

## The Developmental Stages of the Marine Calanoid Copepod *Labidocera rotunda* Mori

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**Abstract** Six naupliar and five copepodid stages excluding the adult of *Labidocera rotunda* Mori (Copepoda: Calanoida) are described and illustrated based on specimens cultured in the laboratory (NI-NII) and collected from the central part of the Inland Sea of Japan (NIII-CV). Naupliar stages of this species are much alike as compared to most of the previously described *Labidocera* nauplii. Copepodid stages are similar to those of the congener of the same species group, *L. pectinata* Thompson & Scott, with slight differences in appendage setation and spinulation. From observations on mouthparts and gut contents, nauplii of this species appear to start feeding from NII possibly on small flagellates.

### INTRODUCTION

The pelagic calanoid copepod *Labidocera rotunda* Mori (= *L. bipinnata* Tanaka) is widely distributed in inshore surface waters in the East Asia from Okhotsk to the Malay Archipelago (FLEMINGER, 1986; FLEMINGER et al., 1982). In the Inland Sea of Japan, the copepod commonly occurs in warmer seasons within the ranges of temperature of 19–29 °C and salinity of 29–34‰, and disappears from the plankton community during colder months (HIROTA, 1964, 1968a, b, 1979). It has recently been demonstrated that this species produces benthic resting eggs to tide over adverse conditions when the planktonic population cannot be sustained (UYE et al., 1979). However, little is known on the life history of this species.

The present paper deals with the description of all the developmental stages of *L. rotunda*, except for the adult. Comparison was made on the morphological characters of each stage between this species and other congeneric species, particularly *L. pectinata*, because these two species have been placed together in the *L. pectinata* species group (FLEMINGER et al., 1982) which is composed of six species inhabiting the Indo-West Pacific region.

### MATERIALS AND METHODS

Neuston samples were collected with a neuston net, ORI 33 (MATSUO et al., 1976), in the central Inland Sea of Japan (33°12'N, 133°11'E) on 9 August 1985. Only later copepodid stages of *Labidocera rotunda* were contained in these samples because of a relatively coarse mesh size (0.33mm) of the net. These specimens were fixed in 10% neutralized formalin-seawater immediately after capture. To collect naupliar stages, early copepodid stages and live adults, plankton samples were obtained by oblique tows of a NORPAC net near Fukuyama (34°22'N, 133°21'E) at irregular intervals from 30 June to 12 November 1986. Early stage nauplii (NI and NII) were obtained after incubating eggs laid by adult females kept in culture dishes at 25°C in the laboratory. Adult females were fed with cirriped and *Artemia* nauplii.

After measurement of size and drawing of body outline, specimens at each developmental stage were dissected and their appendages were mounted on glass slides with Gum-chloral medium. All drawings were made with a camera lucida mounted in a differential interference compound microscope. Descriptions of NI and NII were based on the specimens obtained in the laboratory, whereas the later stages (NIII-copepodid V) were described for field-collected specimens.

## DESCRIPTION

*Nauplius I* (Figs. 1-a, 2-a, g, m) — Body length: 0.15–0.17mm ( $0.15 \pm 0.01$ mm, mean  $\pm$  S.D.), (Number of specimens:  $N=14$ ). Body oval. Caudal armature composed of pair of short spinulose spines. Antenna 1: 3-segmented, terminal segment with 3 terminal setae. Antenna 2: gnathobase with naked short spine, both left and right basipods 2 with naked masticatory spines of subequal length, endopod with 3, exopod with 6 setae. Mandible: endopod with 3, exopod with 5 setae.

*Nauplius II* (Figs. 1-b, 2-b, h, n) — Body length: 0.21–0.23mm ( $0.22 \pm 0.01$ mm) ( $N=23$ ). Body more elongated than in former stage. Caudal armature with long spinulose spine, short seta, and several spinules. Antenna 1: 3-segmented, furnished with 4 terminal setae and several lateral setules on terminal segment. Antenna 2: spinulose seta of left basipod 2 longer than that of right; endopod with 5, exopod with 7 setae. Mandible: endopod with 4, exopod with 6 setae.

*Nauplius III* (Figs. 1-c, 2-c, i, o) — Body length: 0.29–0.32mm ( $0.31 \pm 0.01$ mm) ( $N=18$ ). Caudal armature with 2 short spines and 6 spinules subterminally, and long spinulose spine, 2 minute and plumose setae, and several spinules terminally. Antenna 1: 3-segmented as in NII, bearing 4 terminal and 3 lateral setae on terminal segment. Antenna 2: endopod with 6, exopod with 7 setae. Mandible: endopod with 8, exopod with 6 setae.

*Nauplius IV* (Figs. 1-d, 2-d, j, p) — Body length: 0.35–0.39mm ( $0.37 \pm 0.01$ mm) ( $N=27$ ). Caudal armature with 2 short spines and 14 spinules subterminally, and long and short spinulose spines, 2 plumose setae and several spinules terminally. Antenna 1: 3-segmented; terminal segment bearing 4 terminal and 7 lateral setae. Antenna 2: endopod with 7, exopod with 10 setae. Mandible furnished with masticatory process on gnathobase; endopod with 9, exopod with 6 setae. Maxilla 1 represented by 5 minute setae.

