchell (1928) discussed the rearing and larval stages of *Euchaeta norvegica.* Ewers (1930) described the stages of *Diaptomus silicoides.*

The greatest advance in the detailed knowledge of the larval stages of the Copepoda occurred during the first half of the third decade of the twentieth century. This spurt was initiated by Gurney's three volume work on the British fresh water Copepoda (Gurney, 1931, 1932, 1933), in which he detailed the larval history of a number of copepods belonging to the three main sub-orders, the Calanoida (1931), the Harpacticoida (1932) and the Cyclopoida (1933). Gibbons and Olgivie (1933) critically re-examined the developmental stages of *Oithona helgolandica (= O. similis)*, which had previously been studied by Oberg (1906), and also detailed the development of *O. spinirostris*. Russell (1933) briefly summarized the contemporary knowledge of the development of the Copepoda.

In 1934 Nicholls published descriptions of planktonic larvae of *Euchaeta norvegica*, Campbell (1934) of *E. japonica* and *Calanus tonsus*, Gurney (1934) of *Rhincalanus*, and Johnson (1934a, 1934b) of *Tortanus discaudatus* and *Epilabidocera amphitrites*.

The last mentioned author has published two other papers (1935, 1937) on copepod development, describing the larval stages of *Eucalanus elongatus* var. *bungii (= E. bungii)*, *Labidocera trispinosa*, and *L. jollae*. Other works that have appeared on the development of the Calanoida are Steuer (1935) and Ommanney (1936) on *Rhincalanus gigas*, while papers have appeared on the Harpacticoida by Nicholls (1935) who studied *Longipedia*, and Shaw (1938) who studied a tide-pool copepod, *Tigriopus fulvus*.

From this review of the investigations that have been made, the following generalizations can be arrived at:

1) Larval stages of the Copepoda belonging to the various sub-orders easily can be distinguished from each other in nearly all cases. An exception to this is *Longipedia*, whose adult is classed with the Harpacticoida, but whose nauplius larva has many characteristics differing from those of other members of the sub-order, and resembling in some ways those of both the Calanoida and of the order *Cirripedia!*

2) Larval stages of closely related species and genera are similar, while those of more distantly related forms differ considerably in their structure.

3) The basic number of nauplius stages, each separated from the next by an ecdysis, is six. This is the case in all the Calanoida that have so far been studied, and is also the case in some of the Harpacticoida and Cyclopdoida. However, most forms of the last two sub-orders have only five nauplius stages, and some of the cyclopoids may have less than this. In the parasitic sub-orders there are wide variations from the basic condition. The eggs in most cases hatch into nauplius larvae, but in the case of the sub-order Lernaeopodoida the eggs frequently hatch directly into the first copepodid stage, skipping all the nauplius stages. In other parasitic forms there are only one, two or three nauplius stages.

4) The basic number of copepodid stages also is six, the last of which is the adult stage. This number also may be shortened in some cases, especially in the parasitic forms. For example, in the lernaeopodoid, *Achtheres ambloplitis,* Wilson (1911a) found that after the second molt the animals were sexually mature. There is also some evidence that occasionally the mature adult (copepodid stage VI) may molt into a seventh stage, which is likewise a fertile adult. Grandori (1912), for example, reports having found the shed skins of adults, and also adults that were larger than usual.

MATERIAL AND METHODS

In order to obtain nauplii unquestionably belonging to this species of copepod, ovigerous females of *Eurytemora hirundoides* (Nordquist) were obtained from unpreserved plankton samples taken from the pier of the Chesapeake Biological Laboratory and kept in filtered water from their natural environment until the eggs hatched. Attempts to hatch the eggs separate from the mother were not highly successful unless the eggs were near the point of hatching when removed. When the eggs borne by the ovigerous female were hatched, the mother was then removed and the larvae observed in their progress. Nearly 100 per cent of the first stage nauplii successfully underwent ecdysis, and about 50 per cent of one group of the resulting second stage nauplii successfully molted into the third stage. However, the second and third stage larvae reared in the laboratory, although they had normal structural characteristics, were considerably smaller than the same stage picked out of preserved plankton samples. The reared second stage nauplii varied in size from 0.110 mm. to 0.122 mm., while the same stage picked out of the plankton varied from 0.128 mm. to 0.146 mm. The reared third stage nauplii varied from 0.122 mm. to 0.140 mm., while plankton specimens varied from 0.146 mm. to 0.183 mm. The reason for the discrepancy in size is obviously

that the food supply and other conditions were not normal for the reared nauplii.

The duration of the first stage is short, amounting in the laboratory to from six to ten hours (at 20° C.). In the one case where some of the larvae shed into the third stage, the period of time between the first and the second ecdyses amounted to approximately twenty-four hours (at 20° C.).

In addition to the larvae raised in the laboratory, it was found possible to obtain living nauplii from the plankton, some of which would then shed the skin in the laboratory after being isolated from all other nauplii, thus advancing one stage. In this way third stage, fourth stage and fifth stage larvae shed their skins to become fourth stage, fifth stage and sixth stage nauplii respectively. Thus all six of the nauplius stages were obtained experimentally, and it was possible on the basis of these results to pick numbers of each of the more advanced nauplii (stages two to six) from a preserved sample of the plankton for intensive study.

Also, it was possible to obtain living sixth stage nauplii from the plankton and observe them shed their skins and become first stage copepodid larvae, thus definitely establishing the relation between nauplius and copepodid. The remaining copepodid stages were traced easily, due to their similarity to both the first copepodid stage and the adult stage. Many specimens of all copepodid stages except the first were found in a plankton tow taken with a coarse (No. 6) net of bolting silk in the Patuxent River off the laboratory on March 31, 1943, and many specimens of the nauplius stages from two to six, and also the first copepodid stage, were found in a tow taken with a finer (No. 12) silk net in the same locality on April 2, 1943. Specimens of the first nauplius stage were obtained by hatching eggs, although a few were also found in the plankton.

All drawings were made with the aid of a camera lucida.

THE NAUPLIUS STAGES

In *Eurytemora hirundoides,* as is true of all other Calanoida that have been investigated, there are six nauplius stages. This is also true, as determined by Gurney (1931), for *E. velox.* The body in all the stages is of the usual calanoid nauplius form, and the ratio between the length and the width approximates two to one, thus not being exceptional. The caudal armature differs considerably, however, from that of all other

PLATE I

Figure 1. Nauplius stage I. Ventral view. x 190.

2. Nauplius stage II. Ventral view. x 190.

3. Nauplius stage III. Ventral view. x 190.

4. Nauplius stage I. Mandible. x 390.

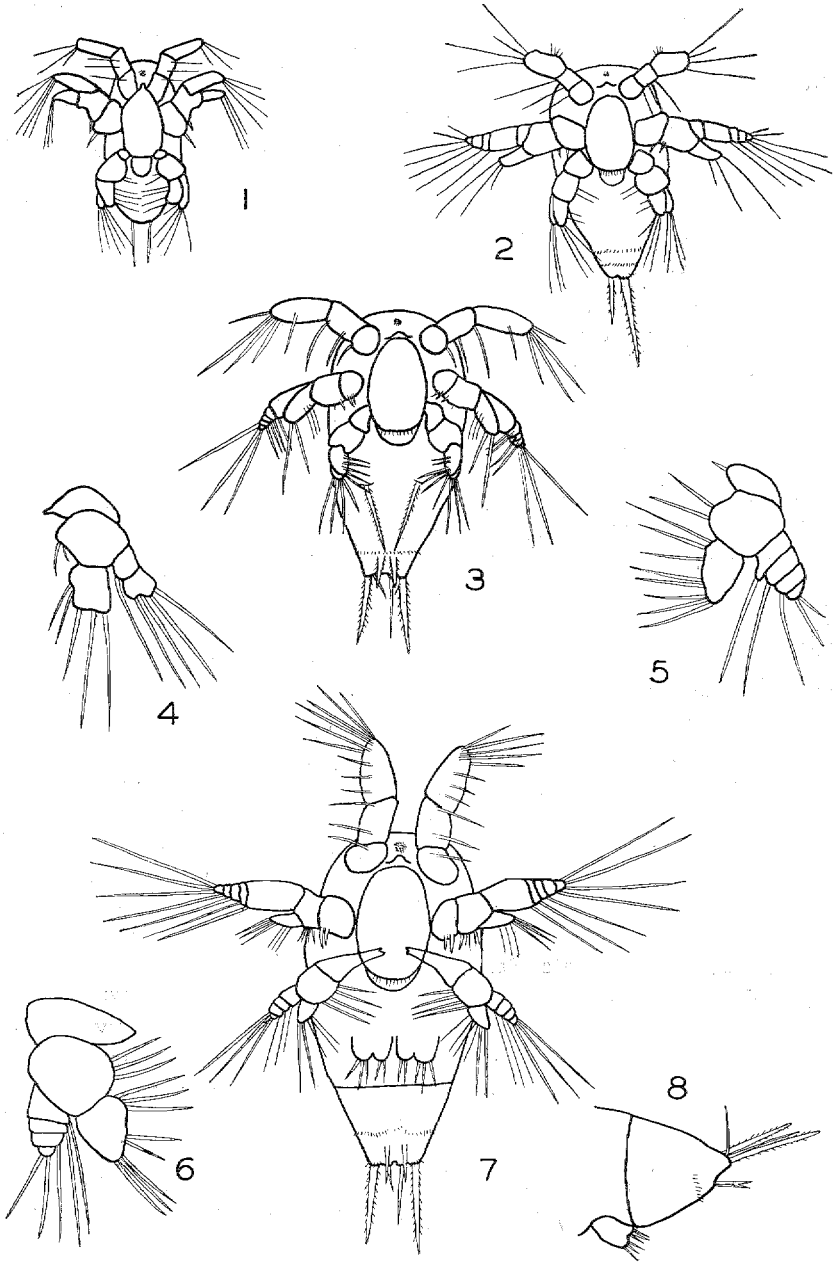
5. Nauplius stage II. Mandible. x 390.

