

## Life History of *Cyclops buxtoni* Gurney (Copepoda)

S. C. GOSWAMI

Biological Oceanography Division, National Institute of Oceanography, Miramar, Panaji

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**Life history of a brackish water cyclopoid copepod-reared (optimum salinity varies from 5 to 18‰) in the laboratory has been studied in detail. Six nauplii stages and Ave copepodite stages precede the adult stage. The development resembles in all the essential features with other cyclopoid copepods. Interesting features being the presence of large labrum and knobbed endopodite of mandible in the nauplii. The important characters for the identification of the different naupliar and copepodite stages are tabulated.**

**D**ESPITE the interest shown in the taxonomy of copepods belonging to the family Cyclopidae<sup>1-6</sup> very little attention has been given to their life-cycle. Krishnaswamy<sup>7</sup> and Rao<sup>8</sup> have described young stages of some cyclopoid copepods. The present paper gives a complete life history of a cyclopoid copepod which was reared under laboratory conditions.

### Materials and Methods

*Cyclops buxtoni* occur abundantly in the Cochin backwater during the period of low salinity. Oviparous females were picked out from the freshly collected zooplankton samples and kept singly in finger-bowls containing 100 ml of filtered seawater. Hatching took place within 15-24 hr after their release in finger-bowls, depending on their state of maturity. Nauplii were fed on a phytoplankton culture of *Dunaliella primolacta* and copepodite stages were fed on phytoplankton culture and detritus material --the latter was collected from the estuary. The development was observed throughout the naupliar and copepodite stages up to the adult stage. The entire life history took about 10 days at normal room temperature (25-28°C). Different stages were preserved in 5% formaldehyde for subsequent study. Drawings were made with the aid of a camera lucida. Total lengths were measured from the anterior margin of the body to the posterior margin of the caudal region, excluding appendages and the caudal setae.

### Results

Experiments performed in the laboratory show that the optimum salinity for the adult copepod varies between 5 and 18‰. However, they were found to live even in seawater with a salinity of 32‰.

During the life history there are 6 naupliar stages, the last of which moults into the first copepodite stage. The instars are separated only by one moult and the duration from hatching of an egg to the copepodite stage I is about a week. Each nauplius is transparent, oval-shaped and dorso-ventrally compressed.

### Naupliar Stages

**Stage I** — It is 0.107 mm in length and has a large labrum. The antennule is 3-segmented. The

first segment bears a single seta on the inner distal end, the second bears two setae; one at the proximal and the other at the distal corner (Fig. 1). The terminal segment has three setae; two apical and one lateral. Generally with every moult, there is an increase in the number of setae along the terminal segment of the antennule. The antenna is biramous with a distinct division of protopodite into coxapodite and basipodite. The coxapodite is provided with a stout, claw-like process and basipodite bears at the proximal end a posteriorly directed seta. The exopodite of the antenna is 4-segmented, the first segment being the largest. The first three segments bear a seta each on the postaxial margin, whereas the last segment bears paired setae terminally. The endopodite is small, notched and unsegmented; the setae are borne at the notch as well as on the terminal end. Mandible consists of a 4-segmented exopodite and the endopodite is represented by two knobs. The first three segments of the exopodite of mandible bear a single, stout seta on the postaxial margin and the terminal segment is provided with a pair of seta. The inner knob-like structure of the endopodite has three setae and the outer bears four setae. The structure of the mandible remains the same in all the naupliar stages.

The caudal armature consists of two delicate furcal setae.

**Stage II** — It shows an increase in length to 0.129 mm. The structural advances over the first nauplius are as follows: The terminal segment of the antennule bears two additional setae along the outer margin (Fig. 2). The posterior side of the body has a cleaved appearance in the middle and the two furcal setae are longer and stouter than in the previous stage.

