

Developmental biology of brackishwater copepod *Oithona rigida* Giesbrecht: A laboratory investigation

Santhanam, P* & P. Perumal¹

*Department of Marine Science, School of Marine Sciences,
Bharathidasan University, Tiruchirappalli 620 024, India.

¹Department of Biotechnology, Periyar University, Salem 636 011, India.
* [E-mail: sanplankton@yahoo.co.in]

Received 17 August 2011; revised 12 July 2012

In the present study, attempt was made on larval metamorphosis of cyclopoid copepod *Oithona rigida* under laboratory condition. In the larval development, *O. rigida* has six naupliar and six copepodite stages precede the adult and it reached adulthood early. Duration of development from egg to adult was 12 days at 28°C. Copepodite stages lasted longer than naupliar stages.

[**Key words:** Developmental biology, Copepod, *Oithona rigida*, Nauplii, Copepodites]

Introduction

The oceanographic community emphasised research on larger representatives and thus the importance of small species has been generally underestimated¹. Likewise, the investigation on biology and taxonomy of any organisms are generally neglected in present days. The marine and brackish water copepods are primary consumers or secondary producers of the marine food web and they form a basic nutrient for variety of fin and shell fish larvae. Among these, the genus of *Oithona* is one of the dominating copepods in Indian waters in terms of numbers and biomass. Hence this tiny copepod, received considerable attention in recent years in aquaculture as live feed. Although the copepods present in the Bay of Bengal and adjacent waters have been studied well taxonomically. But biologically has not been well studied, nevertheless scant reports held to be revealed poorly^{2,3,4,5}. Studies on larval development of copepods yielded considerable information for clear understanding of their biology and behaviour which are important for culture and utilization of copepods as live feed for fish and crustacean larvae⁶. Moreover, very limited studies are made on the developmental biology of marine copepods from Indian waters^{2,3,4}. Hence, the present attempt was made on the developmental biology of common cyclopoid copepod, *O. rigida*.

Materials and Methods

Copepods were collected from the Vellar estuary and ovigerous females of *O. rigida* were isolated from freshly collected samples and kept individually in the finger bowls containing 200-300 mL of filtered estuarine water fed with 1-2 mL suspension of freshly cultured microalga *Chlorella marina*. The temperature was maintained between 27 and 29°C and salinity between 30 and 34 ‰. Hatching occurred within 24 hours with optimum water quality conditions and algal prey. Dead organisms were removed and preserved at every stage in 5% buffered formalin. Figures of the specimens were drawn using camera lucida. Terminology as suggested by Reddy and Devi⁷ was used in the text to describe the morphological features of different stages of *O. rigida*.

Results

Developmental stages

Ovigerous females had a pair of egg sacs on the ventral side of the genital segment. Eggs were spherical and of 0.003 mm in diameter. In *O. rigida*, six naupliar and five copepodite stages preceded the adult. Naupliar stages were dorsoventrally compressed and light yellowish in live condition. Eggs hatched into nauplius-I after 24 hours. The time required for the development from nauplius I to adult was 12 days (Table 1).

Nauplius-I

Body: Length 0.098-0.106 mm, mean 0.105±0.001mm, width 0.701-0.716 mm, mean 0.701±0.001mm. In

*Corresponding author.

Table 1—Developmental stages and time of copepod *O. rigida*

Larval Stages	Duration
Nauplius I	24.00 hours
Nauplius II	0.20 hours
Nauplius III	0.22 hours
Nauplius IV	0.19 hours
Nauplius V	0.21 hours
Nauplius VI	24.00 hours
Copepodite I	24.02 hours
Copepodite II	24.04 hours
Copepodite III	24.03 hours
Copepodite IV	24.05 hours
Copepodite V	48.00 hours
Total	12.00 Days

ventral view, caudal region with 2 equal setae fringed with minute spines.

Antennule: 3 segmented, the first segment consists of single seta on the inner distal corner and the second segment with 2 setae. This is the pattern noticed in all the naupliar stages. Third segment consisted of 3 setae.

Antenna: Coxal and basal end consisted of single seta each. Exopodite 6 was segmented and endopodite unsegmented, as in all the naupliar stages. All the segments of the exopodite have 1 seta each, except the terminal segment which has 3 setae.

