

Complete Larval Development of *Novactaea pulchella* (Crustacea: Decapoda: Xanthidae)

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Abstract: *Novactaea pulchella* was reared in the laboratory, from hatching to the megalopal stage at 25°C. The larval stage of it consists of two zoeal and one megalopal stages. The first zoea of the present study differs from that described by Terada (1990) in the setal presence of the carapace, the maxilla and the maxilliped, and the lateral process on the abdominal somite. It is reported for the first time that brachyuran zoeas belonging to a species share two types of lateral processes on the abdominal somites. They are either on the abdominal somites 2 and 3 or on abdominal somites 2 to 5. A provisional key is provided to aid the identification of the actaeine zoeas in Korea and the adjacent waters.

Key words: Xanthidae, *Novactaea pulchella*, zoea, megalopa, abdomen, lateral process, key, Korea

The crabs of the subfamily Actaeinae (family Xanthidae) contain 40 species belonging to 14 Indo-Pacific genera (Guinot, 1976; Serène, 1984). The actaeine species from Korea are four, *Actaea semblatae* (Guinot, 1976), *Novactaea pulchella* (A. Milne Edwards, 1865), *Forestia depressa* (White, 1847) and *Gaillardiiellus orientalis* (Odhner, 1925) (see KSSZ, 1997; Ko and Takeda, 1999, 2000). *N. pulchella* inhabits crevices of the rocks or under the stones between the high and low tidal marks. It was known to occur on the coasts of Singapore, Indonesia, Vietnam, Taiwan, China, Japan, and Korea (Sakai, 1976; Ko and Takeda, 2000).

The larval stages of four actaeine species have been reported: *A. semblatae* by Terada (1987) and Ko et al. (2002); *G. orientalis* by Fukuda (1978) and Ko (1999); *N. bella* by Lim and Ng (1997); and *N. pulchella* by Terada (1990). Although, Terada (1990) described the first and second zoeal stages of it, his report was limited to the brief

comments and illustrations of them. Moreover, he didn't provide any description of a megalopal stage. Therefore, the aim of this paper is to provide a detailed description of the complete larval stage including megalopa of *N. pulchella*.

MATERIALS AND METHODS

An ovigerous female of *Novactaea pulchella* was collected from Jeju Island (33°13'N; 126°15'E) off the southern part of Korea in July 23, 1998. The larvae collected from laboratory were reared using methods described by Ko (1995) at a constant water temperature of 25°C. Larvae were fixed and preserved in 10% neutral formalin. Dissected appendages were examined and drawn using a Leitz Laborlux S Microscope with camera lucida. Setal counts on appendages and measurements were based on the mean of 10 specimens for zoeal stage. The sequence of the zoeal description (Clark et al., 1998) is based on the malacostracan somite plan and described from anterior to posterior. Setal armature on appendages is described from proximal to distal segments and in order of endopod to exopod. The remaining zoeal stages and the spent female were deposited in Silla University, Korea (SUZ Cr103244).

RESULTS

The larval stage consists of two zoeal and one megalopal stages. The minimum durations of the zoeal stages I and II, the megalopal stage at 25°C were 2, 3 and 16 days, respectively. Metamorphosis to young crab occurred from 22 days after the first stage zoeas hatched from eggs. The first zoeal stage is described and illustrated completely. For the second zoeal stage only the main differences from the first zoea are described in detail.

First Zoea (Fig. 1)

Size. Carapace length 0.92 ± 0.05 mm. Distance from tip of

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dorsal spine to tip of rostral spine 3.09 ± 0.05 mm.

Carapace (Fig. 1A). Dorsal spine straight, longer than rostral spine and with minute spinules; rostral spine about equal in length to antenna; lateral spine short; a pair of posterodorsal setae present; each ventral margin with 7 setae; eyes stalked.

Antennule (Fig. 1B). Endopod bud absent; exopod with 4 (2 long and 2 shorter) terminal aesthetascs plus 1 short terminal seta.

Antenna (Fig. 1C). Endopod bud present; protopod spinous process, about equal in length to rostral spine; exopod about 1/4 in length to protopod, with 2 short subterminal setae.