6. Nauplius stage III. Mandible. x 390.

7. Nauplius stage IV. Ventral view. x 190.

8. Nauplius stage IV. Posterior end, lateral view from the left side. x 190.

PLATE I



known genera except *Temora,* and differs also from this genus in some respects *(see infra)*. In all stages from three to six, the right seta of the inner pair is sharply projected dorsally (see plate I, figure 8), while the other seta of the pair is directed posteriorly. Lateral from this pair of setae is a heavier pair of setae, provided with spinose processes (see, for example plate II, figure 1). The left one of this pair of setae is the longer of the two. In addition, there is a pair of shorter spinose setae arising on the ventral side of the body near the posterior end. The caudal armature of the first two nauplius stages is simpler, and will be described below. The labrum is large, and in all but the first stage its posterior portion is more or less hirsute.

The living nauplii are nearly colorless, except for the eye spot which is bluish-red and rather dark. In stage VI portions of the labrum also develop a red coloration. Preserved specimens are opaque, and all coloration has disappeared.

Nauplius Stage I

Body (plate I, figure 1). Length 0.098—0.104 mm. From a ventral view there appears a small knob just anterior to the large, broad labrum, and just posterior to the position of the eye. This is probably the frontal organ, and appears also in other genera, such as for instance, *Eucalanus, Tortanus,* etc. The posterior end of the body bears two fine setae of approximately equal lengths.

First Antenna (plate III, figure 1). Three segments, the first bearing one large seta on its inner distal corner, the second bearing two similar setae on the inner border, one about in the middle of the segment, and the other on the distal corner. The third segment bears three long setae terminally.

Second Antenna (plate III, figure 7). The first basipod segment bears one relatively stout masticatory seta or hook, which is provided with spinose processes. The second basipod segment bears a relatively stout seta near its proximal corner, with a very fine seta a little farther distal from this position, and with two similar setae close together near the distal corner. This segment is very broad and stout. The endopod is unsegmented, and bears three long and stout setae, which are terminal and subterminal. The exopod consists of four more or less clearly defined segments, the first of which is by far the longest. The second and third segments each bears a single long seta, while the fourth bears three, one

of which is subterminal in a position which subsequent stages show will be the penultimate segment, and two of which are terminal.

Mandible (plate I, figure 4). The masticatory portion is very poorly developed, consisting of a small segment, with a single small point, or tooth, on the inner side. The basal segment of the palp is large and globular in form. On its inner border there are two small setae, one of which is considerably smaller than the other. The broad, flat endopod is unsegmented, and bears five relatively large setae, of which three are terminal and the other two on the distal half of the inner border. The exopod, which is somewhat smaller than the endopod, shows two segments, but these are not very clearly defined. The proximal segment bears one seta near its inner distal corner, while the distal segment bears two terminal setae, and two subterminal setae on the inner border.

Nauplius Stage II

Body (plate I, figure 2). Length 0.128—0.146 mm. The shape is a little more stubby than in stage I. The posterior border of the labrum has become somewhat hirsute. Towards the posterior end two transverse rows of fine hairs have appeared, with a portion of a third row at the very posterior end, at the base of the left hand caudal seta. The caudal armature consists still of two setae, but these are much more strongly developed than in the first nauplius stage. The left member of this pair of setae is much more strongly developed than the right one, and is longer. The right seta is projected dorsally, as described by Gurney (1931) for first stage nauplii of *E. velox*.

First Antenna (plate III, figure 2). The two basal segments are similar to those of the first stage. The third segment is broader and more oval in outline, and bears four instead of three terminal setae. This additional seta, however, is smaller than the other three. On the outer border of the third segment, about one-third of the distance from the proximal end, there is a group of several fine spinules, which show up in this position in all subsequent stages of the nauplius.

Second Antenna (plate IV, figure 3). In addition to the single stout setose hook that was present on the first basipod of stage I, and which is now considerably more prominent than before, there is a second fine seta, which is destined in future stages to become a second hook. It lies just distal to the first hook. The second basipod segment is as in stage I. In addition to the three terminal setae on the endopod, there are now also two fine setae on the inner margin near the base. The segmentation

PLATE II

Figure 1. Nauplius stage V. Ventral view. x 190.

2. Nauplius stage VI. Ventral view. x 190.

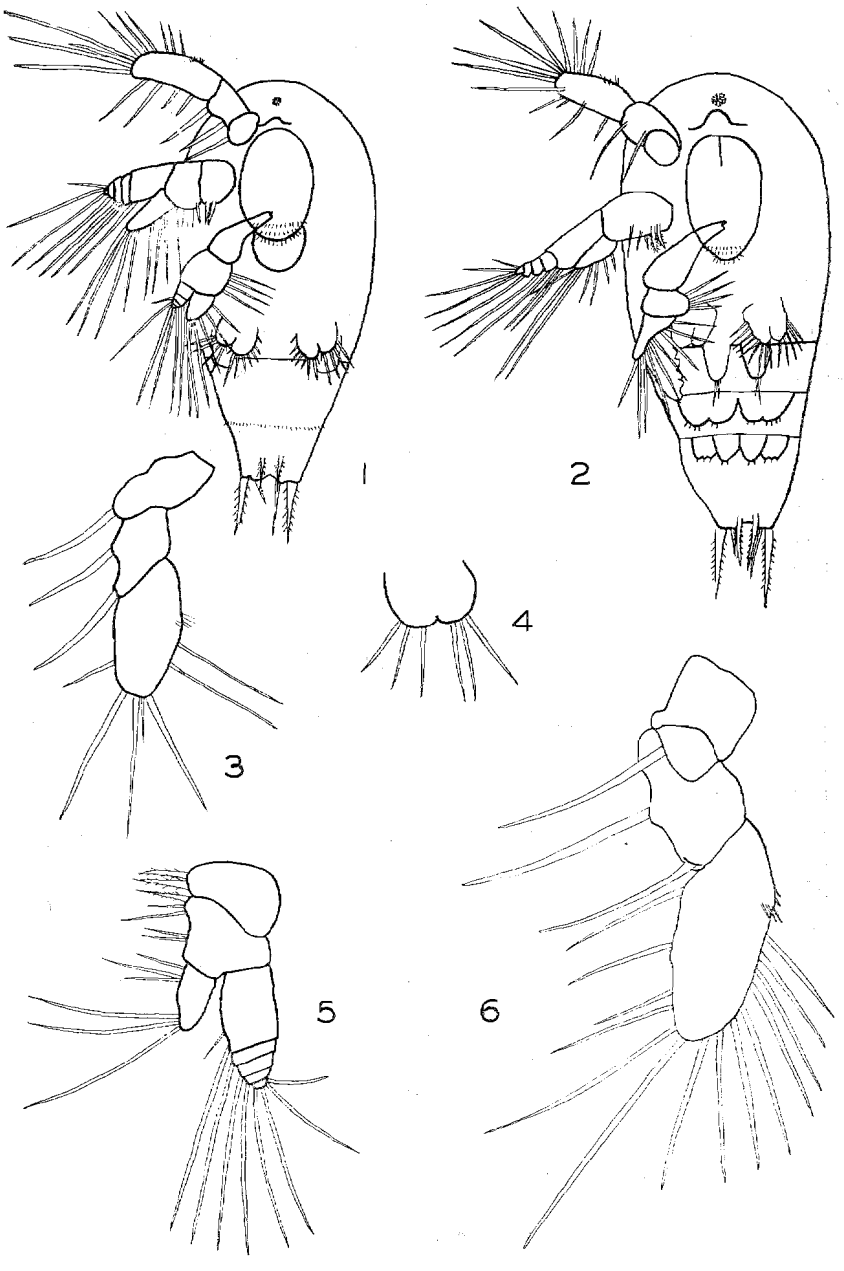
3. Nauplius stage III. First antenna. x 390.

4. Nauplius stage IV. First maxilla. x 390.

5. Nauplius stage III. Second antenna. x 390.

6. Nauplius stage VI. First antenna. x 390.

PLATE II



of the exopod is a little more clear than before, and now six segments are visible, with indications of a seventh. The proximal segment is short and bears no setae. The second segment is much larger, and shows indications of segmentation towards its distal end. The longer proximal portion and the shorter distal portion each bears a seta on its inner distal corner. The following three segments are small, and each bears one seta. The terminal segment is still smaller and bears two setae.

Mandible (plate I, figure 5). The masticatory portion is similar to that of stage I, but the inner tooth is somewhat larger. The two fine setae on the inner border of the basal segment are now equal in size. The unsegmented endopod now bears, in addition to the three terminal setae, five setae on its inner border. The exopod is now four-segmented, although the segmentation is not yet very clear. Each of the first three segments bears one seta, while the terminal segment bears two.

Nauplius Stage III

Body (plate I, figure 3). Length 0.146—0.183 mm. The general shape is as in stage II. The labrum is more hirsute on its posterior border than in stage II. One of the transverse rows of fine hairs towards the posterior end is now lacking, leaving one row remaining. On the posterior end, the base of each of the stout caudal setae, or hooks, is ringed by a similar row of fine hairs. The caudal armature has taken on the general character it will maintain through the sixth nauplius stage. At the posterior end of the body there are two pairs of setae, an outer heavier pair which are spinose, and an inner more delicate pair. The left member of the outer pair is somewhat longer than the right member, and the right member of the inner pair is directed dorsally (see plate I, figure 8), as is the right caudal seta in stage II. In addition, there is a third pair of hooks arising on the ventral side of the body, close to the posterior end. These are not as long as either of the other two pairs, but are stouter than the inner caudal pair.

First Antenna (plate II, figure 3). There has been no change, other than size, in the two proximal segments. The terminal segment now bears, in addition to the four terminal setae found in stage II, one seta on the inner border, and two on the outer border, making a total of seven setae.