Mandible: Coxal endite with 1 long and 1 short seta, basal endite with 2 equal setae. Exopodite 3 segmented with 3 setae. Endopodite 2 segmented with 3 setae.

Nauplius-II

Body: Length 0.108-0.109, mean 0.108±0.0005 mm, width 0.062-0.070 mm, mean 0.068±0.0011 mm caudal region as in previous stage.

Antennule: Third segment has 4 setae.

Antenna: Coxal endite with a single seta, basipodite with 2 setae. Exopodite 6 segmented with 1,1,1,1 and setae. Endopodite unsegmented with 4 setae as previously mentioned.

Mandible: Coxal and basal endites as in nauplius-I. Terminal segment of exopodite consists of one more seta making a total of 4 setae. Endopodite has 4 setae.

Nauplius-III

Body: Length 0.126-0.130 mm, mean 0.129±0.0015 mm, width 0.106-0.110 mm, mean 0.108±0.0015 mm, caudal region remains the same as in the previous stage.

Antennule: Terminal segment of the exopod has 4 setae.

Antenna: Coxal, basal endites and exopodite as in nauplius-I, endopod consists of 5 setae.

Mandible: Terminal segment of the exopod contains 4 setae.

Maxillae: Simple lobe carrying feathered setae.

Nauplius-IV:

Body: Length 0.150-0.154 mm, mean 0.152±0.002 mm, width 0.112-0.123 mm, mean 0.118±0.001 mm. In ventral view, caudal region consists of a pair of unequal setae on either side, besides a number of minute hairs.

Antennule: As in Nauplius-III

Antenna: Resembles that of previous stage except the terminal segment of exopodite with one more seta making a total of 4 setae.

Mandible: As in nauplius-III.

Maxillae: Bilobed with 2 setae each.

Nauplius-V

Body: Length 0.161-0.164 mm, mean 0.161±0.0015 mm, width 0.116-0.164 mm, mean 0.149±0.001 mm. The caudal region presented as nauplius-IV.

Antennule: Terminal segment consist of 4 setae.

Antennae; Coxal and basal endites with 2 divergent, unequal setae, exopodite 6 segmented with 1, 1, 1, 1, 1 and 4 setae. Endopodite had 6 setae.

Mandible: Endopod contains 6 setae.

Maxillae: Biramous exo and endopodite being clearly separated from one another. Exo and endopodites contains 3 setae each.

Maxilla: Simple lobe carrying feathered setae.

Nauplius-VI

Body: Length 0.184-0.196 mm, mean 0.193±0.003 mm, width 0.150-0.166mm, mean 151±2.546 mm. The posterior end of the body protrudes beyond the cephalothoracic shield. In ventral view, caudal region consisted of paired setae as in the preceding setae; in addition there are 2 small setae, one on each side of the posterior end of the body.

Antennule: Terminal segment consists of 4 setae.

Antenna: As in Nauplius-V.

Mandible: A coxal and basal endites are similar to nauplius-V exopodite segmented with 1, 1, 1 and 5 setae. Endopodite 2 segmented with 7 setae.

Maxillae: Resembled previous stage except that the endopod here carrying 5 setae. Maxilla consisted of 3 median lobes with 3, 3 and 4 setae.

Maxilliped has a simple lobe tipped with single seta.

I and II pair of legs: Coxal and basal indistinct. The exo and endopodites with 2 setae each.

Nauplius VI moults into first copepodite stage.

Copepodite stages

All the copepodites were light brown in colour. The presence of rostrum was observed in females from copepodite-IV onwards. Segments of the body were clear in all the stages.

Copepodite-I

Body: Length 0.310-0.316 mm, mean 0.314 ± 0.002 mm, width 0.184-0.252 mm, mean 0.19 ± 0.004 mm. Prosome 4 segmented, urosome unsegmented, each caudal ramus contains 1 lateral spine and 4 unequal setae, of which 2 apical setae were longer than others. All the setae show minute spines.

Antennule: 8 segmented, few setae were present on the segments. Terminal segment with 4 setae.

Antenna: Coxa with single seta, basal long with 2 setae in the middle. Exopodite is greatly reduced and consist of 2 segments with 2 and 4 setae. Endopodite 2 segments with 1 and 3 setae.