**Stage III** — It is bigger in length than in breadth (7.4:5.5) and measures 0.172 mm in length.

Antennule — the terminal segment has an additional seta at the middle of the segment (Fig. 3). The exopodite of the antenna has 5 segments. It has an additional seta on the terminal segment. The notched endopodite also shows one more seta at the terminal end. Maxillule appears as a small notch-like structure, one on either side just behind the mandible.

The furcal armature shows a pair of seta on both sides of the cleavage.

**Stage IV** — This stage is 0.215 mm in length. The body shows differentiation into an anterior, rounded and a posterior tapering half (Fig. 4). The terminal segment of the antennule shows an additional seta at mid length on the outer surface and a pair of seta on the inner side. The exopodite of the antenna (Fig. 5) is 6-segmented; the endopodite bears an additional seta at the notch. The maxillule bears 3 pairs of setae, one pair being stouter and longer than the other two.

The posterior furcal region is bifid in the middle and the two halves are further divided. The caudal armature shows an additional seta on each side which is inner to the longer and stouter seta.

**Stage V** — It is 0.236 mm long. Body is greater in length than in breadth (11.3:7.5). The differentiation into the anterior and the posterior region is distinct (Fig. 6). The mouth parts are as in the previous stage.

The posterior region shows faint segmentation. The caudal armature at the posterior surface has 3 setae on each side.

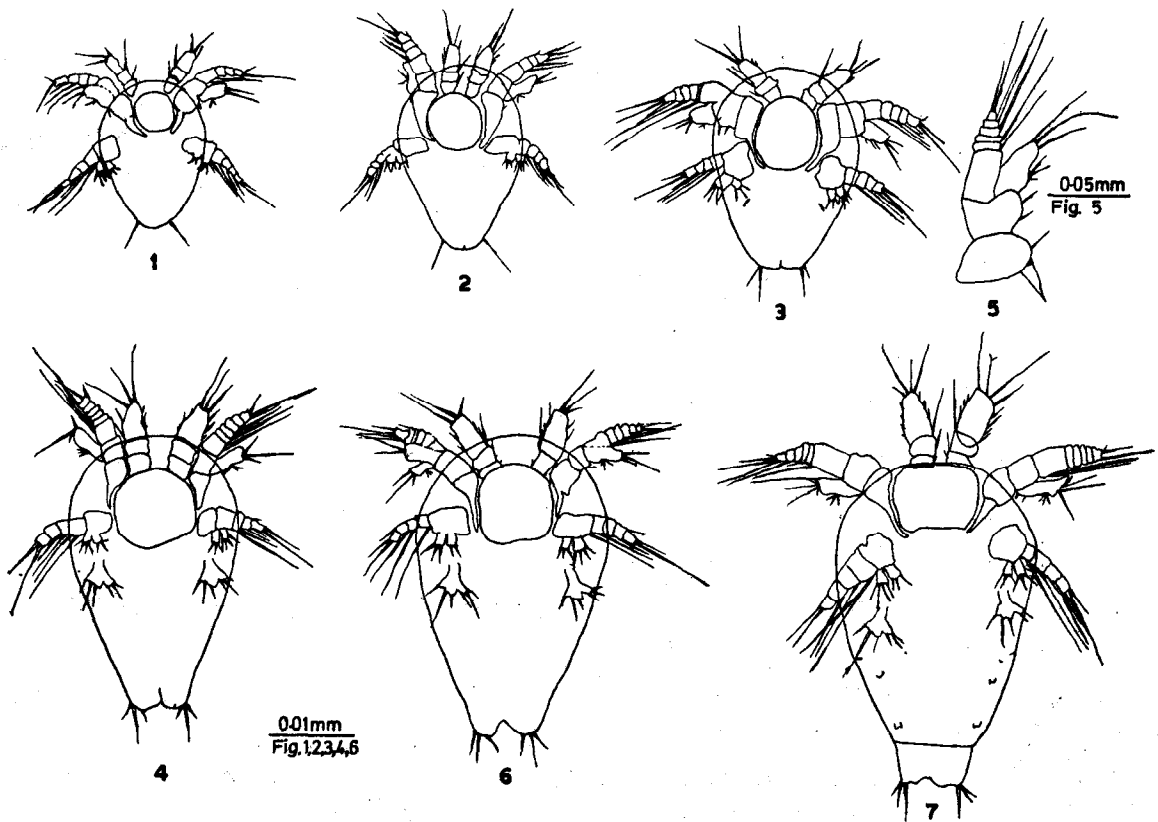
**Stage VI** — It is 0.279 mm long. The labrum has a 3-lobed appearance (Fig. 7). The rudiments of 1st and 2nd pairs of swimming legs are visible. The terminal segment of the antennule bears 4 setae at the distal end. The notched, unsegmented endopodite of the antenna shows an additional seta at the terminal end. Maxillulae are lobed structures. The caudal armature looks similar to that of the previous stage. The important features of the different naupliar stages are given in Table 1.