Second Antenna (plate II, figure 5). The second hook on the first basal segment has become as stout as the first one. On the second basal segment there is one additional fine seta on the distal half of the segment.

The endopod and exopod are much as in stage II, but the terminal segment of the latter bears three instead of two setae, and the former has an additional fine seta on the inner border.

Mandible (plate I, figure 6). Unchanged from stage II, except the inner margin of the basal segment of the palp now bears three instead of two setae.

First Maxilla (see plate I, figure 3). Represented by a single long, relatively stout, spinose seta.

Nauplius Stage IV

Body (plate I, figures 7 and 8). Length 0.195—0.220 mm. Similar to stage III, but the body is now segmented posterior to the second maxillae. The caudal armature is likewise the same as in stage III. The rows of hairs at the base of the two outer caudal hooks are more prominent than previously.

First Antenna (plate III, figure 5). As in stage III, except the terminal segment now bears eleven setae instead of seven. Terminally on the segment there are four setae, one of which is small as before, then there are three setae on the inner border, and four on the outer border.

Second Antenna (plate III, figure 6). There has been little change since stage III.

Mandible (plate IV, figure 5). The masticatory portion is comparatively more robust than before, and the inner end now shows indications of two blunt teeth. The inner margin of the basal segment of the palp bears four setae. The endopod and exopod show no changes.

First Maxilla (plate II, figure 4). The long seta of stage III has completely disappeared, and the appendage has taken on a bilobed structure. Each lobe bears three weak setae terminally.

Second Maxilla. Present, when discernible, as a tiny bud behind the first maxilla.

Nauplius Stage V

Body (plate II, figure 1). Length 0.244—0.262 mm. Body shape and structure nearly as in stage IV, but the suture behind the maxilliped is more clear.

PLATE III

Figure 1. Nauplius stage I. First antenna. x 390.

2. Nauplius stage II. First antenna. x 390.

3. Nauplius stage V. First antenna. x 390.

4. Nauplius stage VI. Mandible. x 390.

5. Nauplius stage IV. First antenna. x 390.

6. Nauplius stage IV. Second antenna. x 390.

7. Nauplius stage I. Second antenna. x 390.

PLATE III

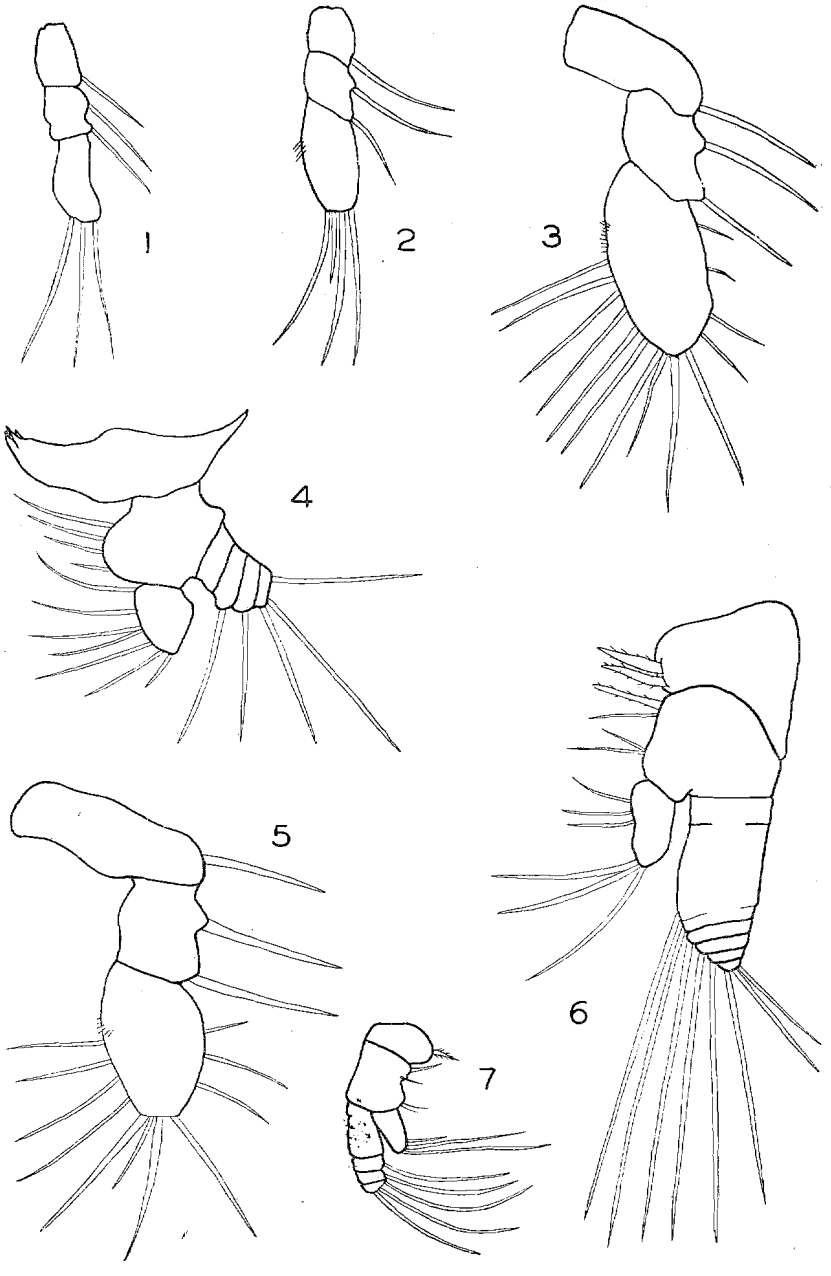


PLATE IV

Figure 1. Nauplius stage VI. Second antenna. x 390.

2. Nauplius stage VI. Second maxilla. x 390.

3. Nauplius stage II. Second antenna. x 390.

4. Nauplius stage V. First maxilla. x 390.

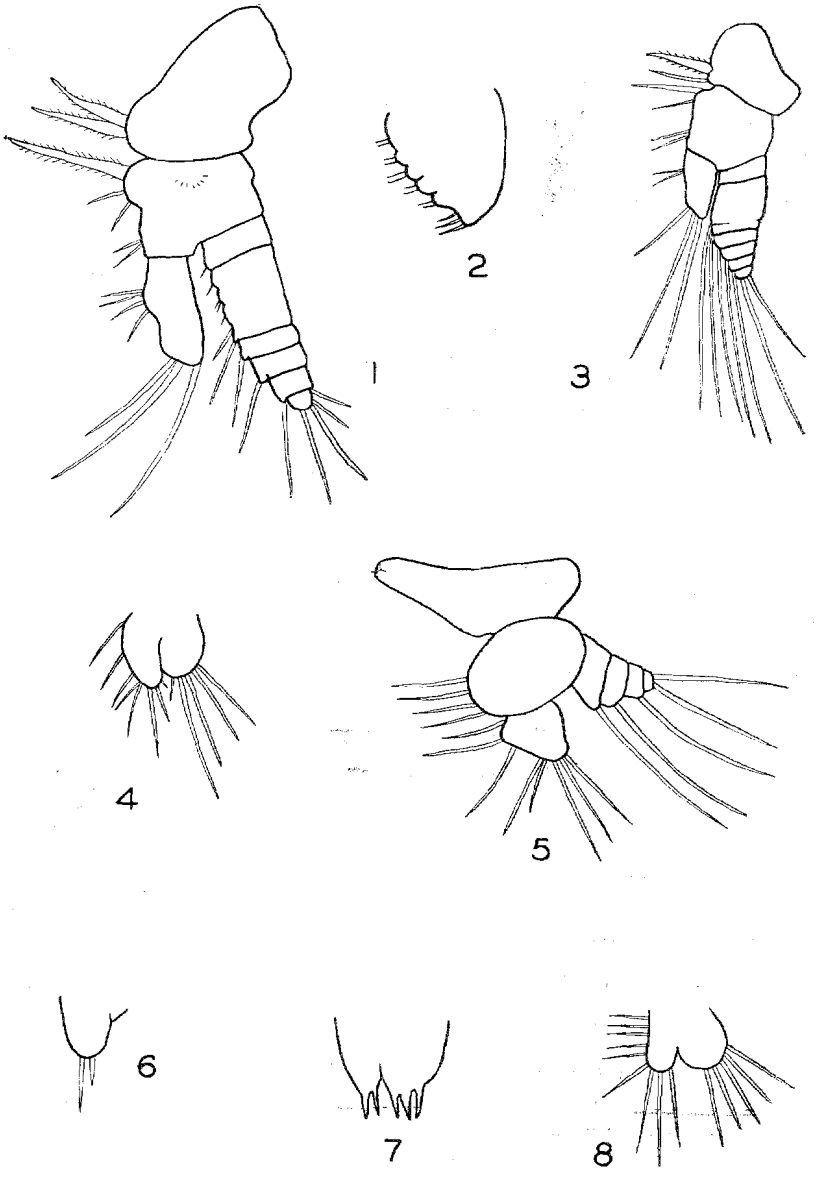
5. Nauplius stage IV. Mandible. x 390.

6. Nauplius stage VI. Maxilliped. x 390.

7. Nauplius stage VI. Second leg. x 390.

8. Nauplius stage VI. First maxilla. x 390.

PLATE IV



First Antenna (plate III, figure 3). As in stage IV, except the terminal segment now bears fourteen instead of eleven setae. In addition to the four terminal setae, there are six on the outer border, and four (the two proximal of which are very small and fine) on the inner border.

Second Antenna. As in stage IV.

Mandible. As in stage IV.

First Maxilla (plate IV, figure 4). The general form is as in stage IV, but the inner lobe now bears eight setae, and the outer lobe bears five.

Second Maxilla (see plate II, figure 1). Easily discernible as a large bud without setae, lying behind and lateral to the first maxilla.