Mandibles (Fig. 1D). Asymmetrical; right molar and left molar processes with 3 and 1 teeth, confluent with incisor process, respectively; endopod absent.

Maxillule (Fig. 1E). Coxal endite with 8 setae; basal endite with 5 setae; endopod 2-segmented, proximal segment with 1 seta, distal segment with 2 subterminal plus 4 terminal setae.

Maxilla (Fig. 1F). Coxal endite bilobed with 4 + 4 setae; basal endite bilobed with 5 + 4 setae; endopod bilobed with 3 + 5 (2 subterminal and 3 terminal) setae; exopod (scaphognathite) margin with 4 plumose setae plus 1 distal stout process.

First maxilliped (Fig. 1G). Coxa with 1 seta; basis with 10 setae arranged as 2, 2, 3, 3; endopod 5-segmented with 3, 2, 1, 2, 5 (1 subterminal + 4 terminal) setae, respectively; exopod 2-segmented, distal segment with 4 terminal natatory setae.

Second maxilliped (Fig. 1H). Coxa without seta; basis with 4 setae; endopod 3-segmented, with 1, 1, 6 (3 subterminal + 3 terminal) setae, respectively; exopod 2-segmented, distal segment with 4 terminal natatory setae.

Abdomen (Fig. 1I, J). Incompletely 6 somites; somite 1 with 1 dorsomedial seta; somite 2 with a pair of lateral processes directed laterally; somite 3 or somites 3-5 with a pair of lateral processes directed posteriorly; somites 2-5 each with a pair of posterodorsal setae, somites 3-5 with long posterolateral processes; pleopod buds present as buds.

Telson (Fig. 1J). Each fork long, with 1 stout lateral spine, 1 simple seta and 1 dorsomedial spine; each posterior margin with 3 serrated setae.

Second Zoea (Fig. 2)

Size. Carapace length 1.00 ± 0.04 mm. Distance from tip of dorsal spine to tip of rostral spine 3.72 ± 0.05 mm.

Carapace (Fig. 2A). Two pairs of anterodorsal and a pair of posterodorsal setae present; each ventral margin with 8 setae.

Antennule (Fig. 2B). Exopod with 2 rows of subterminal

aesthetascs arranged 7, 1 and 5 terminal aesthetascs plus 1 short terminal seta.

Antenna (Fig. 2C). Endopod bud longer than exopod.

Mandibles (Fig. 2D). Endopod bud absent.

Maxillule (Fig. 2E). Epipod plumose seta now present; coxal endite with 10 setae; basal endite with 9 setae.

Maxilla (Fig. 2F). Coxal endite with 5 + 4 setae; basal endite with 5 + 5 setae; exopod (scaphognathite) margin with 25 marginal plumose setae.

First maxilliped (Fig. 2G). Coxa with 2 setae; endopod 5-segmented with 3, 2, 1, 2, 6 (2 subterminal + 4 terminal) setae, respectively; exopod 2-segmented, distal segment with 8 terminal natatory setae.

Second maxilliped (Fig. 2H). Exopod 2-segmented, distal segment with 9 terminal natatory setae.

Pereiopods (Fig. 2I). Bilobed cheliped plus 4 buds differentiated into segments.

Abdomen (Fig. 2J). Six somites; pleopod buds more developed.

Telson (Fig. 2J). Each posterior margin with 4 (3 long + 1 shorter) serrated setae.

Megalopa (Fig. 3)

Size. Carapace length 1.28 ± 0.02 mm. Carapace width 0.96 ± 0.03 mm.

Carapace (Fig. 3A). Subquadrated shape, with 1 posterior tubercle.

Antennule (Fig. 3B). Last segment of peduncle with 2 setae; endopod with 2 subterminal and 4 terminal setae; exopod 3-segmented, segment 1 without seta, segment 2 with 8 aesthetascs and 1 short seta, segment 3 with 4 subterminal aesthetascs and 1 seta.

Antenna (Fig. 3C). Nine-segmented, with 2, 1, 2, 0, 0, 4, 0, 3, and 4 setae.

Mandible (Fig. 3D). Endopod palp 3-segmented, distal segment with 7 marginal setae.

Maxillule (Fig. 3E). Coxal endite with 14 setae; basal endites with 18 setae; endopod with 1 subterminal seta.