Mandible: Coxa is curved in nature. Basis with 2 setae. Exopodite 4 segmented with 1, 1, 1 and 3 setae. Endopodite unsegmented with 4 setae.

Maxillule: Coxa is greatly enlarged with 4 equispaced setae. Basis contains 4 setae, exo and endopodite distinct with 4 and 3 setae respectively.

Maxilla: 5 endites with 2, 3, 3, 2 and 2 setae of which the last endite represents the endopodite.

Maxilliped: Coxa appears to be 2 segmented. The first segment consists of 3 setae and the second segment with 2 setae. Basis with a single endopodite 2 segmented with 2 and 4 setae.

I and II pair of legs: Coxa unarmed basis with a long setae. Exo and endopodites unsegmented. Exopodite contains 2 spines. I terminal blade and 4 setae. Endopodite with 6 setae.

Copepodite-II

Body: Length 0.340-0.390 mm, mean 0.362 ± 0.024 mm, width 0.187-0.213 mm, mean 0.201 ± 0.005 mm. Prosome 4 segmented, urosome 2 segmented.

Antennule: 9 segmented, terminal segment with 4 setae as in copepodite-I.

Antennae: As in copepodite-I except the second segment of the endopodite with one seta.

Mandible: Mandible blade in coxa with minute teeth. Basis has 2 divergent setae. Exopodite segmented with 4 setae, showing 1, 1, 1 and 4. Endopodite unsegmented with 4 setae.

Maxillule: Coxa with 6 setae, basis with 5 setae. Exopodite similar to copepodite-I. Endopodite contains 4 setae.

Maxillae: Except I endopodite with 3 setae resemble as copepodite-I.

First pair of legs: Coxa unarmed, basis with single seta. Exo and endopods with 2 segments each. First segment of the exopod has single spine second with 2 spines. One terminal blade and 5 setae. The first and second segment of endopod with 1 and 6 setae.

II pair of legs: The second segment of the exopod contains 4 setae.

III pair of legs: Coxa unarmed, basis with single seta. Exo and endopods unsegmented, exopod has 2 spines, 1 terminal blade and 4 setae. Endopod consist of 6 setae.

Copepodite-III

Body: Length 0.442 mm, width 0.213-0.264 mm, and urosome consists of 4 segments each.

Antennule: Ten segmented, terminal segment as in copepodite-IV except the endopod of the maxilliped with one more seta counts in number five.

I pair of legs: Coxa unarmed, basis with single seta. Exo and endopod with 2 segments each I segment with single spine, II with 2, 1 terminal blade and 6 setae. I and II endopod with 1 and 6 setae.

II and III pair of legs: Except the II segment of the exopod with 5 setae resembles the former.

IV pair of legs: Coxa unarmed, basis with single seta. Exopod 1 segmented with 2 spines, 1 terminal blade and 5 setae endopod segment with 5 setae.

Copepodite-IV: Female

Body: Length 0.506-0.520 mm, width 0.236-0.278 mm, prosome and urosome consist of 43 segments each. Rostrum was observed in females.

Antennule: 12 segmented. Terminal has 5 setae.

Copepodite-IV: Male

Body: Length 0.502-0.516 mm, width 0.198-0.249 mm. Prosome is 4 segmented, urosome 5 segmented.

Antennule: 4 segmented, terminal segments consist of setae.

I pair of legs: Coxa unarmed, with single seta basis, exopod 2 segmented with single spine and II segment with 3 spines, 1 terminal blade and 6 setae.

II pair of legs: Exopod 3 segmented, I and II segmented with 1 spine each. Third segment with 2 spines, 1 terminal blade and 6 setae. Endopod 3 segmented with 1, 1 and 1 setae.

III pair of legs: Terminal segment with 2 spines, 1 terminal blade and 8 setae.

IV pair of legs: Resembles as 3rd.

V pair of legs: Bilobed tipped with setae.

Copepodite-V: Female

Body: Length 0.608-0.620 mm, width 0.249-0.298 mm. Rostrum well developed, prosome and urosome has 5 segments each, genital segment with a bunch of fine hairs each side ventrally.

Antennule: 13 segmented, terminal with 5 setae.

I pair of legs: Coxa unarmed, basis with single seta. Exopod 3 segmented I and II segment with 1 spine each, III segment with 3 spines, terminal blade and 5 setae. Endopod 3 segmented with 1, 1, 7 setae.