Maxilliped. Rudimentary.

Nauplius Stage VI

Body (plate II, figure 2). Length 0.301—0.366 mm. As in stage V, except that there are no transverse rows of fine hairs towards the posterior end of the body. Also, beginning just behind the second maxillae, there are three clearly defined sutures, thus dividing the body into four clear segments.

First Antenna (plate II, figure 6). As in stage V, but all of the four setae on the inner border of the third segment are of fairly good size.

Second Antenna (plate IV, figure 1). Much as in stage V. However, the inner border of the endopod bears four instead of three setae, and the terminal segment of the exopod bears also four setae instead of three. In addition, on the face of the second basal segment, near its proximal border, there is an arc of fine spinules. This was not observed in any other stage.

Mandible (plate III, figure 4). There are now two well developed teeth and a third less well defined tooth on the masticatory portion. Otherwise as in stage V.

First Maxilla (plate IV, figure 8). Form as in stages IV and V, but the inner lobe bears nine setae and the outer five.

Second Maxilla (plate IV, figure 2). This appendage is rather well developed, and is approaching the form found in the copepodid stages. The inner edge exhibits the development of the rudiments of lobes and segments. There are seven of these, the terminal of which bears three small setae, and each of the others two.

Maxilliped (plate IV, figure 6). This appendage consists of a simple bud bearing two unequal, fine setae.

First and *Second Legs* (plate IV, figure 7). These appear at this stage as rudimentary, bilobed buds. The inner lobe bears two minute setae, and the outer lobe bears three.

Comparison of Nauplii of *E. hirundoides* and *E. velox*

Gurney (1931) described the larval stages of *E. velox,* and the detailed comparison below is based on his descriptions and figures: In general, nauplii of *hirundoides* are somewhat smaller than those of *velox,* but the nauplial structure is on the whole similar, with the following minor exceptions.

Nauplius Stage I. In *velox,* the right member of the caudal pair of setae projects dorsally, whereas in *hirundoides* this does not appear to be the case until stage II. *E. velox* bears three long and one short setae on the third segment of the first antenna, whereas *hirundoides* bears only the three long setae. The second basal segment of the second antenna of *velox* bears two fine setae and one stout, while *hirundoides* bears three fine and one stout.

Nauplius Stage II. The caudal armature in *velox* is as in stage I, which Gurney figures as consisting of two setae equal in length. In *hirundoides* the two setae are very asymmetrical, the left one being the longer and the stouter. The right one projects dorsally. The third segment of the first antenna of *velox* bears, in addition to the group of small spinules found on the outer border about one-third of the distance from the proximal margin in *hirundoides,* two other groups of similar spinules. One of these groups is found subterminally on the outer border, and the other in the middle of the inner border.

Nauplius Stage III. The ventral pair of hooks in the caudal armature is lacking in *velox.*

Nauplius Stage IV. The ventral pair of hooks in the caudal armature is still lacking in *velox.* There is no group of fine spinules on the outer border of segment three of the first antenna in *velox.* The inner lobe of the first maxilla in *velox* apparently does not bear any setae, whereas in *hirundoides* this lobe bears three setae.

Nauplius Stage V. There is a subterminal group of fine spinules in *velox* on the inner border of the third segment of the first antenna, which

was not observed in *hirundoides*. *E. velox* does not bear a similar group on the outer border of the segment, as is characteristic of *hirundoides*. The setae on the inner border of this segment in *velox* are better developed than in *hirundoides*. The exopod of the second antenna in *velox* bears ten, rather than eight setae. The first maxilla in *velox* has developed four inner lobes, while that of *hirundoides* has developed only one.

Nauplius Stage VI. The group of fine spinules on segment three of the first antenna is absent in *velox*. On the same segment, *velox* bears five instead of four setae on the inner border. The exopod of the second antenna of *velox* bears eleven instead of nine setae. The first maxilla of *hirundoides* is still much retarded compared to that of *velox*.

Comparison of Nauplii of *E. hirundoides* and *E. hirundo*

Oberg (1906) figured three stages of the nauplius of *E. hirundo* Giesbrecht. *E. hirundo* is close to *affinis* structurally in the adult, and *hirundoides* is sometimes considered to be a sub-species of *affinis*, or to be a local environmental form of it. Consequently, one would expect that the larvae would be similar. From Oberg's limited figures the following comparison can be made between *hirundoides* and *hirundo* nauplii: 1) In the late stages of *hirundo* the posterior portion of the labrum is figured as being provided with a row of short spines, and similar spines are also shown on the body wall just posterior to the labrum whereas in *hirundoides* fine hairs only are to be found. It should be mentioned here in passing that Gibbons and Ogilvie (1933) found that in *Oithona similis* Oberg had been very inaccurate in his depiction of the labrum, apparently not considering this organ to be of great importance. Perhaps the same is true here. 2) In nauplius stage III *hirundo* is shown with the seta of the first maxilla comparatively very short. In both *hirundoides* and *velox*, as well as in *Temora longicornis* (also described by Oberg), this seta is very long. 3) In *hirundo* there are transverse rows of small spines towards the posterior end of the body, instead of transverse rows of fine hairs as in *hirundoides*.

Comparison of Nauplii of *Eurytemora* and *Temora*

Oberg (1906) described in detail the nauplius stages of *Temora longicornis* Müller. The nauplii are in general similar to those of *Eurytemora* as described above for *E. hirundoides*, by Gurney (1931) for *E. velox*, and by Oberg (1906) for *E. hirundo* (three stages). There are several essential differences, however. In *Temora* the asymmetry of the two

outer caudal setae is more pronounced than in *Eurytemora*. Also, in the later stages there are two pairs of ventral hooks near the posterior end of the body of *Temora,* but only one such pair in *Eurytemora*. Both pairs of hooks are more anterior in *Temora* than in *Eurytemora*. Furthermore, there are two pairs of similar lateral hooks in *Temora,* and these are lacking in *Eurytemora*.

THE COPEPODID STAGES

In the copepodid stages the body finally takes on the calanoid form. The appendages, especially the mouthparts, are very similar in structure to those of the adult. The segmentation of the first antennae, however, and that of the legs, is very retarded and undergoes a number of changes as the animals develop. Most of the cephalic appendages are relatively weakly developed, as is characteristic of the genus. In most of the Calanoida it is usual that there be six copepodid stages, the last of which is the adult form. On the other hand, in certain species, Grandori (1912) has found evidence that a seventh copepodid stage may occur, and that both the sixth and seventh stages are fertile adults. In *Eurytemora hirundoides* the usual six stages are passed through, and no evidence was obtained of a molt in stage six. However, in the water near the mouth of the Patuxent River, there occur two forms of the adult female, one of which has a somewhat more robust appearance than the other, and the two showing very slight structural differences (these will be described below in the discussion of copepodid stage VI). It is conceivable that the more robust form is the result of an ecdysis in stage VI, although no proof of this exists.

The earlier copepodid stages are colored similar to the nauplii. That is, the eye is bluish-red and dark, while there are small flecks of red around the mouth. In later stages the red coloration appears also on appendages posterior to the mouth, and at their bases, although not in great abundance. It does not appear posterior to the first legs, except in the adult female the color extends more posteriorly.

Copepodid Stage I

Body (plate V, figure 1). Length 0.439—0.549 mm. The calanoid form has been assumed, and the appendages approach in structure those of the adult. There is no trace of a rostrum, which is only weakly developed in the adult. The body consists of six segments, and the furcal rami, the first four segments constituting the metasome and the last two

PLATE V

Figure 1. Copepodid stage I. Dorsal view. x 90.

2. Copepodid stage II. Dorsal view. x 90.

3. Copepodid stage IV. Female. Urosome and last three segments of the metasome, dorsal view. x 90.

4. Copepodid stage II. Third leg. x 190.

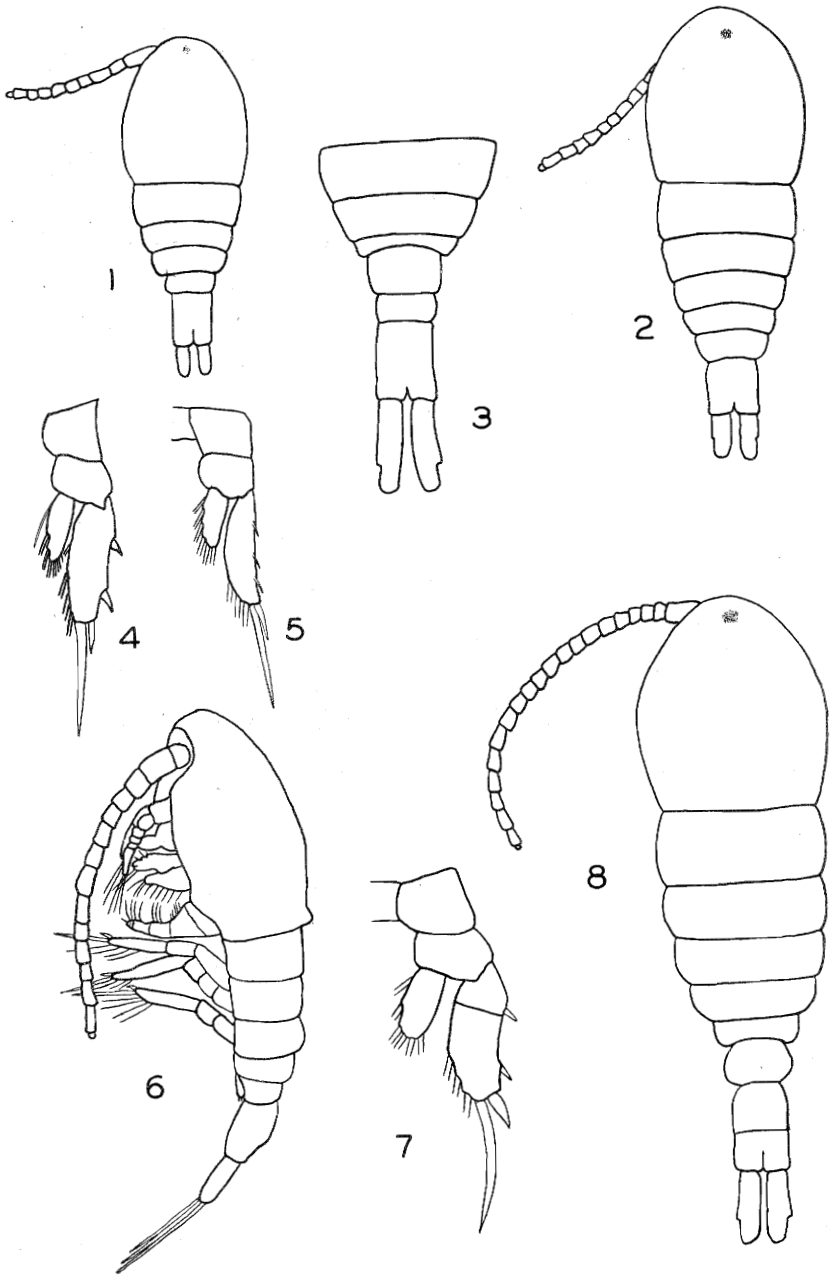
5. Copepodid stage I. First leg. x 190.