*Nauplius V* (Figs. 1-e, 2-e, k, q) — Body length: 0.40–0.45mm ( $0.43 \pm 0.01$ mm) ( $N=28$ ). Caudal armature with pair of spinulose lateral spines and several spinules added to former stage. Antenna 1: segmentation as in NIV; terminal segment bearing 4 terminal and 9 lateral setae. Antenna 2: endopod with 9, exopod with 12 setae. Mandible: endopod with 10, exopod with 6 setae. Maxilla 1 bilobed, inner lobe with 2, outer one with 5 setae.

*Nauplius VI* (Figs. 1-f, 2-f, l, r) — Body length: 0.43–0.49mm ( $0.47 \pm 0.02$ mm) ( $N=25$ ). Caudal armature similar as in NV. Antenna 1: segmentation as in former stage; terminal segment having 4 terminal and 11 lateral setae. Antenna 2: setation of endo- and exopods as in NV. Mandible: endopod with 11, exopod with 6 setae. Maxilla 1 bilobed, inner lobe with 3 and outer one with 7 setae. Maxilla 2 composed of at least 10 short processes. Maxilliped represented by single small lobe with small projection on whose tip round protuberance present. Legs 1 and 2 rudimentary, bilobed, inner lobes with 3 and 2, and outer ones with 4 and 3 short processes, respectively.

*Copepodid stages* (Figs. 3–6): Copepodid stages are similar to those of *Labidocera pectinata* (PILLAI, 1971). Sexual dimorphism becomes apparent from the copepodid IV (CIV).

*Copepodid I* (Figs. 3-a, g, 4-a, g, 5-a, f, k, p, 6-a, f, k) — Body length: 0.57–0.66mm