II pair of legs: Coxa unarmed, basis with single seta and the outer margin with minute plumose setae in dorsal view. Exo and endopod as in I pair of legs except terminal segment of the exopod bears 6 setae.

III pair of legs: Coxa basis as the I pair of legs. Exopod 3 segmented I and II segments with 1 spine each and III segmented with 3 spines, 1 terminal and 5 setae. Endopod 3 segmented with 1, 1, 7 setae.

IV pair of legs: Endopodite terminal segment with 8 setae and 2 spines in terminal exopod segments.

V pair of legs: Exo and endopod unsegmented. Exopod with 1 spine 3 setae, endopod with 1 seta (Plate 1-V).

Copepodite-V: Male

Body: Length 0.602-0.607 mm, width 0.242-0.278 mm, rostrum absent. Prosome 5 segmented, urosome

6 segmented.

Antennule: 13 segmented, terminal with 5 setae. Genucation observed in both right and left side antennae.

I pair of legs: Coxa unarmed, basis with 1 seta, some observation can be seen up to 4th pair of legs. Exopod 3 segmented I and II with 1 spine each. III with 3 spines, terminal blade and 6 setae. Endopod 3 segmented with 1, 1, 7 setae.

II pair of legs: Terminal segment with 3 spines, 1 terminal blade and 6 setae.

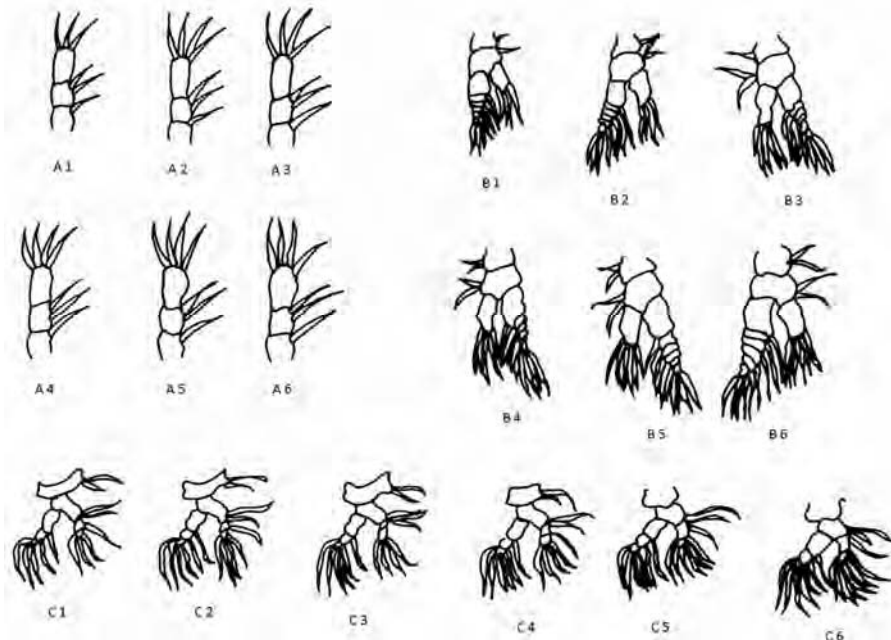
III pair of legs: Resembles as II pair.

IV pair of legs: Coxa unarmed, basis with 1 seta. Exopod 3 segmented, I and II segmented with 1 spine each. III with 2 spines 1 terminal blade and 6 setae. Endopod 3 segmented with 1, 1, 7 setae.