6. Copepodid stage II. Lateral view. x 90.

7. Copepodid stage III. Fourth leg. x 190.

8. Copepodid stage III. Dorsal view. x 90.

PLATE V



the urosome. The first segment is the cephalic segment, and bears all the cephalic appendages. Dorsally on its posterior border it bears a hump (see plate V, figure 6). The second segment, which is somewhat larger than the remaining segments, bears the first pair of legs. Segment three bears the second pair of legs, while segment four bears the rudiments of the third pair. Segment six is longer than the other segments, except for the cephalic segment, and bears the pair of furcal rami. Each furcal ramus bears terminally three long robust setae, and one additional very small seta on each the inner and outer distal corner. In addition, there is a very small seta about midway on the outer margin of the ramus.

First Antenna (plate VII, figure 3). Consists of ten segments, those toward the middle and proximal end rather difficult to distinguish.

Second Antenna. First basal segment and second basal segment each with one seta on the inner distal corner. The endopod consists of two segments, the first of which is fused with the second basal segment. It bears two very fine setae on the inner border. The second segment bears three relatively strong setae terminally and three very fine ones on the inner border. The exopod consists of six segments, the proximal of which bears one inner seta. The second segment bears three such setae, and is a relatively long segment. The next three segments are very short, each bearing a single seta. The terminal segment is longer than the previous three together, and bears, in addition to three terminal setae, one on the inner border.

Mandible (plate VII, figure 2). The masticatory portion bears six teeth, and on the anterior border there is a conspicuous hump, which is not so marked in future stages. The first basipod segment of the palp is very small and difficult to determine, and bears no setae. The second is large and globular, and bears three setae on the inner border. The endopod and exopod are approximately equal in length, but the former consists of but two segments, while the latter consists of five short segments, each of which bears a single seta. The first segment of the endopod bears two setae on the inner border, while the second segment bears four terminal setae, one of which is very fine.

First Maxilla. First inner lobe with eight or nine short strong setose spines. Second inner lobe with four normal setae. Outer lobe with four strong well developed setae. The second basal segment bears three fine setae on its inner distal corner. The endopod apparently consists of only two segments, the first of which bears two fine setae on its inner border, and the second of which bears four stronger setae and one fine seta ter-

minally. The exopod consists of but one segment, which bears seven setae terminally and along its outer border.

Second Maxilla. The segmentation is very obscure, but five inner lobes, part of the basipodite, stand out very clearly. Each of these lobes bears two very heavy setae, while on some of the lobes a third, very fine seta is also visible. The portion of the appendage distal to these lobes constitutes the endopod, and consists of two short segments, each of which bears two long setae, which are finer than those found on the lobes.

Maxilliped (plate VI, figure 3.) This uniramous appendage consists of five segments, the proximal of which is short and bears no setae. The second segment is the largest on the appendage. It bears three lobes, the first of which bears one, and the second and third of which each bears two fine setae. The third segment has one lobe and bears three setae. The fourth segment is smaller than the preceding ones, and bears one seta on its distal corner. The terminal segment is much smaller than any of the others, and bears four setae.

First Leg (plate V, figure 5). The two segments of the basipod are simple and bear no setae. Both the exopod and endopod consists of a single segment. The endopod bears two terminal setae and four setae on the inner border. The exopod bears three setae on the inner margin in the distal half of the segment, and on the outer margin it bears three small, somewhat obscure spines. Terminally there is a long smooth spine, and subterminally on the outer margin is a fourth small spine, which, however, is considerably larger than the other marginal spines.

Second Leg (plate VIII, figure 5). Similar in its general characteristics to the first leg, but larger. The endopod bears only five setae, three of which are on the inner margin, and two of which are terminal. There are only three marginal spines on the exopod. One of these is subterminal. They are much stronger than the marginal spines of the exopod of the first leg.

Third Leg. Present, but rudimentary.

Copepodid Stage II

Body (plate V, figures 2 and 6). Length 0.555—0.671 mm. Shape as in stage I, but there are now seven body segments. The last two segments constitute the urosome, and the first five the metasome. Segment four bears the third legs, and segment five the rudimentary fourth legs. The

PLATE VI

Figure 1. Copepodid stage IV. Male. Urosome and the last two segments of the metasome, lateral view. x 90.

2. Copepodid stage IV. Female. Urosome and the last two segments of the metasome, lateral view. x 90.

3. Copepodid stage I. Maxilliped. x 190.

4. Copepodid stage V. Female. Urosome and the last two segments of the metasome, lateral view. x 90.

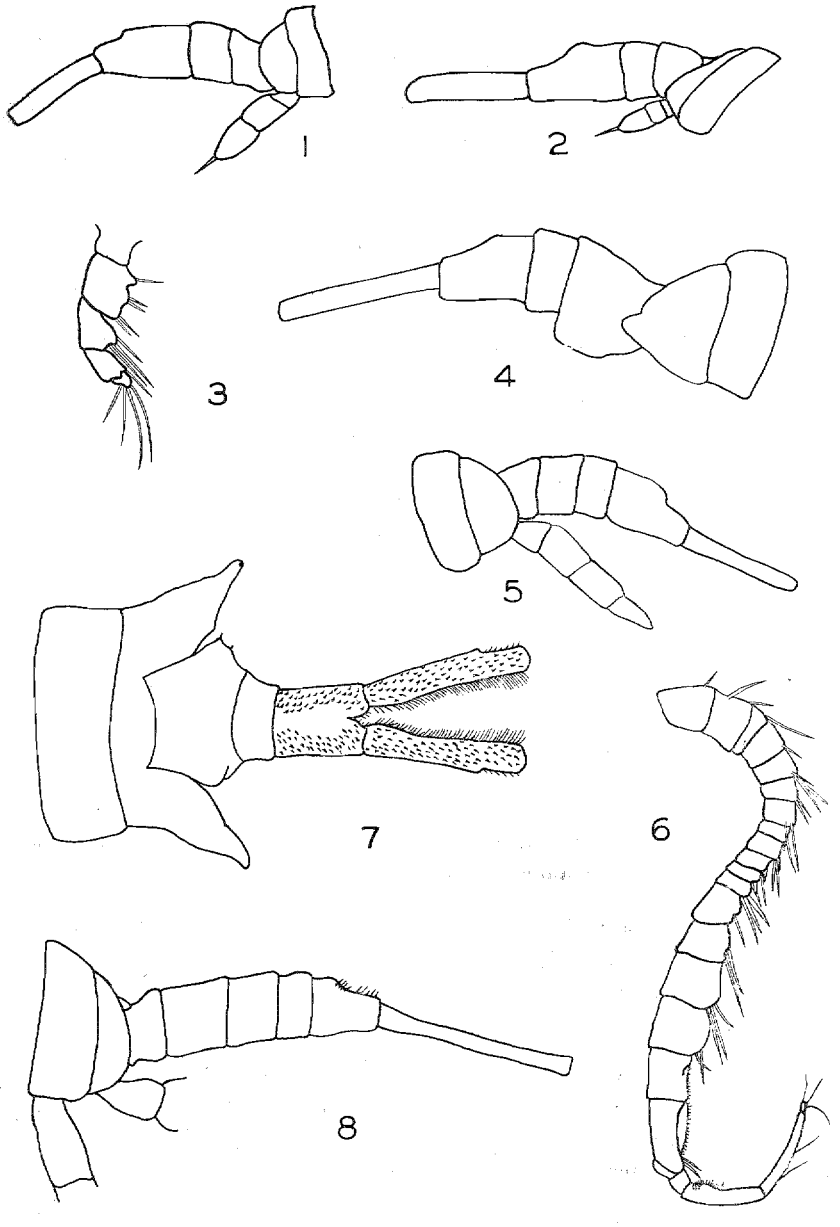
5. Copepodid stage V. Male. Urosome and the last two segments of the metasome, lateral view. x 90.

6. Copepodid stage VI. Male. Right first antenna. x 90.

7. Copepodid stage VI. Female. Urosome and the last two segments of the metasome, dorsal view. x 90.

8. Copepodid stage VI. Male. Urosome and the last two segments of the metasome, lateral view. x 90.

PLATE VI



furcal rami are relatively longer than in stage I, and the outer of the five terminal setae is considerably stronger than it was. The seta on the outer border of each furcal ramus is also stronger.

First Antenna (plate VII, figure 4). There are now fifteen segments, those towards the middle and the proximal end still being somewhat obscure.

Second Antenna. Much as in stage I, but the second segment of the endopod bears four instead of three terminal setae. The setae on the inner border are stronger, and there are four of them. Also, there is an additional one of the very short segments in the exopod, and it bears a single seta, as do the others.