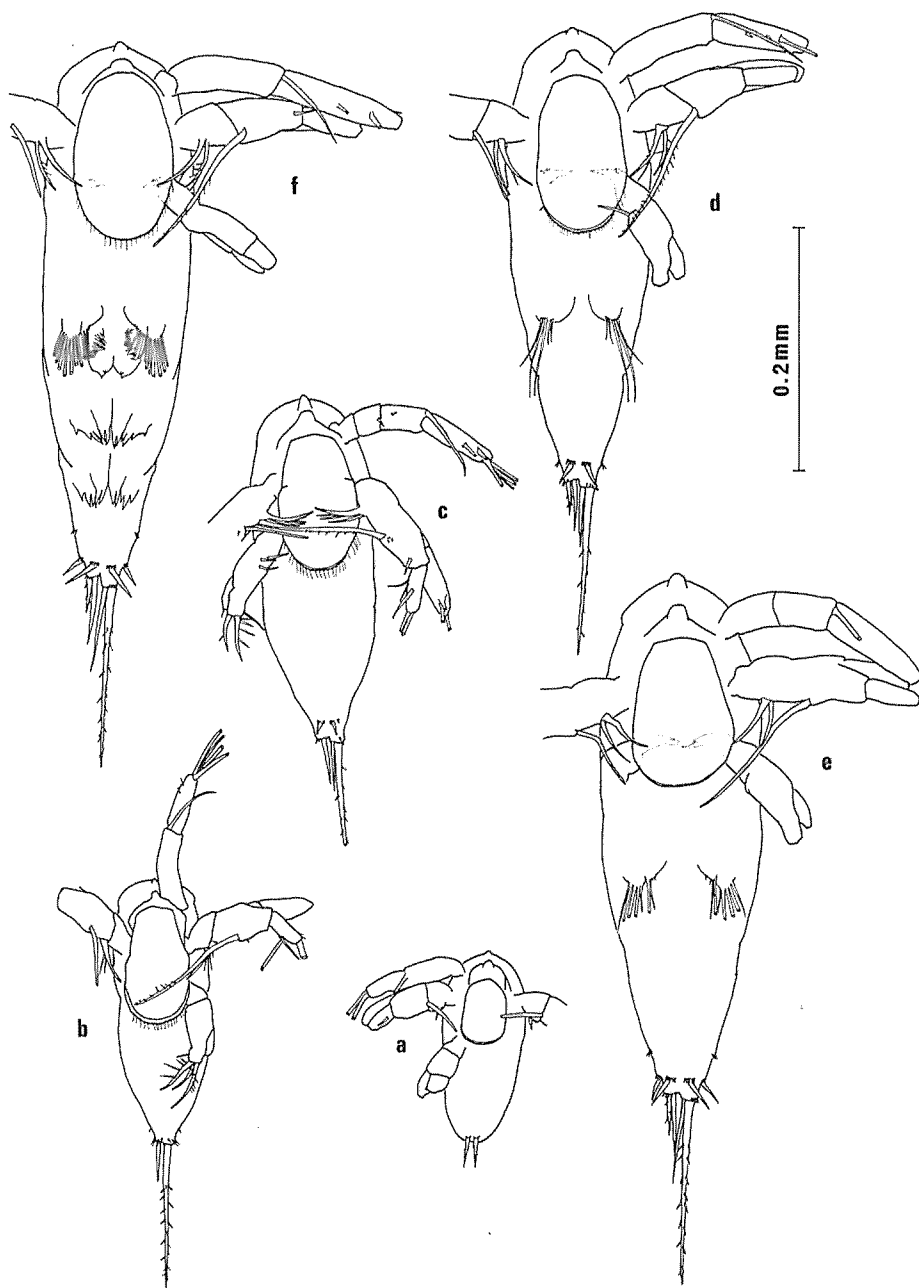


Fig. 1. *Labidocera rotunda* Mori, naupliar stages, ventral view: a-f, Nauplius I-VI.

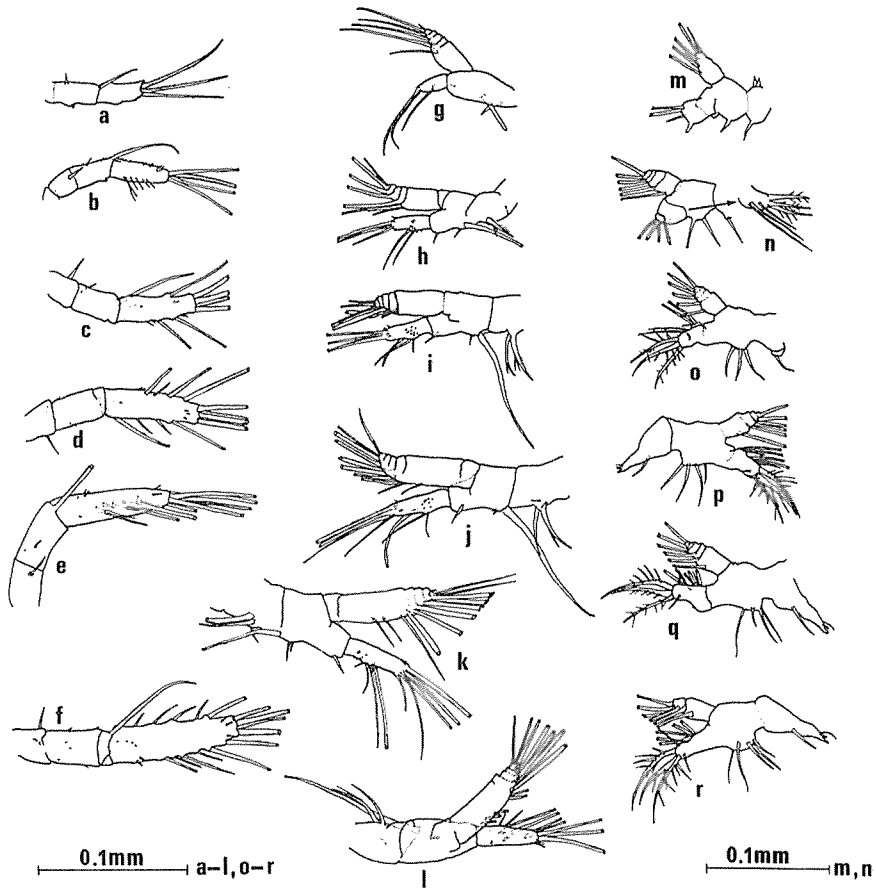


Fig. 2. *Labidocera rotunda* Mori, naupliar stages: a-f, 1st antenna, Nauplius I-VI; g-l, 2nd antenna, Nauplius I-VI; m-r, mandible, Nauplius I-VI.

( $0.62 \pm 0.02$ mm) ( $N=47$ ). Metasome 3-segmented. Urosome 2-segmented. Rostrum small and not pointed. Dorsal and ventral lenses not developed. Lateral hook absent. Antenna 1: 9-segmented. Cephalic appendages similar to those of adult. Legs 1-3 present; leg 3 rudimentary, bilobed, inner lobe with 2 hooks and outer one with 3 processes on tip.

*Copepodid II* (Figs. 3-b, h, 4-b, h, 5-b, g, l, q, 6-b, g, l, p) — Body length: 0.72–0.83mm ( $0.78 \pm 0.03$ mm) ( $N=23$ ). Metasome 4-segmented. Urosome 2-segmented. Pair of dorsal lenses present; single ventral lens present. Rostrum pointed. Lateral hooks present. Antenna 1: 14-segmented. Legs 1-4 present; leg 4 rudimentary, similar to leg 3 of CI.

*Copepodid III* (Figs. 3-c, i, 4-c, i, 5-c, h, m, r, 6-c, h, m, q, t) — Body length: 0.86–0.93mm ( $0.89 \pm 0.02$ mm) ( $N=13$ ). Metasome 5-segmented. Urosome 2-segmented. Dorsal and ventral lenses, rostrum, and lateral hooks well developed as in adult. Antenna 1: 20-segmented. Legs 1-5 present; leg 5 rudimentary, bilobed, inner lobe rounded, outer one with 2 small pointed protuberances.