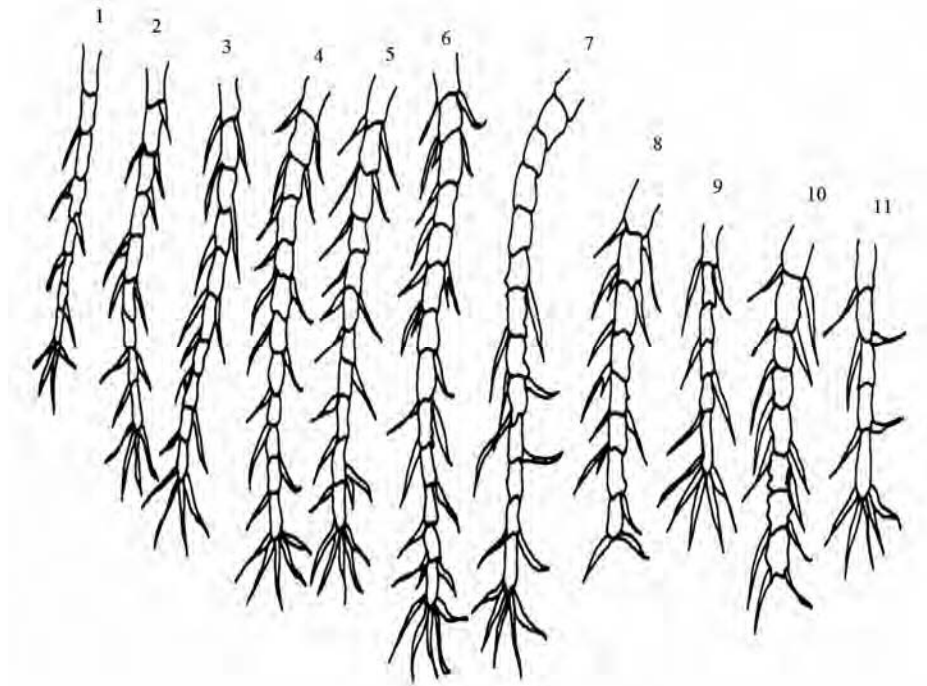
V pair of legs: Coxa unarmed, basis with 1 seta. Exo and endopod unsegmented. Exopod with 2 spines and 3 setae. Endopod with 4 setae only.

Adult female

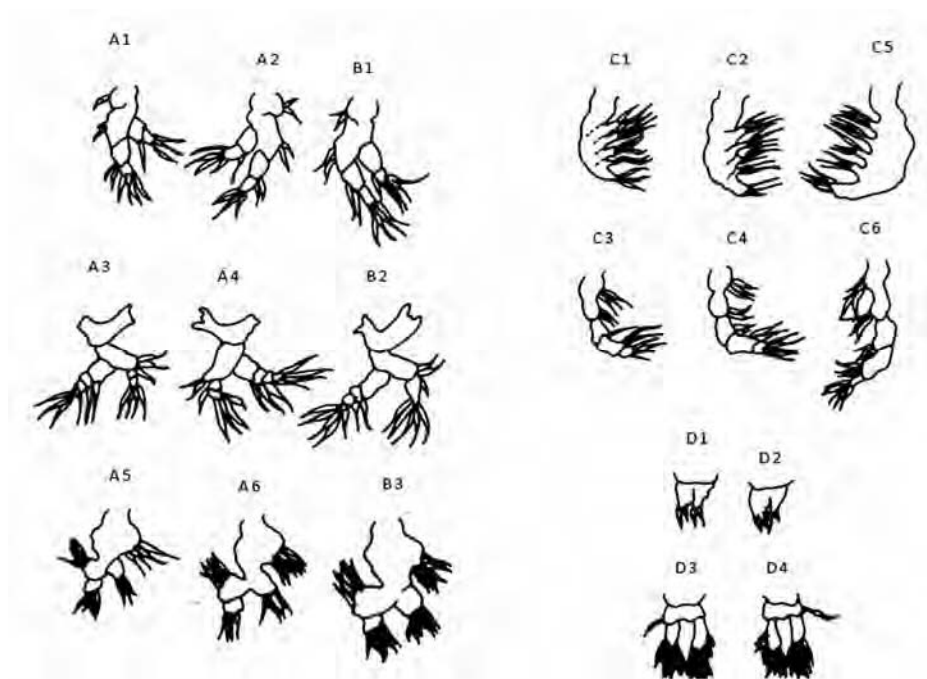
Body: Length 0.72-0.84 mm, width 0.379-0.418 mm, prosome fusiform. Prosome and urosome 5 segmented each. Genital segments were larger than other urosome segments and each side transparent and paired egg sacs were present in the ventral side of the urosome.