Mandible. The masticatory portion is very similar to that of the adult (see plate VIII, figure 1), and bears eight teeth. The conspicuous hump is no longer present. The basal segment of the palp bears four instead of three inner setae. The exopod is as before, and the endopod approaches very closely that of the adult. The first segment bears four setae on the inner border, and the second segment six setae.

First Maxilla. As in stage I, but the outer lobe with five strong setae. The second segment of the endopod bears five terminal setae and five along its inner border.

Second Maxilla. As in stage I.

Maxilliped. As in stage I.

First Leg. The exopod is obscurely segmented just distal to the first marginal spine. Also, there are now four instead of three setae on the inner border of the exopod, all found on the distal one of the two segments. Otherwise as in stage I.

Second Leg (plate VIII, figure 6). The first basal segment bears a very fine plumose seta on the inner border. The exopod is clearly two-segmented, the new suture appearing just distal to the first marginal spine. There are four setae on the inner margin of the distal segment.

Third Leg (plate V, figure 4). Similar to the second leg of stage I, but the endopod bears two additional fine setae, one on the inner and one on the outer border. The exopod bears an additional fine seta proximal to the others on the inner margin.

Fourth Leg. Present, but rudimentary.

Copepodid Stage III

Body (plate V, figure 8). Length 0.830—0.933 mm. There are now nine segments, the last three of which constitute the urosome. The fifth segment bears the fourth legs, and the sixth segment the rudimentary fifth legs. The sixth segment is considerably shorter than the others. The furcal rami are relatively still more elongate, and the outer one of the terminal setae is nearly as strong as the middle three. The inner one, however, remains very fine, and is not visible in all specimens. The seta on the outer border of the ramus is much stronger than previously, and is longer than the remaining portion of the remus.

First Antenna. There are now twenty-one segments, many of the proximal ones somewhat obscure.

Second Antenna. As in stage II.

Mandible. As in stage II.

First Maxilla. The outer lobe with six strong setae, and two fine setae proximally. The third inner lobe is now present and bears three setae. the exopod bears eight setae. Otherwise as in stage II.

Second Maxilla. The segmentation is now clear. The two proximal lobes are part of the first segment, the two following part of the second, and the fifth lobe part of the third. Each lobe bears three heavy setae. The endopod consists of three short segments, each of the first two of which bears a single long seta, not as heavy as those on the lobes. The terminal segment, which is very small, carries two setae.

Maxilliped. All three of the lobes of the second segment bear two setae. The third segment bears four instead of three setae. There is an additional segment towards the distal end of the appendage, making six in all. The fourth segment bears two setae, the fifth one, and the sixth seven.

First Leg. The first basal segment carries a tiny plumose seta on its inner margin. There is an inner seta on the first segment of the exopod. Otherwise as in stage II.

Second Leg (plate VII, figure 10). The seta on the inner margin of the first basal segment is stronger. There is an additional seta on the inner margin of the endopod. The first exopod segment is provided with an inner seta, and the second segment has five instead of four inner setae. The second segment now has three marginal spines, one of which is subterminal. Otherwise as in stage II.

PLATE VII

Figure 1. Copepodid stage V. Male. Right first antenna. x 90.

2. Copepodid stage I. Masticatory portion of the mandible. x 390.

3. Copepodid stage I. First antenna. x 190.

4. Copepodid stage II. First antenna. x 90.

5. Copepodid stage IV. First leg. x 190.

6. Copepodid stage VI. First leg. x 190.

7. Copepodid stage VI. Second leg. x 190.

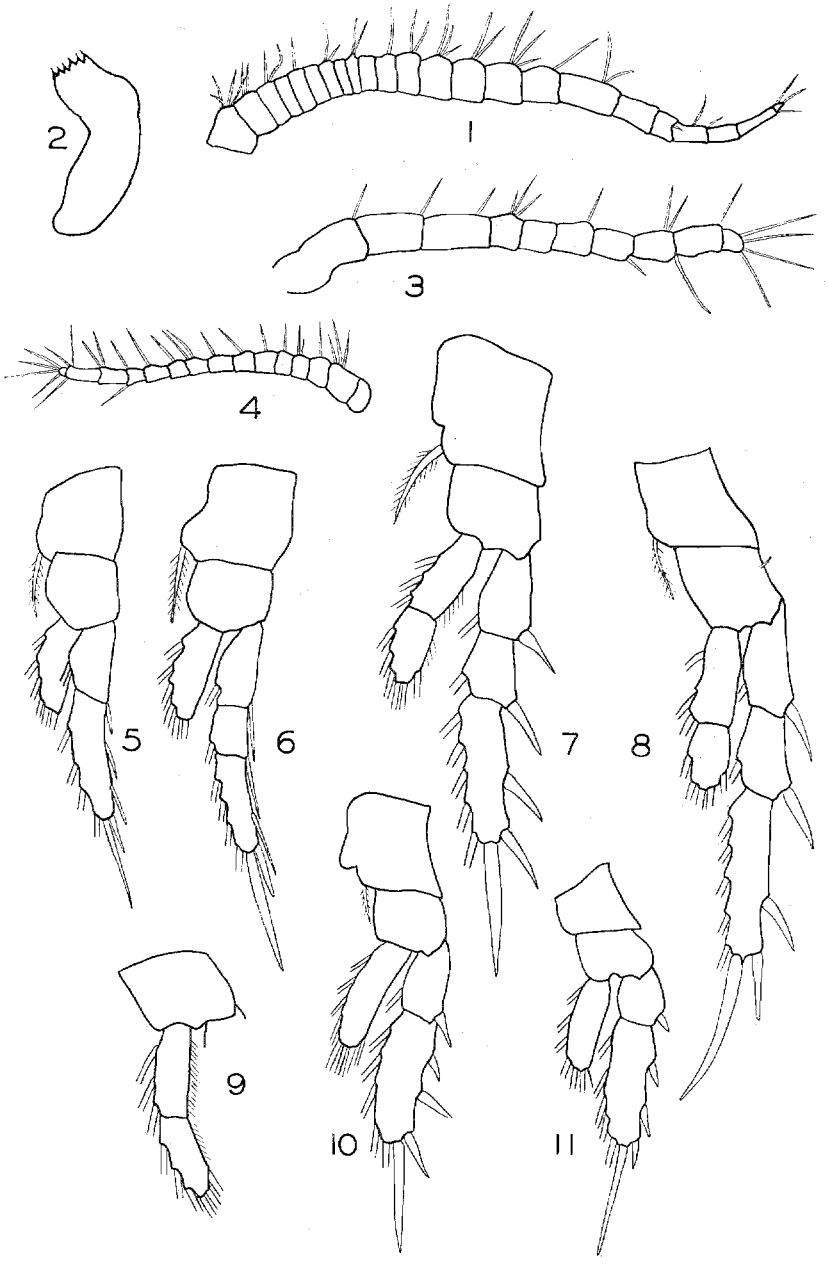
8. Copepodid stage VI. Fourth leg. x 190.

9. Copepodid stage VI. Endopod and second basal segment of the third leg. x 190.

10. Copepodid stage III. Second leg. x 190.

11. Copepodid stage IV. Fourth leg. x 190.

PLATE VII



Third Leg (plate VIII, figure 4). Very similar to the second leg of stage II.

Fourth leg (plate V, figure 7). Basal segments simple and without setae. The endopod is one-segmented and bears six setae, while the exopod is two-segmented. The first exopod segment is provided with a marginal spine on the outer distal corner, and the second segment bears two such spines, one of which is subterminal. This segment has the usual long terminal spine and three setae on the inner border.

Fifth Leg. Present, but very rudimentary.

Copepodid Stage IV

Body (plate V, figure 3; plate VI, figures 1 and 2). Length: male 0.854—0.994 mm., female 1.037—1.220 mm. The body consists of nine segments in both sexes, but the female can be determined by the fact that the female fifth thoracic segment (segment number six) is slightly angular, while that of the male is rounded. The anal (ninth) segment is also slightly different in shape, from a lateral view, in the two sexes. The furcae remain essentially unchanged.

First Antenna. The difference between the sexes is discernable in that the middle segments of the right antenna of the male are somewhat thicker than the corresponding segments of the left antenna, whereas in the female the right and left antennae are identical. In addition, the seventh segment from the end in the male right antenna has a heavy spine, which is lacking in the left antenna and in the female antennae. The antennae in both sexes consist of twenty-three segments, many of those in the proximal portion being rather obscure.

Second Antenna. As in stage III, but the second basal segment bears two setae, and the second endopod segment has two additional small setae on its inner border, making a total of six inner setae.

Mandible. As in stage III.

First Maxilla. As in stage III, except the exopod with nine setae.

Second Maxilla. As in stage III.

Maxilliped (plate VIII, figure 2). There are now seven segments in this appendage. The third lobe of the second segment bears three instead of two setae. The sixth segment bears one seta, and the seventh bears seven.

First Leg (plate VII, figure 5). The plumose seta on the inner margin of the first basal segment is much larger. The segmentation of the exopod into two segments is no longer obscure. Otherwise as in stage III.

Second Leg. The endopod now bears ten setae, of which three are terminal and one on the outer margin. The first indications of the segmentation of the endopod appear, but these are extremely faint. Otherwise as in stage III.

Third Leg. The first segment of the exopod bears a single seta on the inner border. The second segment has three instead of two marginal spines, and there are four instead of three inner setae. One additional seta is present on the endopod.

Fourth Leg (plate VII, figure 11). Similar to the third leg.

Fifth Leg (plate IX, figures 1 and 2). Sexual dimorphism is clearly evident in the structure of the fifth legs. In both sexes they are three-segmented, with the first segment of the two legs fused together. In the male the legs are of a larger size than in the female. In the case of the female the legs are symmetrical, while in the male the second segment of the right leg has an enlarged portion on the inner distal corner, which is lacking on the left leg.