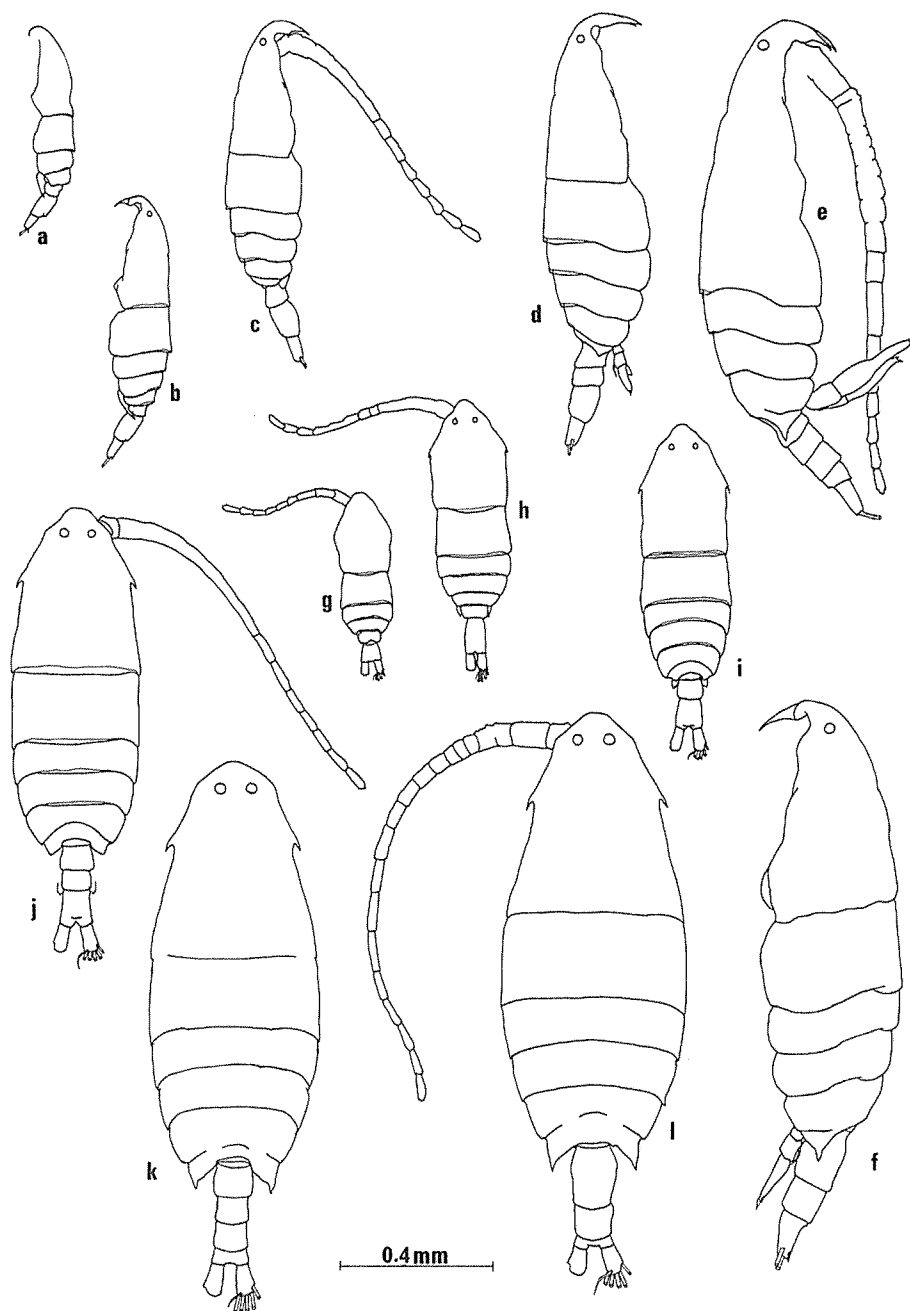


Fig. 3. *Labidocera rotunda* Mori, copepodid stages: a-f, lateral view; g-l, dorsal view; a-c, g-i, Copepodid I-III; d, j, Copepodid IV female; e, k, Copepodid V male; f, l, Copepodid V female.