Maxilla (Fig. 3F). Coxal and basal endites both with 12 setae; endopod with 2 proximal and 1 medial setae; exopod (scaphognathite) margin with 45 plumose setae and 4 surface setae.

First maxilliped (Fig. 3G). Epipod with 9 long simple setae; coxal and basal endites each with 10 and 16 setae, respectively; endopod unsegmented with 2 setae; exopod 2-segmented, proximal segment without seta, distal segment with 5 long terminal plumose feeding setae.

Second maxilliped (Fig. 3H). Epipod with 1 terminal simple seta; coxa and basis not differentiated; endopod 4-segmented, with 2, 1, 5, and 7 setae; exopod 2-segmented, proximal segment with 1 medial seta, distal segment with 5 long terminal plumose feeding setae.

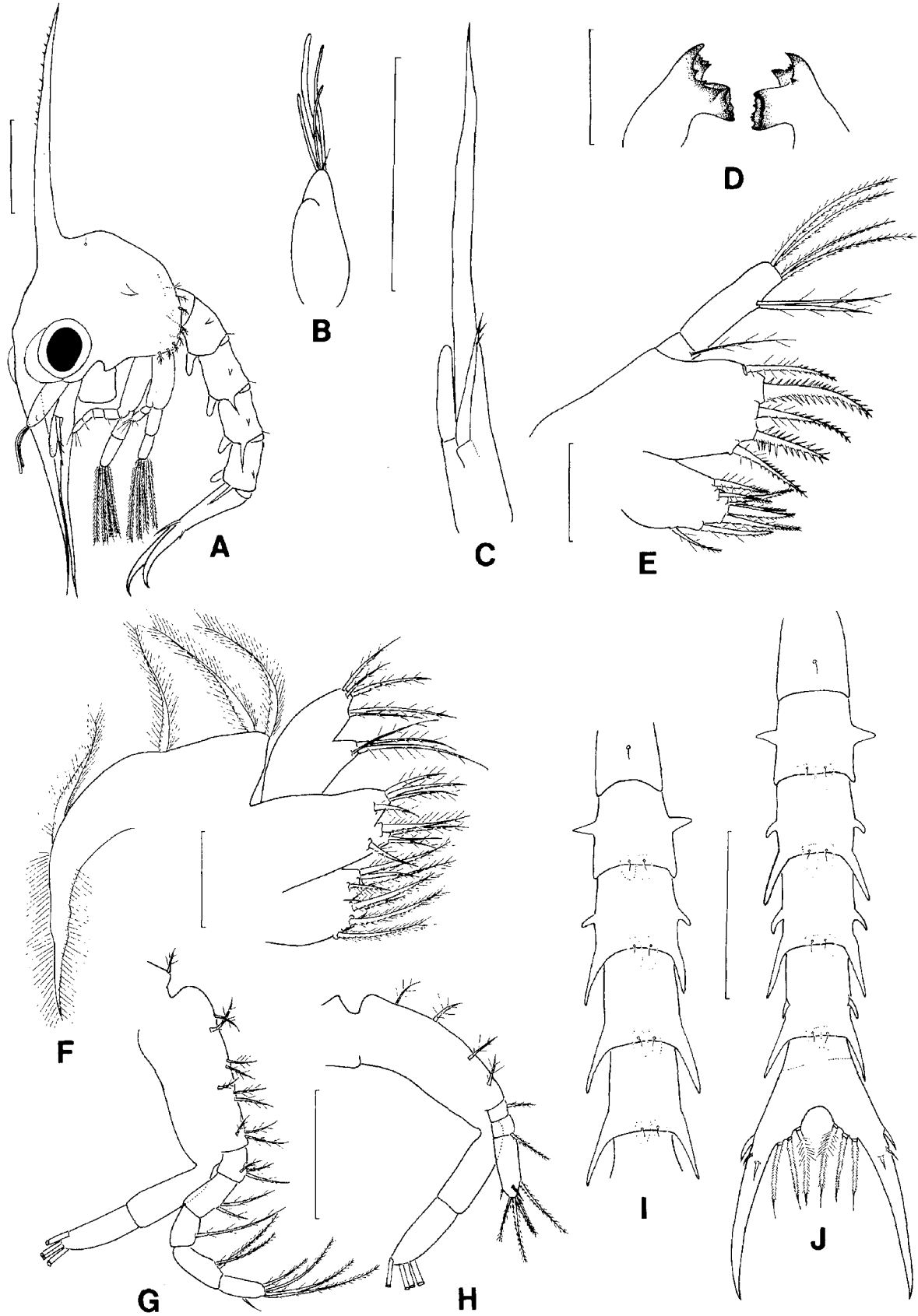


Fig. 1. *Novactaea pulchella*, first zoeal stage. A, Lateral view. B, Antennule. C, Antenna. D, Mandibles. E, Maxillule. F, Maxilla. G, First maxilliped. H, Second maxilliped. I, Dorsal view of abdomen. J, Dorsal view of abdomen and telson. Scale bars = 0.5 mm (A-C, G-J), 0.1 mm (E, F) and 0.25 mm (D).