Gurney (1931) speaks of a similar, but more pronounced, protuberance in *E. velox* as representing a vestigial endopod, but in *hirundoides* there is no evidence of any suture demarking the protuberance from the main body of the segment, nor does Gurney's figure indicate this clearly. However, Gurney's explanation is a conceivable one, especially in the light of the development of the male fifth legs in the closely related genus *Epischura,* as described for an American species by Marsh (1900), and for a Soviet-Siberian species by Rylov (1928). In the adult male of *Epischura* each leg bears a process on the inner border of the basis, but these processes are so much modified that it is not possible to say for sure, from the evidence offered by the adult, whether they are modified endopods or modified spines. In the fourth copepodid stage, however, the male fifth legs have large endopods, and in tracing these endopods through the molts to the adult stage it becomes obvious that the inner processes of the legs are modified endopods.

The two basal segments of the fifth legs in both sexes are unarmed with either spines or setae. The terminal segment differs in the two sexes. In the male there are three short naked setae or spines on the outer margin, and one similar but much longer terminally, while in the female there is one marginal spine, one subterminal, and a longer one terminally.

PLATE VIII

Figure 1. Copepodid stage VI. Mandible. x 190.

2. Copepodid stage IV. Maxilliped. x 190.

3. Copepodid stage VI. Maxilliped. x 190.

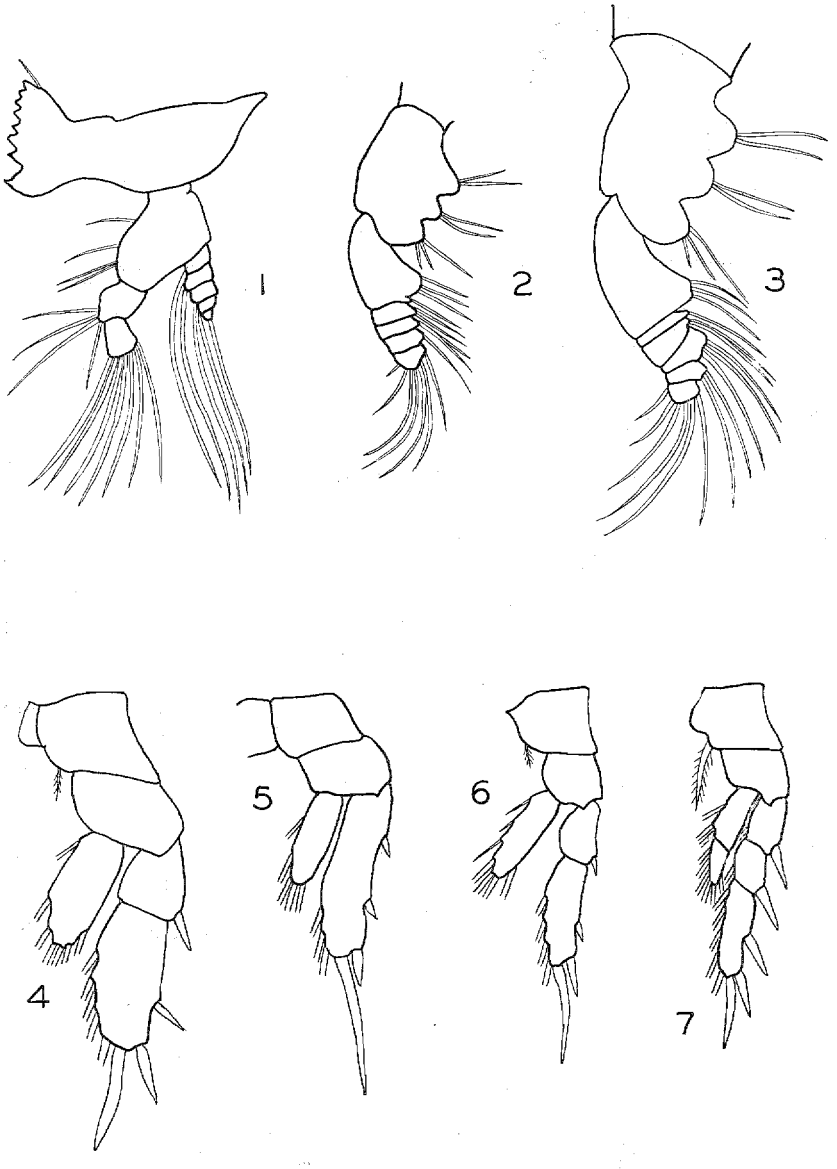
4. Copepodid stage III. Third leg. x 190.

5. Copepodid stage I. Second leg. x 190.

6. Copepodid stage II. Second leg. x 190.

7. Copepodid stage VI. Second leg. x 90.

PLATE VIII



Copepodid Stage V

Body (plate VI, figures 4 and 5). Length: male 1.135—1.287 mm., female 1.257—1.525 mm. There are nine segments in the body of the female (three in the urosome) and ten segments in the male (four in the urosome). The fifth thoracic segment remains rounded in the male, but develops into pronounced points in the female which are much more prominent than in the fourth stage, although by no means as large as in the adult. The genital segment (first urosome segment) of the female is considerably swollen, and the impression is easily obtained, when specimens of the female copepodid stage V are encountered, that one is dealing with adult specimens of some species other than *hirundoides*. The examination of the fifth feet and other characters, however, soon shows that the specimens are immature.

In this stage the rostrum first appears as two small lobes, difficult to discern, between the bases of the antennae. The inner border of the furcal ramus also begins to show the characteristics of the adult, and there appears at that position a row of fine hairs.

First Antenna (plate VII, figure 1). As in stages IV and VI, the sexes differ in the structure of the antennae. In stage V the right antenna of the male shows a further development of the swollen condition of the segments towards the middle. In the female the antennae have twenty-four segments, while in the male the right antenna has twenty-three and the left antenna twenty-four.

Second Antenna. The second segment of the endopod has seven setae on its inner border, and there are six terminal setae. The exopod remains the same as before, except for one additional small seta near the end of the terminal segment.

Mandible. As in the adult. It differs from stage IV in the fact that there are seven terminal setae on the second segment of the endopod.

First Maxilla. Outer lobe with nine setae. Exopod with ten setae. The second segment of the endopod bears seven setae terminally and seven along its inner border.

Second Maxilla. As in stage IV.

Maxilliped. As in stage IV.

First Leg. The plumose seta on the inner border of the first basal segment is well developed. The exopod is three-segmented, the new suture appearing just distal to the second marginal spine. The first and second

segments each bears a seta on the inner border, while the third segment bears four such setae. Thus the first leg has attained its adult characteristics.

Second Leg. The endopod is two-segmented and the exopod is three-segmented, the new suture coming just distal to the second marginal spine. The first and second exopod segments have one inner seta each, while the third segment has five. The third segment also bears two marginal spines, one of which is subterminal. The endopod bears three setae on the inner border of the first segment, and six setae on the second segment, one of these being on the outer border, and two terminal.

Third Leg. Similar to the second leg.

Fourth Leg. Basipod and exopod as in the third leg. The segmentation of the endopod is discernible, but not as clear cut as in the second and third legs. The first segment bears two inner setae, and the second segment bears five setae, of which one is on the outer border and two are terminal.

Fifth Leg (plate IX, figures 3 and 4). The female legs are symmetrical, while the male legs are again asymmetrical. However, in contrast to copepodid stage IV, it is now the left male leg that is the larger. The second basal segment of the left leg is stouter and longer than the corresponding segment of the right leg, and the left leg as a whole is longer. However, the armature of the two legs is almost identical. The third segment (first exopod segment) bears a single spine near the outer distal corner. The terminal segment on each leg bears a short terminal spine, a similar subterminal spine (somewhat farther from the distal end of the segment on the right leg), a smaller lateral spine about one-fourth of the distance from the distal end of the segment, and a somewhat larger spine about one-third the distance from the proximal end of the segment (somewhat closer to the proximal end on the left leg). The second segment of the right leg does not show any indication of a rudimentary endopod, nor of a protrusion such as is present in stage IV. Gurney (1931, page 210), in a figure of the fifth legs of a copepodid stage V male of the closely related *E. affinis* (which he considers to be synonymous with *E. hirundoides*), shows a small knob in this position.

The female fifth leg consists of three segments, the first two of which are simple. The terminal segment, however, bears a large internal protuberance about midway on the segment. This is not nearly as large as it becomes in the adult. Terminally there is a long naked spine or seta, and the segment bears three smaller spines on the outer border. The first

PLATE IX

Figure 1. Copepodid stage IV. Female. Fifth leg. x 190.