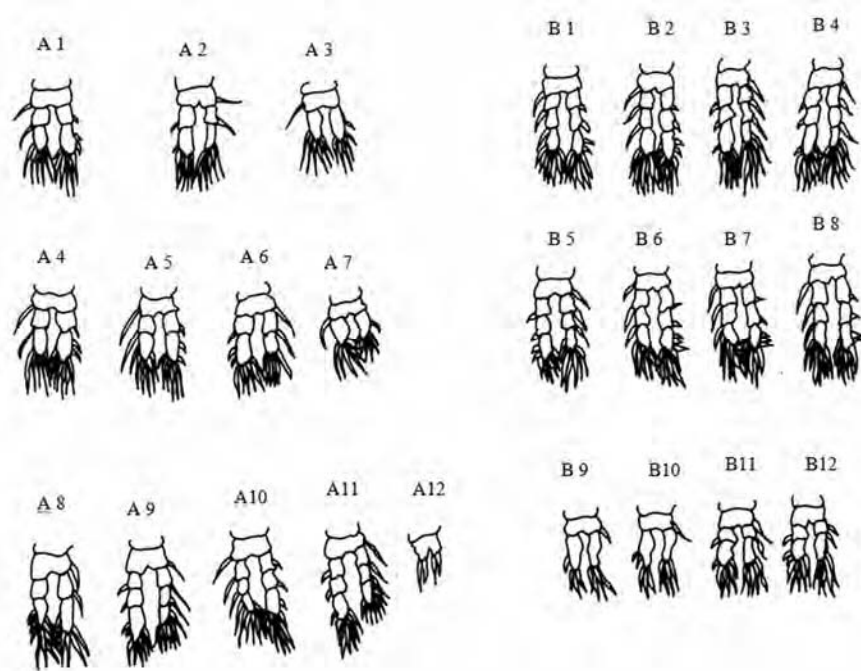
Plate—1: A1-A6: Antennules of Nauplii I to VI; B1-B6: Antennae of Nauplii I to VI; C1-C6: Mandible: Nauplii I to VI.



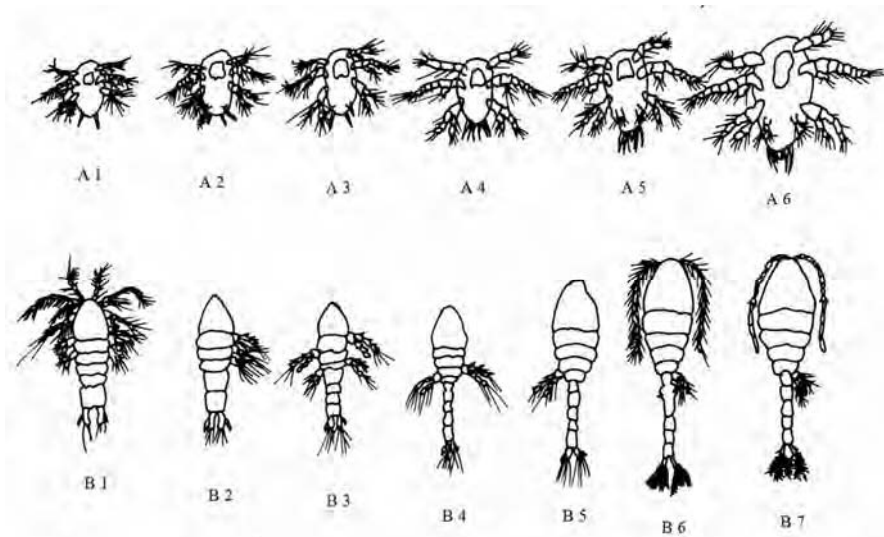
Plate—2: 1-3: Antennules of Copepodites I to III; 4 & 5: Antennules of Copepodite IV Female and Copepodite IV Male; 6 & 7: Copepodite V Female and Copepodite V Male; 8 & 9: Antennules of Adult Female; 10 & 11: Antennules of Adult Male.



Plate—3: A1 & A2: Antennae of Copepodites I and II; A3 & A4: Mandibles of Copepodites I and II; A5 & A6: Maxillules of Copepodites I and II; B1: Antennae of adult; B2: Mandible of adult; B3: Maxillule of adult; C1 & C2: Maxilla of Copepodites I and II; C3 & C4: Maxillepede of Copepodites I and II; C5: Maxilla of adult; C6: Maxillepede of adult; D1 & D2: Legs of Nauplii VI; D3 & D4: Legs of Copepodite I.