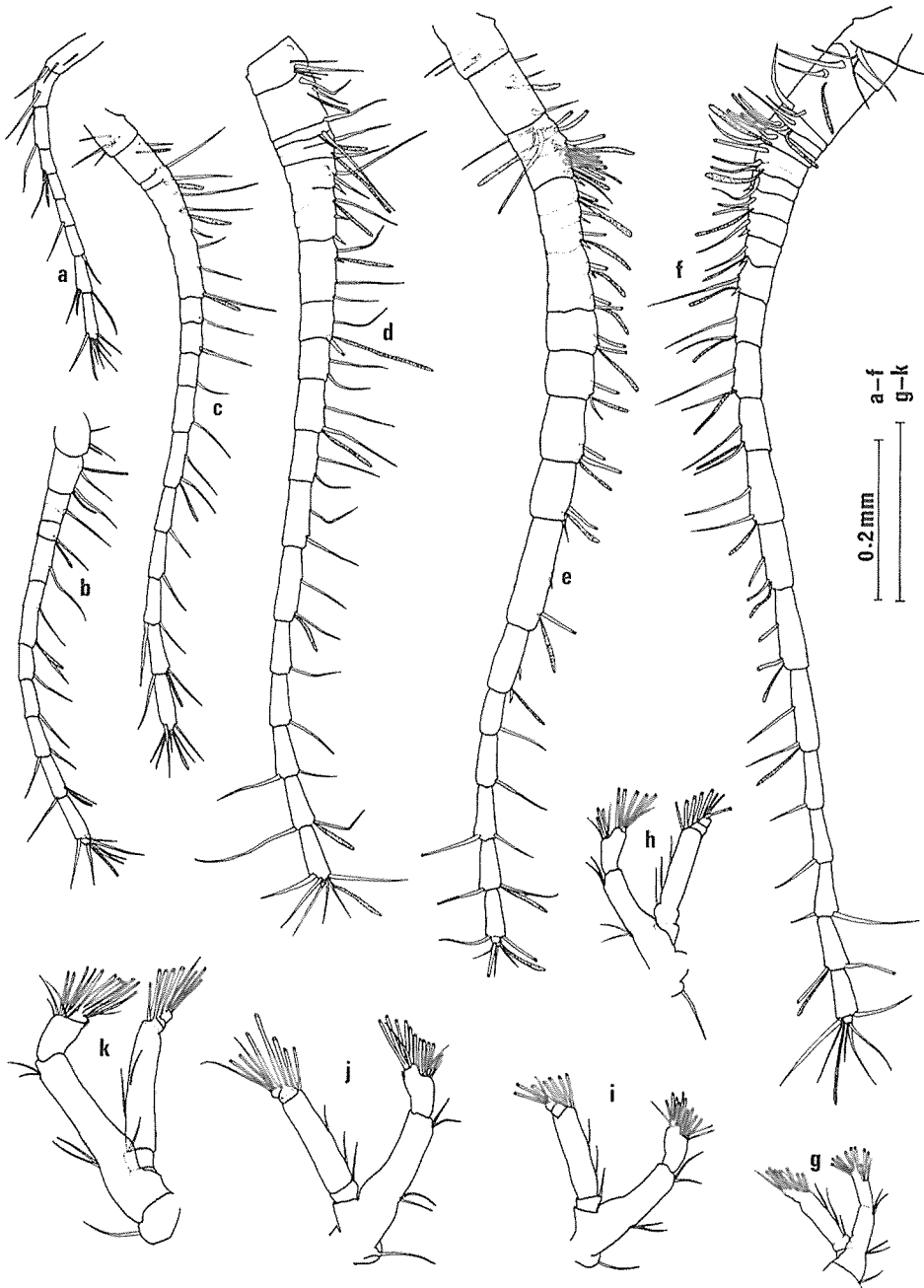


Fig. 4. *Labidocera rotunda* Mori, copepodid stages: a-f, 1st antenna, Copepodid I-III, IV female, V male (right), V female; g-k, 2nd antenna, Copepodid I-III, IV female, V. male.



Fig. 5. *Labidocera rotunda* Mori, copepodid stages: a-e, mandible, Copepodid I-III, IV male, V female; f-j, 1st maxilla, Copepodid I-III, IV male, V female; k-o, 2nd maxilla, Copepodid I-III, IV female, V male; p-t, maxilliped, Copepodid I-III, IV female, V male.