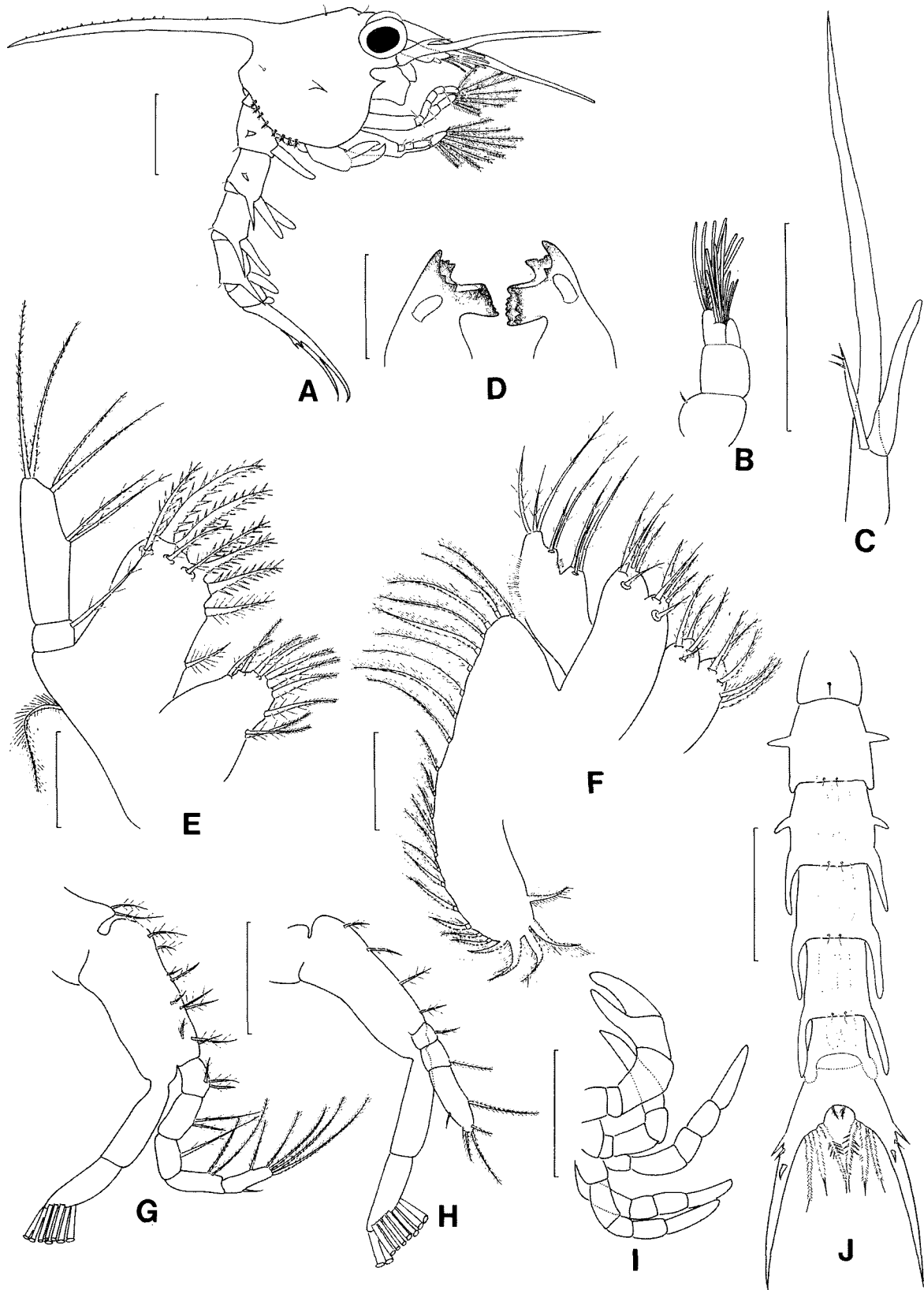


Fig. 2. *Novactaea pulchella*, second zoeal stage. A, Lateral view. B, Antennule. C, Antenna. D, Mandibles. E, Maxillule. F, Maxilla. G, First maxilliped. H, Second maxilliped. I, Pereiopods. J, Dorsal view of abdomen and telson. Scale bars = 0.5 mm (A-C, G-J), 0.1 mm (E, F) and 0.25 mm (D).