Plate—4: A1-A3: I to III Legs of Copepodite II; A4-A7: I to IV Legs of Copepodite III; A8-A12: I to V Legs of Copepodite IV; B1-B4: I to IV Legs of Copepodite V Female; B5-B8: I to IV Legs of Copepodite V male; B9 & B10: I Leg of Copepodite V male & Female; B11 & B12: I Leg of adult female and male.



Plate—5: A1-A6: Metamorphosis of *O. rigida* nauplii I to VI; B1-B5: Metamorphosis of *O. rigida* copepodite I to V; B6 & B7: Adult *O. rigida* Female and Adult male

Antennule: 14 segmented without geniculation on either side.

Antenna: Coxa with 2 divergent short setae. Basis elongated with 2 setae. Exopodite 2 segmented with 2 and 4 setae. Endopodite 2 segmented with 1 and 2 setae.

Mandible: In coxa mandibular teeth were well pronounced. Basis has 4 setae. Exopodite 4 segmented with 1, 1, 1, 4 setae, unsegmented

endopod with 5 setae.

Maxillule: Coxa with 8 setae. Basis consists of 5 setae. Exo and endopod with 5, 6 setae.

Maxilla: 5 endites with 3, 3, 3, 3, 4 setae with minute bristles.

Maxilliped: Coxa with 2 segments, I segment with 4 setae II with 3 setae. Basis has 3 setae. Endopod 2 segmented with 2 and 5 setae.

I and IV pair of legs: Resembles copepodite-V stages.

V pair of legs: Coxa unarmed basis with 1 seta. Exopod 2 segmented 1 segment with 1 spine, II segment with 1 spine, 1 terminal blade and 4 setae. Exopod 2 segmented with 1 and 5 setae.

Adult male

Body: Length 0.686-0.747 mm, width 0.292-0.328 mm.

Antennule: 13 segmented. Genuation observed in both right and left side antennules.

I and II pair of legs: Resembles copepodite 5 of male.

V pair of legs: Coxa unarmed. Basis with 1 seta, exopod 2 segmented, 1 segment with 1 spine, 1 terminal blade and 4 setae endopod 2 segmented with 1 and 5 setae.

Discussion

The present study revealed that the copepods reach adulthood early in *O. rigida* as the development was not isochronal. Copepodite stages tends to take longer time than naupliar development while metamorphosis. Rates of development have a tendency to be slower in the first copepodite stage than V copepodite stage as evidenced by earlier worker⁸. Similar type of development was found in *Pseudocalanus* sp.⁹. In the present experiment, six naupliar stages were evidenced in the life history of *O. rigida*^{3,4}. Similar number of naupliar stages was reported for other cyclopoid species like *O. nana*¹⁰, *O. helgolandica* and *O. spinirostris*¹¹, *O. similis*¹². The 3-segmented antennule was observed in the first naupliar stages in *O. rigida* as reported by Krishnaswamy², and Rao³ in other Oithonid species and Stephens *et al.*¹³ in calanoid copepod, *Acartia biflosa*. In *O. rigida*, 3 setae were present on the terminal segment, as that of the observation of Krishnaswamy² from Madras waters. Thus the present study optimistically related with the earlier observation of Krishnaswamy² and refute with Rao³ who reported that the 4 bristles on the terminal segment in the first nauplius stage of *O. rigida*.

In the present investigation, the 6-segmented exopodite was observed in the 1st naupliar of *O. rigida*. But there was no change found in the number of segments of exopodite in all the stages of nauplii². However in the same species, Rao³ described that the exopod had two segments. Endopodite was unsegmented in the nauplii of all the stages and the biramous mandible and twin segmented exopodite

was noted in 1st nauplius in the present study as evidence by Krishnaswamy² who reported the 2-segmented exopodite in the first nauplius of same species. However, the present result was pessimistically correlated with the earlier report³ who depicted 3 segmented bodies at the corresponding stage.