2. Copepodid stage IV. Male. Fifth pair of legs. x 190.

3. Copepodid stage V. Male. Fifth pair of legs. x 190.

4. Copepodid stage V. Female. Fifth leg. x 190.

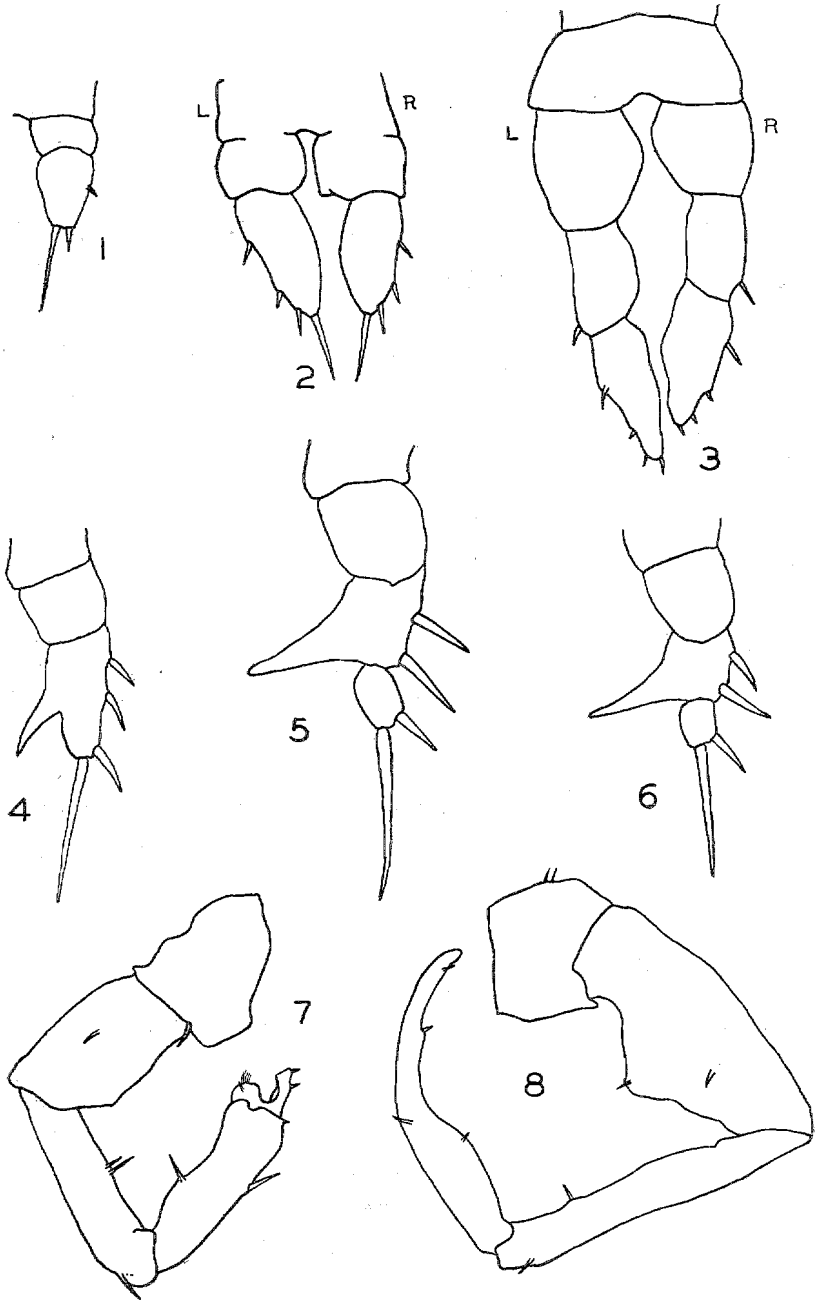
5. Copepodid stage VI. Female. More robust form. Fifth leg. x 190.

6. Copepodid stage VI. Female. More delicate form. Fifth leg. x 190.

7. Copepodid stage VI. Male. Left fifth leg. x 190.

8. Copepodid stage VI. Male. Right fifth leg. x 190.

PLATE IX



of these is about one-fourth of the distance from the proximal margin of the segment, the second lies about midway on the segment, and the third is subterminal.

Copepodid Stage VI—Adult

Body (plate VI, figures 7 and 8). Length: male 1.403—1.647 mm., female 1.482—1.708 mm. The body segmentation is as in stage V in the female, but the male has developed a fifth segment in the urosome, making a total of eleven segments. The sexual dimorphism in the structure of the fifth thoracic segment is further accentuated, the segment still being rounded in the male, but being greatly expanded into large triangular wings in the female. The urosome of the male is symmetrical. The anal segment is provided dorsally with numerous fine spine-like hairs. The furcal rami are twelve times as long as wide, and are provided along the whole of their inner border with a row of very delicate hairs. The furcal setae are well developed, except that the very fine inner terminal seta on each ramus is no longer visible. The female urosome is asymmetrical in the genital segment. The anal segment and the furcal rami are densely covered on the dorsal side with spine-like hairs. Of the two forms of the adult female found at the mouth of the Patuxent River, these hairs are more dense on the more robust form. In both forms the rostrum is present, though small.

First Antenna (plate VI, figure 6). Of the two observed forms, the female of the more robust form has an antenna with twenty-five segments, while the more delicate form has twenty-four. In the latter form, segments eight and nine are fused together. The male right antenna is greatly modified for grasping and consists of twenty-two segments, while the left one has twenty-four segments.

Second Antenna. As in stage V.

Mandible (plate VIII, figure 1). As in stage V.

First Maxilla. As in stage V.

Second Maxilla. As in stage V.

Maxilliped (plate VIII, figure 3). Eight segments, the first three as in stage V. The fourth segment has one seta, the fifth two, the sixth three, the seventh two, and the terminal segment six setae.

First Leg (plate VII, figure 6). As in stage V. In the female of the more robust form the endopod is a little shorter than in the second form.

In the former it is as long as the first exopod segment plus two-thirds of the second segment, while in the latter it is nearly as long as the first two segments together.

Second Leg (plate VII, figure 7; plate VIII, figure 7). As in stage V.

Third Leg (plate VII, figure 9). As in stage V, but the outer margin of the endopod is provided with a row of fine hairs.

Fourth Leg (plate VII, figure 8). The segmentation of the endopod is clear cut. The outer border of the endopod is provided as in the third leg, with a row of fine hairs. Otherwise as in stage V.

Fifth Leg (plate IX, figures 5, 6, 7, and 8). In the male the fifth legs again are asymmetrical. Again the asymmetry has changed, so that now, as in stage IV, the right leg is the larger. The right leg consists of four segments, the first of which is short and stout and provided on its outer border with two small spines. The second segment is very large, and protrudes on its inner border on the middle of the segment, giving the appearance of a human upper arm with its biceps muscle. Towards the peak of this protuberance is borne a small spine, and a second spine, somewhat larger, is to be found on the face of the segment, about one-third of the distance from the distal margin. The third segment is of about the same length as the second, but is more cylindrical, and bears no protuberance. About one-fourth of the distance from its distal margin it bears a small spine on its inner border, and there is a second spine near the outer border in the region of the distal margin. The terminal segment is again about the length of each of the previous two. It is larger towards the base than distally, where it tapers to form a very blunt point. On its inner border, near the place where it begins to taper, there is a small spine, and a little distal from this position, near the outer border, there is another. Approximately half the distance from the beginning of the tapered portion to the end of the segment there is another spine, and finally, close to the distal end of the segment there is another.

The left fifth leg of the male is considerably shorter than the right. The basal segment is short and stout, with a spine near the inner distal corner. The second segment is longer than the first, and is broad, but does not protrude on the inner border as does the corresponding segment of the other leg. On its face, near the middle of the segment, there is a small spine. The third segment is similar to the third segment of the right leg, although not as long. Near the middle on the inner border there are two small spines, and there is a third spine near the outer distal

corner. The terminal segment is heavier, but shorter than that of the right leg, and ends in a complicated structure. About one-third of the distance from the proximal margin on the inner border there is a spine, and nearly two-thirds the distance from the same margin on the outer border there is another.

The female fifth legs are symmetrical. The two basal segments are as in stage V, but the third segment of stage V has divided into two entirely separate segments. The third segment, then, bears a very large, sharply pointed protuberance on the distal corner of the inner border, and it bears two good sized spines on the outer border. The terminal segment is small and globular and bears two spines, one terminally which is very long, and one which is short and on the outer distal corner. In the more robust form of the female the terminal spine is comparatively longer than in the more delicate form, while the inner protuberance on the penultimate segment is heavier and more blunt in the robust form.

Comparison of Copepodid Stages of *E. hirundoides* and *E. velox*

Gurney's (1931) descriptions of the copepodid stages of *velox* are not sufficiently detailed and complete to allow for a thorough comparison of these stages in *hirundoides* and *velox*. However, much of value in comparing the two species can be found in his descriptions and figures. In general, contrasted with the nauplii, the copepodid stages of *hirundoides* are somewhat smaller than those of *velox*. The body segmentation is the same in the stages of the two species.

Copepodid Stage I. The first antenna of *velox* consists of eight or nine segments instead of ten. In *hirundoides* there is a very fine seta on the inner distal corner of each furcal ramus, and this is absent in *velox*.

Copepodid Stage II. The third leg of *velox* has a two-segmented exopod, whereas in *hirundoides* this is one-segmented.

Copepodid Stage III. The endopod of the first to the third legs is one-segmented in *hirundoides* and two-segmented in *velox* (in the adult of *velox*, the first endopod consists of one segment only, as in *hirundoides;* thus there must be a typographical error in Gurney's account).

Copepodid Stage IV. The first antenna consists of twenty-three segments in *hirundoides* and twenty-four in *velox*. The two basal segments of the fifth leg of *velox* are not separated as they are in *hirundoides*. In *velox* the two female fifth legs may be asymmetrical, whereas no evidence of this was found in *hirundoides*. In *velox* the second segment of the

right leg bears a small papilla on its inner distal corner, whereas in *hirundoides* this portion of the segment is slightly enlarged, but not protruding as a papilla. The subterminal spine on the outer border of the terminal segment of the male fifth legs is more proximal in *hirundoides* than in *velox*.

Copepodid Stage V. The outer border of the terminal segment of the female fifth leg, forecasting the specific characters of the adult, bears two spines in *velox* and three in *hirundoides*. The inner protuberance in *velox* is not as large as in *hirundoides*. The fifth legs of the male of *velox* are nearly symmetrical, whereas in *hirundoides* the left leg is definitely larger than the right one. The second basal segment of the right leg of *hirundoides* does not bear a vestigal endopod, nor any indication of it. The exopod of each leg of *velox* and *hirundoides* differ in the number of segments, the former having three and the latter two. However, the number of spines on the outer border of the three segments of the exopod of *velox* is identical to that of the two segments of *hirundoides*, namely, five, and the relative position of these spines is similar, although not identical.

Copepodid Stage VI. The differences between the species in this stage constitute, of course, the frequently described specific characters, and any of a number of standard references may be consulted.

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