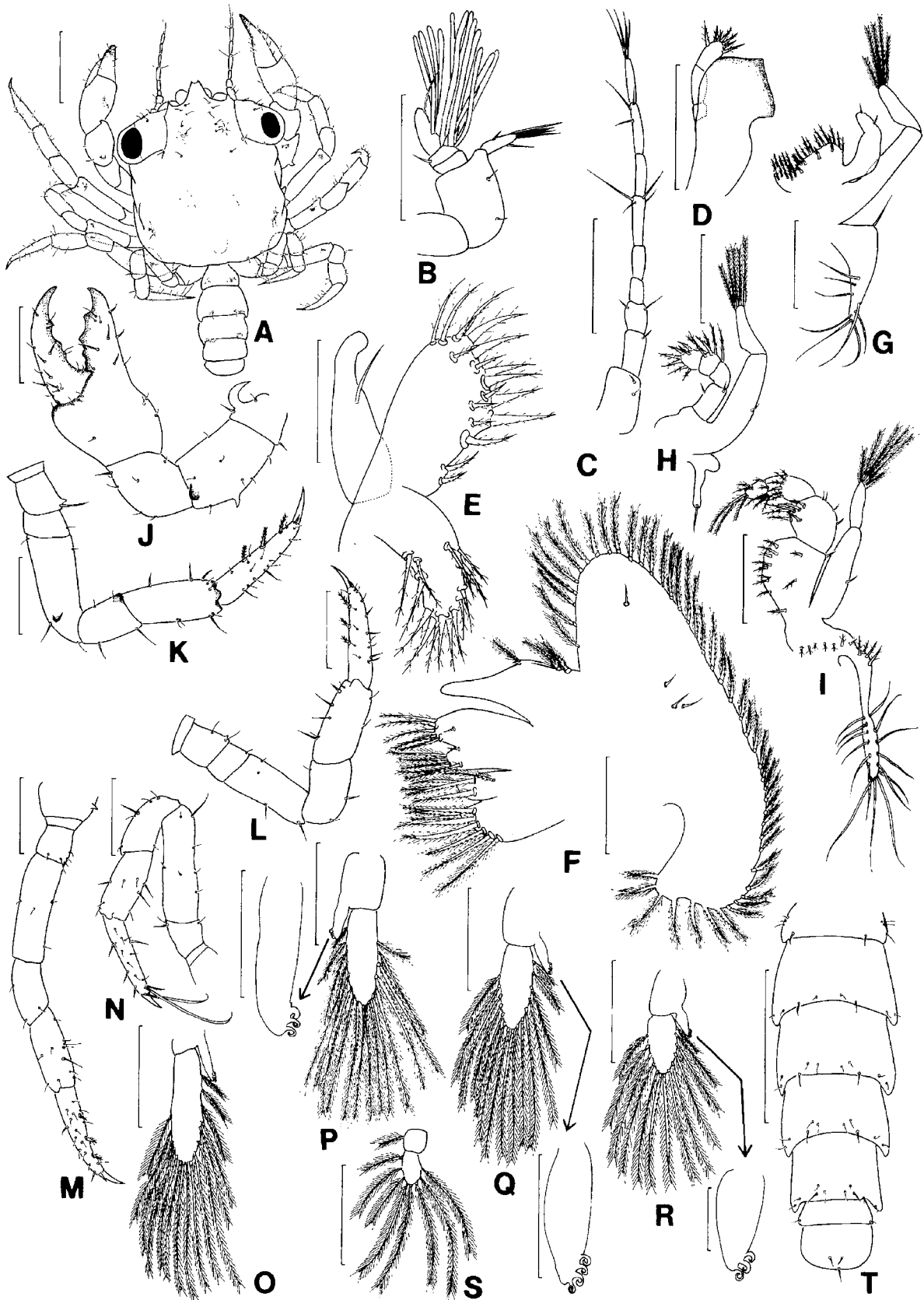


Fig. 3. *Novactaea pulchella*, megalopal stage. A, Dorsal view. B, Antennule. C, Antenna. D, Mandible. E, Maxillule. F, Maxilla. G, First maxilliped. H, Second maxilliped. I, Third maxilliped. J, Chela. K-N, Pereiopods 2-5. O-S, Pleopods 1-5. T, Dorsal view of abdomen and telson. Scale bars = 0.5 mm (A, T), 0.1 mm (E, F) and 0.25 mm (B-D, G-S).

Third maxilliped (Fig. 3I). Epipod with 15 long simple setae and 11 proximal shorter setae; coxa and basis not differentiated; endopod 5-segmented, with 12, 10, 6, 5, and 5 setae; exopod 2-segmented, proximal segment with 1 medial seta, distal segment with 6 long terminal plumose feeding setae.

Chela (Fig. 3J). Propodus with a few small setae; tip slightly hooked; inner margins of immovable and movable fingers each with 4 and 3 elevations.

Pereiopods 2-5 (Fig. 3K-N). All segments well differentiated and sparsely armed with setae; dactylus sharp pointed.

Pleopods (Fig. 3O-S). Endopod with 3 or 4 hooks; pleopods 1-5 each with 16, 17, 15, 13, and 8 plumose setae on distal segment.

Abdomen and telson (Fig. 3T). Abdomen 6-segmented, with a few of small setae on surface; broad, rounded telson with 2 posterodorsal setae and 1 posteromarginal seta.

DISCUSSION