### Copepodite Stages

There are 6 copepodite stages as in most of the free living copepods. The last copepodite moults into an adult. The copepodites are quite active stages. They move about at the bottom of the finger-bowls and make quick movements on slight disturbance. The segmentation of prosome and urosome as well as the development of the swimming legs are their chief distinguishing features.

**Stage 1** — The body (0.344 mm length) consists of five segments: 3-segmented prosome and 2-segmented urosome (Fig. 8). The 2 regions have a proportion of 74:26. The furcal rami are bigger in length than in breadth. Each ramus bears a seta in the middle and 4 setae at the terminal end. There is a small spine also. The 2nd innermost furcal seta is the longest. It is bigger than the urosome.

The mouth parts resemble the adult in basic components. The antennule (Fig. 9) is 6-segmented. The endopodite of antenna (Fig. 10) is 3-segmented; the 1st segment bears a single seta, the remaining 2 segments bear 4 setae each. The exopodite appears to be a 3-segmented structure with 3 delicate setae at the terminal end. The maxilla is 3-segmented (Fig. 11), bearing 5 setae terminally. The maxilliped (Fig. 12) is a 3-segmented structure and is provided with stout setae. There are 2 pairs of biramous legs. The protopodite is divided into coxapodite and basipodite. In the 1st leg (Fig. 13) the single jointed exopodite bears 3 lateral



Figs. 1-4 — Naupliar stages I to IV respectively  
 Fig. 5 — Antenna of naupliar IV stage  
 Figs. 6 and 7 — Naupliar stages V and VI

TABLE 1 — CHARACTERISTIC FEATURES OF NAUPLII OF *C. burtoni*

| Stage | Length<br>mm | Furcal armature  | Setae on terminal segment of antennule | Antenna            |                     | Mandible           |                     | Remarks  |
|-------|--------------|--|--|--------------------|---------------------|--------------------|---------------------|--|
|       |              |  |  | Setae on exopodite | Setae on endopodite | Setae on exopodite | Setae on endopodite |  |
| I:    | 0.107        | 2 delicate setae   | 3                                      | 6                  | 4                   | 5                  | 7                   | Maxillule absent<br>do   |
|       | 0.129        | 2 strong setae, cleaved appearance on posterior surface                | 5                                      | 6                  | 4                   | 5                  | 7                   |  |
| III   | 0.172        | Cleavage distinct on posterior surface. 2 setae on each side           | 6                                      | 7                  | 5                   | 5                  | 7                   | Maxillule rudimentary  |
| IV    | 0.215        | Each half further subdivided, an additional delicate seta on each side | 9                                      | 7                  | 6                   | 5                  | 7                   | Maxillule with 3 pairs of setae  |
| V     | 0.236        | 3 strong setae on each side of half                                    | 9                                      | 7                  | 6                   | 5                  | 7                   | do   |
| VI    | 0.279        | do   | 11                                     | 8                  | 7                   | 5                  | 7                   | Maxillule lobed structure, rudiments of 1st and 2nd pairs of swimming legs present |