Developmental schedules of *O. rigida* were, (i) The first naupliar stage, it would take 24 hours (1.0 day) to hatch out from the eggs. (ii) The naupliar stages II, III, IV and V had a short duration (iii) the naupliar stage VI and other copepodite stages (CI, CII, CIII and CIV) developed at the same rate. The nauplii VI has taken prolonged time (1 day) for development than other nauplii stages (iv) 5th copepodite stage prolonged (2 days) than other copepodite stages. Present study was similar to previous report of Landry⁸ in calanoid group of copepod. Temperature has been reported to be an influencing factor in the development of copepods since it directly affects the metabolic activity of copepods thereby influencing reproduction, growth and longevity^{14,15}. It is also believed that along with temperature the food supply and concentration also may affects the development rates and body lengths of copepods^{16,17}. Development of presently examined species was resembles in all the essential features with those of other Oithonid species reported earlier^{10, 11,12}. Present study suggested that the temperature, food type, food levels besides the nutritive value of food may have a strong impact on the developmental biology of *O. rigida*. Unfortunately, only few studies have been conducted on marine copepods. Therefore, much work to be needed on this aspect especially the temperature, food and salinity effect on developmental biology of this and other copepod species.

Acknowledgements

Authors are grateful to Head, Department of Marine Science and authorities of Bharathidasan University for facilities .

References

- 1 Mazzocchi, M. G. & Paffenhoper, G. A., First observations on the biology of *Clausocalanus furcatus* (Copepoda: Calanoida), *J. Plankton Res.*, 20 (2) (1998) 331-342.
- 2 Krishnaswamy, S., Larval stages of some copepods in the Madras plankton and their seasonal fluctuation, *J. Madras Univ. B.*, 19 (1950) 35- 58.
- 3 Rao, V. R., The development of a cyclopoid copepod, *Oithona rigida* (Giesbrecht), *Memoir, Andhra University, India.*, 2 (62) (1958) 128- 131.

- 4 Goswami, S. C., Metamorphosis of two species of Genus *Oithona* Baird (Copepoda), *Indian J. Mar. Sci.*, 4 (1975) 60-67.
- 5 Goswami, S. C., Developmental stages, growth and sex ratio in *Pseudodiaptomus binghami* Sewell (Copepoda: Calanoida), *Indian J. Mar. Sci.*, 7 (1978) 103- 109.
- 6 Merrell R Jeffrey & Diane K Stoecker., Differential grazing on protozoan microplankton by developmental stages of the calanoid copepod *Eurytemora affinis* Poppe., *J. Plankton Res.*, 20 (2) (1998) 289-304.
- 7 Reddy, Y. R. & Devi, C. R., The complete post embryonic development of *Megadisptomus hebes* Kiefer, 1936 (Copepoda: Calanoida) reared in the laboratory, *Crustaceana.*, 48 (1985) 40- 63.
- 8 Landry, M., The development of marine calanoid copepods with comment on the isochronal rule, *Limnol. Oceanogr.*, 28 (1983) 614-624.
- 9 Kiorboe, T & Sabatini, M., Scaling of fecundity, growth and development in marine planktonic copepods, *Mar. Ecol. Prog. Ser.*, 120 (1995) 285- 298.
- 10 Murphy, H., The life cycle of *Oithona nana* reared experimentally. *Publication in Zoology. University of California, California.*, 22 (1923) 449- 454.
- 11 Gibbons, S. G. & Ogilvie, H. S., The development stages of *Oithona helgolandica* and *Oithona spirostris* with a note on the occurrence of body spines in cyclopoid nauplii, *J. Mar. Biol. Ass., U.K.*, 18 (1933) 529- 655.
- 12 Fish, C. J., Biological Bulletin, Woods Hole, 71 (1936) 168.
- 13 Stephens, J. A., Jordan, M. B., Taylor, A. H. & Proctor, R., The effects of fluctuations in North sea flows on zooplankton abundance, *J. Plankton Res.*, 20 (5) (1998) 923-942.
- 14 Peterson, W. T. & Painting, S. J., Developmental rates of the copepods *Calanoides carinatus* in the laboratory with discussion of methods used for calculation of development time, *J. Plankton Res.*, 12 (2) (1990) 283-293.
- 15 Huntley, M. E. & Lopez, M.D.G., Temperature-dependent production of marine copepods: a global synthesis, *Am. Nat.*, 140 (1992) 201-242.
- 16 Klein Breteler, W.C.M. & Gonzalez, S.R., Influence of cultivation and food concentration on body length of calanoid copepods, *Mar. Biol.*, 71 (1982) 157-161.
- 17 Paffenhofer, G.A., Cultivation of *Calanus helgolandicus* under controlled conditions, *Helgol. Wiss. Meeresunters.*, 20 (1970) 346-359.