The zoeas of *N. pulchella* observed in the present study slightly differs from that described for the same species by Terada (1990) according to Table 1. It could be resulted from his overlooking the setae of the carapace, the maxilla, the coxa of a first maxilliped and the first abdominal somite. Also, he did not provide any descriptions and figures about the mandibles. The unusual thing is that the zoeas of *N. pulchella* share two types of lateral abdominal processes, that is, either on somites 2 and 3 or on somites 2 to 5 (Fig. 1I, J). The former takes 62% and 50% of observed specimens (total 30 specimens in each zoeal stage) in the first and second zoeas, respectively. As far as the author has known, any brachyuran zoeas have not shown two types of lateral abdominal processes in a species. It is the first report that two types of lateral abdominal processes are found in the brachyuran zoeas belonging to a species.

Most of brachyuran larval researchers have recognized the lateral abdominal process as an important character (Aikawa, 1929, 1933, 1937; Lebour, 1944; Wear, 1968; Rice, 1980; Martin, 1984). It had been considered even in the classification of the adult crabs, for example, Davie (1989) redefined the genera *Heteropanope* Stimpson, 1858, and *Pilumnopus* A. Milne Edwards, 1863, of the family Pilumnidae (superfamily Xanthoidea) and established the new genus *Benthopanope* Davie, 1989, based on the adult and larval characters such as carapace spines, lateral abdominal processes and zoeal stages. He found that the lateral abdominal processes of the new genus present on somite 2 only, whereas, they are on somites 2 and 3 in the *Heteropanope* and *Pilumnopus*.