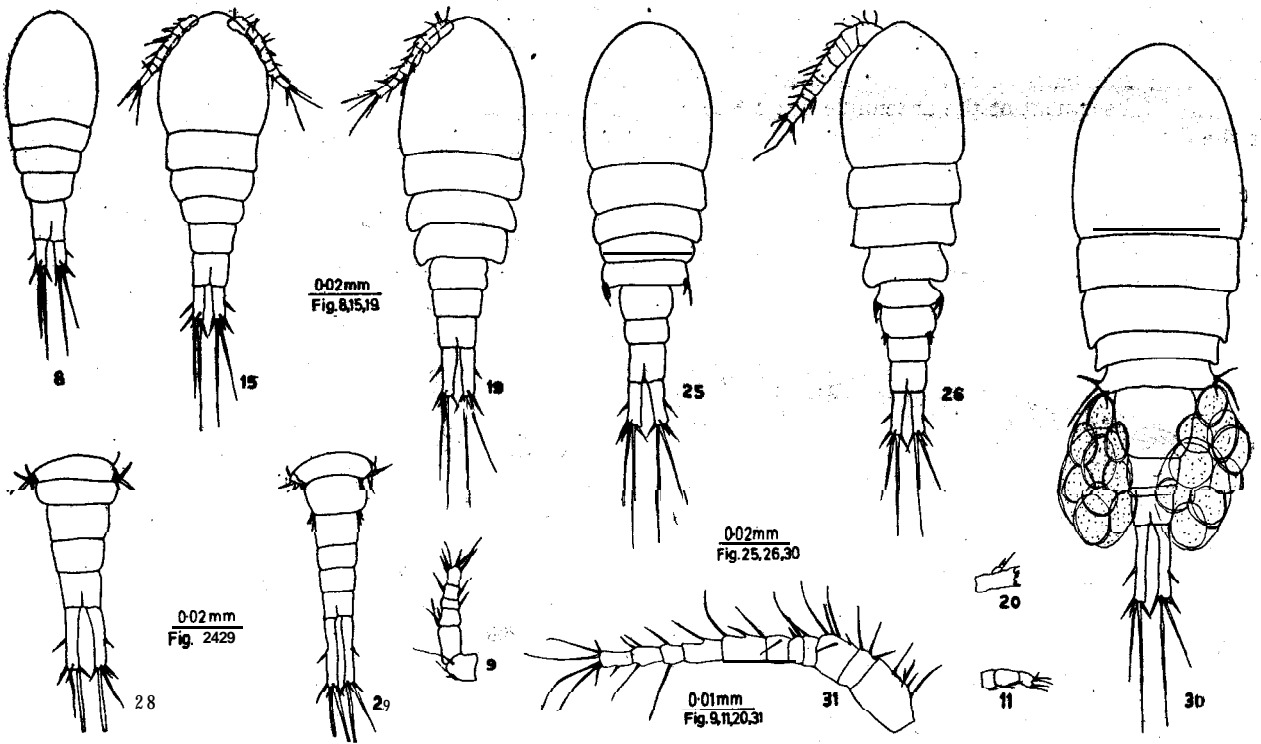


Fig. 8 — Copepodite stage I  
 Fig. 9 — Copepodite stage I with antennule  
 Fig. 11 — Copepodite stage I with maxilla  
 Fig. 15 — Copepodite stage II  
 Fig. 19 — Copepodite stage III  
 Fig. 20 — Copepodite stage III with mandible  
 Figs. 25 and 26 — Copepodite stage IV with female and male respectively  
 Figs. 28 and 29 — Copepodite stage V with urosomal segments of female and male respectively  
 Fig. 30 — Adult female  
 Fig. 31 — Adult female with antennule

spines and 4 setae. The single jointed endopodite has an apical spine and 5 setae. The exopodite of the 2nd leg (Fig. 14) has 4 lateral spines and 3 setae. The endopodite is similar to that of the 1st leg. The 3rd swimming leg becomes rudimentary.