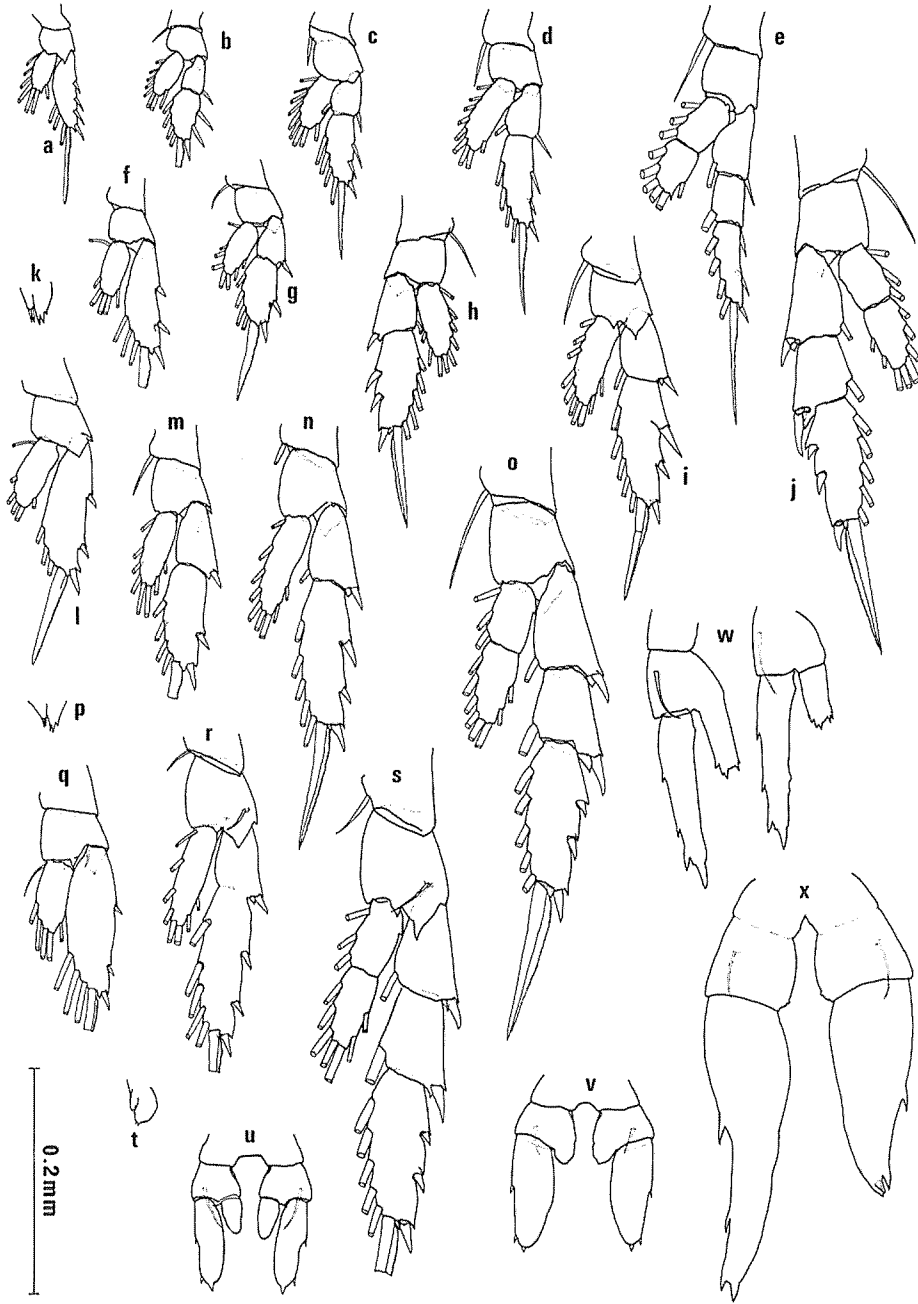


Fig. 6. *Labidocera rotunda* Mori, copepodid stages: a-e, leg 1, Copepodid I-III, IV female, V female; f-j, leg 2, Copepodid I-III, IV female, V female; k-o, leg 3, Copepodid I-III, IV female, V female; p-s, leg 4, Copepodid II, III, IV female, V female; t-x, leg 5, Copepodid III, IV female, IV male, V female, V male.



*Copepodid IV* (Figs. 3-d, j, 4-d, j, 5-d, i, n, s, 6-d, i, n, r, u, v) — Body length: 0.98–1.24mm ( $1.12 \pm 0.05$ mm) ( $N=247$ ). Sex distinguishable by structure of leg 5, but not by body length and antenna 1. Metasome 5-segmented in both sexes. Urosome 3-segmented in both sexes. Antenna 1: 23-segmented in both sexes. Leg 5: endopod of female slightly asymmetrical and that of male symmetrical, smaller than in female.

*Copepodid V* (Figs. 3-e, f, k, l, 4-e, f, k, 5-e, j, o, t, 6-e, j, o, s, w, x) — Body length: female, 1.40–1.60mm ( $1.46 \pm 0.05$ mm) ( $N=50$ ); male, 1.27–1.48mm ( $1.37 \pm 0.04$ mm) ( $N=42$ ). Sex easily distinguishable by body length, structure of right antenna 1 and leg 5, and number of urosome segments. Metasome 5-segmented in both sexes; 4th and 5th segments partially fused; posterior corner of both sexes symmetrical. Urosome 3-segmented in female, 4-segmented in male; female urosome segment 2 slightly asymmetrical. Right antenna 1: 24-segmented in female and 22-segmented in male. Leg. 5: endopod and exopod of female asymmetrical; right exopod of male longer than left one, and male endopod absent.

*Copepodid VI* (adult). FLEMINGER et al. (1982) reported that the body lengths of adult females range from 1.83 to 2.26mm ( $1.94 \pm 0.14$ mm,  $N=15$ ) and of adult males, from 1.58 to 2.14mm ( $1.77 \pm 0.19$ mm,  $N=15$ ).