Further, 16 known zoeas of xanthid crabs always have

Table 1. Differences in the zoeas of *Novactaea pulchella* as described by Terada (1990) and in the present study

Characters	Terada (1990)	Present study
ZOEA I		
Carapace		
dorsal spine	naked	with minute spinules
lateral expansion	naked	with 7 marginal setae
posterodorsal	without seta	with a pair of setae
Antennule		
terminal	with 3 aesthetascs	with 4 aesthetascs
Mandibles	no description	asymmetrical
Maxilla		
basial endite	with 8 setae	with 9 setae
Maxilliped I		
coxa	no description	with a seta
Maxilliped II		
coxa	no description	without seta
Abdomen		
somite 1	naked	with a dorsomedial seta
lateral processes	on somites 2-5	on somites 2-5 or somites 2, 3
ZOEA II		
Carapace		
lateral expansion	naked	with 8 marginal setae
anterodorsal	without seta	with 2 pairs of setae

lateral abdominal processes on somites 2 and 3: *Cycloxanthops truncatus* (De Haan, 1837) by Hong (1977), *Atergatus reticulatus* De Haan, 1833, *Macromedaeus distinguendus* (De Haan, 1835), *Leptodius exaratus* (H. Milne Edwards, 1834), *Pilodius nigrocrinitus* Stimpson, 1858, *Calvactaea tumida* Ward, 1933, *Medaeops granulipes* (Haswell, 1882), *Paraxanthias elegans* (Stimpson, 1858) by Terada (1980, 1982, 1987, 1988, 1990), *Xantho incisus* Leach, 1814, and *X. pilipes* A. Milne Edwards, 1867, by Ingle (1991), *X. poressa* (Olivi, 1792) by Rodriguez and Martin (1997), *Gaillardiiellus orientalis* by Ko (1999), *Actaea semblatae* by Ko et al. (2002), *Nanocassiope granulipes* (Sakai, 1939) by Ko and Clark (2002), *Palapedia valentini* Ng, 1993, by Clark and Ng (1998), and *P. integra* (De Haan, 1835) by Ko et al. (2004). Concerning the lateral abdominal processes on somites 2-5, Rice (1980) described them as an ancestral brachyuran characteristic and reported that the derived structure included a reduction in the number of somites carrying lateral processes. Hence, existence of two types of zoea with different lateral abdominal process in a species may be caused by a retention of the primitive characteristic. Actually, the type locality of *N. pulchella* (A. Milne Edwards, 1865) was Reunion Island in the Indian Ocean. Guinot (1976) tentatively assigned Japanese species by Sakai (1976) to *N. pulchella* when she established the new genus *Novactaea* Guinot, 1976, from the *Actaea* De Haan,

1833. Consequently, to know species status of *N. pulchella*, comparative studies of larvae and adult crabs from Reunion Island, Japan, and Korea are needed.

In the subfamily Actaeinae the larval descriptions of four species are available, *Actaea semblatae*, *Gaillardiiellus orientalis*, *Novactaea bella*, and *N. pulchella* (see Fukuda, 1978; Ko, 1999; Ko et al., 2002; Lim and Ng, 1997; Terada, 1987, 1990). The common characteristics of them can be summarized as followings: carapace with all spines; endopod of maxillule with 1, 2 + 4 setae; endopod of maxilla with 3 + 5 setae; basis and endopod of first maxillipeds each with 10 and 3, 2, 1, 2, 5 setae; basis and endopod of second maxillipeds each with 4 and 1, 1, 6 setae; lateral abdominal processes on somites 2 and 3 (occasionally except in *N. pulchella*). However, they differ in characteristics of the antenna and the telson. The following provisional key is for the rapid identification of the actaeine zoeae in Korea and the adjacent seas. The characteristics employed are consistent during the zoeal development.

1. Tip of antennal protopod is rounded tip ----- 2
- Tip of antennal protopod is spinous process -----
----- *Novactaea pulchella*
2. Exopod of antenna is less than 20% length to protopod
and with setae ----- 3
-Exopod of antenna is as 1 seta ----- *Actaea semblatae*
3. Fork of telson is naked ----- *Novactaea bella*
-Fork of telson is with 3 or 4 setae -----
----- *Gaillardiiellus orientalis*

ACKNOWLEDGMENT

The author thanks Miss Se Jin Ok for help with drawings.

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[Received January 20, 2006; accepted March 15, 2006]