Stage II — It measures 0.473 mm in length (Fig. 15). There are 6 segments, 4 prosomal and 2 urosomal. The 2 regions have the Proportion of 79 : 21.

The antennule is 7-segmented. The antenna and the mouth parts are as in copepodite I. There are 3 pairs of swimming legs. The remnant of the 4th leg is also present. The rami of the first 2 pairs of swimming legs are 2-jointed and those of the 3rd pair are one-jointed.

In the 1st leg (Fig. 16) the distal joint of the exopodite bears 3 spines and 5 setae while its proximal joint has only a single spine. The distal joint of

endopodite carries the apical spine and 5 setae. The structure of 2-jointed endopodite is the same as in the 1st two pairs of swimming legs. The exopodite of the 2nd leg (Fig. 17) bears 4 spines on the distal joint and a single spine on its proximal joint. The one-jointed exopodite of 3rd leg (Fig. 18) has 4 lateral spines and 3 setae. The notch in its centre indicates its division into 2-jointed structure in the next copepodite stage. The endopodite of the 3rd leg is similar to those of the 2 legs of the previous stage.

**Stage III** — It measures 0.580 mm in length (Fig. 19). There are 7 segments. The prosome and urosome have the proportion of 73: 27. The length of the furcal ramus is greater than its breadth. The antennule is 9-segmented. The 2nd segment of endopodite of antenna bears 3 setae along the outer margin. The terminal segment has 2 more setae than in copepodite I. The exopodite now is in the form of 2 long setae. The mandible (Fig. 20) has 2-jointed mandibular palp and a stout biting ramus with numerous teeth. The maxillae and maxillipeds are as in the previous stage.

The rami of the first 3 pairs of legs are 2-jointed, the 4th developing leg has one joint. The proximal joint of exopodite of the 1st leg (Fig. 21) shows a spine and a single seta on the inner margin. The 2nd and 3rd paired legs (Figs. 22 and 23) have the

same structure as the 2nd leg of the previous stage. The exopodite of the 4th leg (Fig. 24) has 4 spines and 3 setae and the endopodite bears a spine and 5 setae.

**Stage IV** — Sexes can be distinguished in this stage. The female and male (Figs. 25 and 26) are almost of the same size and measure 0.645 mm in length. The sexes can be differentiated by the presence of a pair of spine in the first urosomal segment of the male.

The antennule is 9-segmented in both the sexes. The antenna and the mouth parts are as in the previous stage. There are 4 pairs of swimming legs with 2-jointed rami; the first 3 pairs of legs resemble the corresponding legs of the copepodite III. The 4th leg (Fig. 27) is well developed. The distal joint of the exopodite bears 3 lateral spines and 5 setae. The proximal joint has a single spine. The endopodite looks similar to that of the swimming legs of the previous stages.

**Stage V** — The males have an additional urosomal segment (Figs. 28 and 29). The antennule in male is geniculated. The bodies of both sexes show all the adult features, except for their sizes and the presence of genital segment in the female.

The female measures 0.712 mm in length. The antennule is 10-segmented. The 2nd segment