## DISCUSSION

In the genus *Labidocera*, all or parts of developmental stages of 12 species have so far been described and illustrated (JOHNSON 1935, UMMERKUTTY 1964, SAZHINA 1967, PILLAI 1971, BJÖRNBERG 1972, TAW 1974, GIBSON & GRICE 1977, GRICE & GIBSON 1982, LI & FANG 1983). Among these, all the naupliar and copepodid stages were described for five species: *L. aestiva* Wheeler (GIBSON & GRICE 1977), *L. bengalensis* Krishnaswamy (UMMERKUTTY 1964), *L. euchaeta* Giesbrecht (LI & FANG 1983), *L. rotunda* (present study), *L. trispinosa* Esterly (JOHNSON 1935), and *L. wollastoni* (Lubbock) (GRICE & GIBSON 1982). There are 6 naupliar and 6 copepodid stages in all of these species except for *L. bengalensis*, whose naupliar stages are reported to be abbreviated into five (UMMERKUTTY 1964).

Nauplii of most species of *Labidocera*, including *L. rotunda*, are furnished with long spines (masticatory hooks by JOHNSON, 1935) on the basipods of the antennae 2 from NII and stout (pointed) gnathal lobes of the mandible from NIV. They appear to start feeding from NII. Gut content analysis revealed that the nauplii of *L. rotunda* feed possibly on small dinoflagellates such as *Prorocentrum* from NII (HOTTA unpubl.). In *L. aestiva* and *L. wollastoni*, nauplii have been successfully reared in the laboratory fed with various flagellates such as *Isochrysis*, *Gymnodinium*, *Gonyaulax*, *Prorocentrum* and *Peridinium* (GIBSON & GRICE 1977, GRICE & GIBSON 1982). In *L. euchaeta*, all the naupliar stages have reduced mouthparts lacking such feeding apparatus and appear to depend their entire nutrition on their own yolk substances (LI & FANG 1983).

Excluding *L. euchaeta* with reduced mouthparts and *L. bengalensis* with much elongate body, other described nauplii of the genus were similar in structure to one another. However, they can be distinguished by such morphological characters as the shape of body and labrum, presence and absence of an elongate masticatory hook on the left antenna 2, etc.

The early-stage copepodids (CI-CIII) of the described species of *Labidocera* are difficult to distinguish from one another, whereas in later stages (CIV-CVI) from which sexual dimorphism appears, species-specific characteristics become more apparent.

*L. rotunda* belongs to the *L. pectinata* species group (FLEMINGER et al. 1982), which is composed of six species of the Indo-West Pacific region. Within this species group, copepodid

Table 1. Segmentation, setation, and spinulation of appendages of copepodid stages of *Labidocera rotunda* and *L. pectinata*. Numbers of setae, aesthetascs, spines, teeth and segments are shown respectively as arabic number only, and numbers accompanied by a, s, t and sg. Number in parentheses is for *L. pectinata* only when there are differences in number.

	CI	CII	CIII	CIV	CV
Antenna 1	9sg, 17, 3a, 0s (14, 2a)	14sg, 22 6a, 0s (12sg, 20, 4a)	20sg, 30, 7a, 0s (6a)	23sg, 40, 10a, 4s (43, 12a, 0s)	♀ 24sg, 49, 16a, 4s (47, 14a, 0s) ♂ 22sg, 50, 16a, 4s (23sg, 44, 12a, 3s)
Antenna 2					
basipod	3	3	3	3	3
endopod	12	13	15	16(15)	17
exopod	11	11	11	12(11)	12
Mandible					
gnathobase	4t, 1	5t, 1	5t, 1	5t, 1	5t, 1
basipod	4(3)	4	4	4	4
endopod	9	11(10)	11(10)	12(11)	12(11)
exopod	6	6	6	6	6
Maxilla 1					
1st inner lobe	12(9)	13(10)	14(10)	15(11)	16(11)
2nd inner lobe	3	3	3	3	3
3rd inner lobe	4(3)	4(3)	4	4	4
1st outer lobe	4	6	8	8	9
2nd outer lobe	1	1	1	1	1
basipod	2(3)	2(3)	3	3	3
endopod	8(9)	9	9	9	9
exopod	7	7	8	9	10(9)
Maxilla 2					
basipod	16(15)	19(15)	19(15)	20(16)	20(17)
endopod	5(4)	5	5	5	5
Maxilliped					
basipod (=B1)	4	6(5)	8(7)	8	8
B2+ endopod	3sg, 5(4)	4sg, 8(6)	5sg, 9(8)	5sg, 10(9)	5sg, 10(9)
Leg 1					
basipod 1	0	1	1	1	1
basipod 2	0	0	0	0	0
endopod 1	7	8	9	9	3
endopod 2	—	—	—	—	6
exopod 1	5s, 3	1s	1s, 1	1s, 1	1s, 1
exopod 2	—	4s, 4	4s, 4	4s, 4	1s, 1
exopod 3	—	—	—	—	3s, 4
Leg 2					
basipod 1	0	1	1	1	1
basipod 2	0	0	0	0	0
endopod 1	6	8	9	10	3
endopod 2	—	—	—	—	8
exopod 1	4s, 3	1s, 1	1s, 1	1s, 1	1s, 1
exopod 2	—	3s, 4	4s, 5	4s, 5	1s, 1
exopod 3	—	—	—	—	4s, 5
Leg 3					
basipod 1	—	0	1	1	1
basipod 2	—	0	0	0	0
endopod 1	—	6	8	9(8)	3
endopod 2	—	—	—	—	8
exopod 1	—	4s, 3 (4s, 4)	1s	1s, 1	1s, 1
exopod 2	—	—	3s, 4 (4s, 4)	4s, 5	1s, 1
exopod 3	—	—	—	—	4s, 5
Leg 4					
basipod 1	—	—	0	1	1
basipod 2	—	—	1(0)	1(0)	1(0)
endopod 1	—	—	6	8	3
endopod 2	—	—	—	—	7
exopod 1	—	—	4s, 3	1s	1s, 1
exopod 2	—	—	—	4s, 5	1s, 1
exopod 3	—	—	—	—	4s, 5