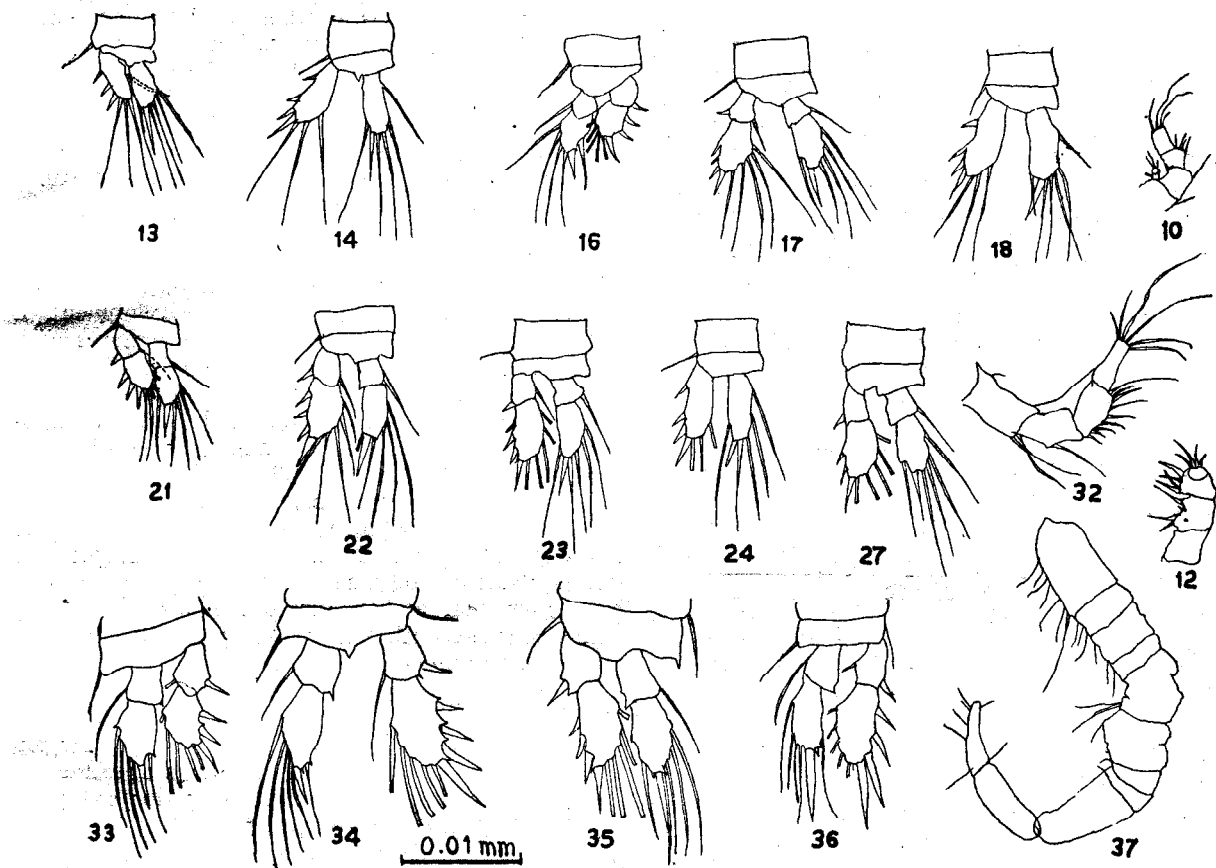


Fig. 10 — Copepodite stage I with antenna  
 Fig. 12 — Copepodite stage I with maxilliped  
 Figs. 13 and 14 — Copepodite stage I with 1st and 2nd swimming legs  
 Figs. 16-18 — Copepodite stage II with 1st-3rd swimming legs  
 Figs. 21-24 — Copepodite stage III with 1-4 swimming legs  
 Fig. 27 — Copepodite stage IV with 4th swimming legs  
 Fig. 32 — Adult female with antenna  
 Figs. 33-36 — Adult female with 1-4 swimming legs respectively  
 Fig. 37 — Adult male with antennule