stages have been described only for *L. pectinata* Thompson & Scott (PILLAI 1971) other than *L. rotunda*. Comparison was made of the body size, setation and spinulation of mouthparts and legs between these two species (Table 1). Appendage setation and spinulation differ only slightly from each other. Sexual difference in size appears at CV in *L. rotunda*, whereas in *L. pectinata* it is observed from CIV. Endopod of leg 5 of CV male is relatively larger and more clearly articulated in the former species than in the latter. Growth is similar in both species as shown in Fig. 7. However, females are larger in *L. pectinata* than in *L. rotunda*, and males of the former are larger at CIV-CV and smaller at CVI than the corresponding stages of the latter.

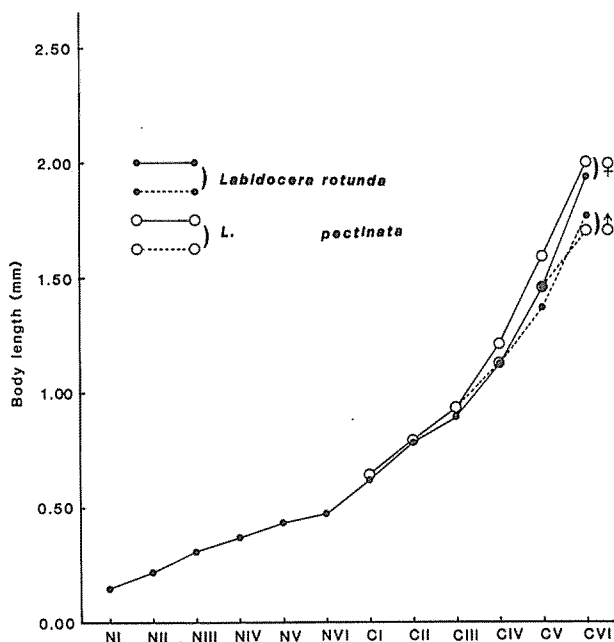


Fig. 7. Growth of *Labidocera rotunda* Mori as compared with the copepodids of *L. pectinata* Thompson & Scott. Data for adult *L. rotunda* and copepodids of *L. pectinata* taken from FLEMINGER et al. (1982) and PILLAI (1971), respectively.

Only *L. rotunda* is known to occur in the central part of the Inland Sea of Japan (HIROTA, 1964, 1968a, b, 1979), although *L. japonica* Mori is found to be distributed in the Bungo Strait and the Kii Strait connecting the Inland Sea to the Pacific Ocean (OHTSUKA, unpubl.). Accordingly, the possibility of contamination of the developmental stages of *L. rotunda* in the present study with other congeneric species might be minimized.

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## 海産浮遊性カイアシ類 *Labidocera rotunda* Mori (カラヌス目) の発生段階

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瀬戸内海において暖期に出現する浮遊性カイアシ類 *Labidocera rotunda* Mori のノウプリウス及び成体を除くコペポデイド幼生の全発生段階の形態を室内飼育と野外採集から得られた標本により記載した。ノウプリウス, コペポデイド期の発生段階は何れも6期であり, *L. bengalensis* Krishnaswamy で報告されているようなノウプリウス期の5期への短縮は見られなかった。また, 口器の形態と消化管内容物の観察から, 本種のノウプリウス期の栄養摂取様式は *L. euchaeta* Giesbrecht の様な卵黄依存型ではなく, 2期から小型の鞭毛虫等を摂食しているものと推測された。本種のコペポデイド期は同じ種群に属する *L. pectinata* Thompson & Scott の同期に極めてよく類似するが, 付属肢の刺毛数等に相違が見られた。性的二型が発現するのはコペポデイド4期からで, 右第1触角, 第5脚に相違点が見られた。体長の雌雄差は *L. pectinata* ではコペポデイド4期から認められるが, 本種では5期以降にみられた。