TABLE 2—CHARACTERISTIC FEATURES OF COPEPODITES OF *C. luxtoni*

| Stage | Length mm | No. of body segments | Swimming legs                       |                                     |                                     |                                     | Remarks  |
|-------|-----------|----------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|--|
|       |           |                      | Ist                                 | IIInd                               | IIIrd                               | IVth                                |  |
| I     | 0.344     | 5                    | 1-jointed expopodite and endopodite | 2-jointed expopodite and endopodite | Vestigial                           | Absent                              | 2 pairs of swimming legs   |
| I I   | 0.473     | 6                    | 2-jointed expopodite and endopodite | 2-jointed expopodite and endopodite | 1-jointed expopodite and endopodite | Vestigial                           | 3 pairs of swimming legs   |
| III   | 0.580     | 7                    | do                                  | do                                  | 2-jointed expopodite and endopodite | 1-jointed expopodite and endopodite | 3 pairs of swimming legs; 4th pair is developing                             |
| IV    | 0.645     | 8                    | do                                  | do                                  | do                                  | P-jointed expopodite and endopodite | 4 pairs of swimming legs   |
| V     | 0.712     | 9                    | do                                  | do                                  | do                                  | do                                  | 4 pairs of swimming legs; 5th leg is vestigial                               |
| VI    | 0.860     | 9, 10                | do                                  | do                                  | do                                  | do                                  | 4 pairs of swimming legs, vestigial 5th pair in female and 6th pairs in male |

of endonodite of the antenna bears 2 more bristles on the outer surface than in copepodite IV. The expopodite remains unchanged. The mouth parts and 4 pairs of legs are as in the previous stage, the 5th leg is rudimentary.

Stage VI — The 5th copepodite moults into the adult stage; the females become larger in size than the males.

Female : It measures 0.860 mm in length (Fig. 30). The genital segment is swollen and well developed ; the ovary and its branches are seen as dark bands. The paired egg sacs are borne laterally and each sac contains 9 eggs.

The body is robust and comprises 9 segments; 5 prosomal and 4 urosomal. The two regions are in the proportion of 73: 27. The epimera of 1-3 prosomal segments is not prominent. Segment 4 is somewhat extended laterally. Furcal rami are long, slender, non-divergent and equal in length to the 3 preceding abdominal segments.

The antennule (Fig. 31) is 11-segmented, segments having the following proportions of percentage of total length of the antennule:

|    |    |    |   |   |   |    |    |    |    |       |
|----|----|----|---|---|---|----|----|----|----|-------|
| 1  | 23 | 4  | 5 | 6 | 7 | 8  | 9  | 10 | 11 | = 100 |
| 19 | 6  | 10 | 4 | 4 | 7 | 13 | 12 | 6  | 9  |       |

The endopodite of antenna (Fig. 32) is 3-segmented as in the previous stages; however, the number of setae on the 2nd and 3rd segment show an increase. There are 3 pairs of setae on the terminal segment. The mouth parts are as in the previous stage.

All the 4 pairs of swimming legs (Figs. 33-36) are 2-jointed like those of the previous stages. Small spinule-like structures appear on the inner side of the spines. The distal joint of the expopodite of the first leg bears 3 spines, while that of each of the other three pairs bear four spines. The 5th leg is borne laterally along the last prosomal segment. The first joint of the 5th leg is in the form of a seta borne on the outer dorsal edge of the segment. The second joint has a seta along the outer side and a spine on the inner side.

Male: It measures 0.795 mm in length. The body consists, of 10 segments, with equal number of prosomal and urosomal segments.

The antennule (Fig. 37) is 11-segmented with double geniculation as in other members of the sub-order Cyclopoida. The first geniculation is between 5th and 6th segment; the second between 9th and 10th segment.

The antenna, mouth parts and the swimming legs are as in the female. The sixth vestigial leg is present. Table 2 shows the important features of the different copepodite stages.

Discussion

Although larval studies on *Cyclops* species are not available for comparison, the development of *C. luxtoni* resembles in all the essential features with that of the other cyclopoid copepods. Developmental features as the 3-segmented antennule, biramous antenna, lobed maxillule and knobbed endopodite of mandible of the nauplii agree with the observations of Rao<sup>8</sup> on *Oithona rigida*. Krishna-swamy<sup>7</sup> has, however, shown the endopodite of the naupliar mandible as 2-jointed structure with setae in *O. rigida*. In the copepodite stages, the development of body segments and the swimming legs is gradual and confirms the observations of earlier workers with minor changes in size of segments and number of setae.

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