

Larval Development of *Parapilumnus trispinosus* Sakai, 1965 (Crustacea, Brachyura, Xanthidae) Reared in the Laboratory

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The larval development of *Parapilumnus trispinosus* Sakai, 1965 completed in the laboratory consisted of four zoeal stages and one megalopal stage. Completion of the larval development required at least 18 days at 20-25°C. The morphology of the larvae of each stage is described in detail, and comparisons are made with larvae of other 11 species of the subfamily Pilumninae. Although, the zoeae of the subfamily Pilumninae show almost consistent characteristics of the mouthpart appendages, in the characteristics of the carapace spines and the abdominal lateral knobs they can be divided into five groups: (1) the genera *Heteropanope* and *Heteropilumnus*, (2) the genera *Actumnus* and *Pilumnus*, (3) *Pilumnopeus makiana* and *P. serratifrons*, (4) *Parapilumnus trispinosus*, and (5) *Pilumnopeus eucratoides* and *P. indica*.

KEY WORDS: Larval development, Xanthidae, Pilumninae, *Parapilumnus trispinosus*

Crabs of *Parapilumnus trispinosus* inhabit in the rocky beaches covered with the sea weed, *Ulva pertusa*. The distribution of this crab is known from Japan and Korea (Kim and Kim, 1982)

The family Xanthidae is a very large family containing over 130 genera and almost 1000 species (Rice, 1980). Within this family, 17 genera and 22 species of crabs are listed in Korea (Kim, 1973; Kim and Kim, 1982) and the subfamily Pilumninae is represented by the genera *Pilumnus*, *Heteropilumnus*, *Actumnus*, *Pilumnopeus* and *Parapilumnus*. Among the Korean species of this subfamily, the complete larval development is studied for only *Pilumnopeus indica* (Ko, unpublished). In the world, the complete larval stages of *Heteropanope glabra*, *Pilumnus dasypodus*, *P. hirtellus*, *P. vespertilio* and *Pilumnopeus*

eucratoides have been described (Lim *et al.*, 1984, 1986; Sandifer, 1974; Salman, 1982; Lim and Tan, 1981). The zoeal stages of *Pilumnopeus serratifrons* and *P. makiana* have been described (Green and Fielder, 1984; Lee, 1993). *Actumnus setifer*, *Heteropilumnus ciliatus*, and *Pilumnus minutus* have been described only for the first zoeal stage (Aikawa, 1929, 1937; Takeda and Miyake, 1968). However, any larval stages of *Parapilumnus trispinosus* have been unknown so far.

The purpose of the present paper is (1) to describe the complete larval development of *Parapilumnus trispinosus*; (2) to compare it with the previously described larvae of Pilumninae; and (3) to discuss the phylogenetic relationship of the genus *Parapilumnus* based on the larval morphology.

Materials and Methods

In June, 1993, an ovigerous female of *Parapilumnus trispinosus* was collected from a rocky beach on Cheju Island, Korea. In the laboratory, it was placed in an aquarium containing sea water with salinity 33.3‰ under room temperature ranging 20-25°C. When the larvae hatched, some were immediately preserved in 10% neutral formalin for later use. The larvae showing the greatest activity were reared individually in the 24 polystyrene cell wells. They were fed on *Brachionus* sp. and newly hatched *Artemia* nauplii every day. Daily the larvae were moved into new wells with freshly filtered sea water.

Specimens and exuviae of each developmental stage were preserved in 10% neutral formalin to check the setation of the appendages. Drawings were made with the help of a camera lucida, and measurements were based on the mean of 10 specimens in each zoeal stage. The chromatophore patterns were determined by observation of living larvae.

Results

Four zoeal stages and one megalopal stage were recognized.

First Zoea (Fig. 1)

Size. Carapace length 0.51 mm. Distance from tip of dorsal spine to tip of rostral spine 0.77 mm.

Carapace (Fig. 1A). Dorsal spine slightly curved with minute spinules and longer than vestigial rostral spine. Lateral spines absent.

Antennule (Fig. 1B) with 3 aesthetascs, a small simple seta and 2 hairs.

Antenna (Fig. 1C). Exopodite about equal in length to spinous process, armed with a number of small spinules distally, and with a prominent outer spine and a smaller spine about half-way along its length.

Mandibles (Fig. 1D) asymmetrical: right molar process with 3 teeth and left molar process with a

tooth which join margin of incisor process. Right and left molar processes irregularly dentate.

Maxillule (Fig. 1E). Endopodite 2-segmented: distal segment with 4 terminal and 2 subterminal plumodenticulate setae; proximal segment with a plumodenticulate seta as well. Basal and coxal endites with 5 and 7 plumodenticulate setae, respectively.

Maxilla (Fig. 1F). Endopodite 2-lobed, with 5 and 3 plumodenticulate setae, respectively. Basal and coxal endites with 9 and 10 plumodenticulate setae, respectively. Scaphognathite bearing 4 marginal plumose setae and a terminal process.

First maxilliped (Fig. 1A, G). Basipodite with 2, 2, 3 and 3 plumodenticulate setae, endopodite 5-segmented with 3, 2, 1, 2 and 1+4 plumodenticulate setae on each segment, increasing distally. Exopodite with 4 plumose natatory setae.

Second maxilliped (Fig. 1A, H). Basipodite with 4 plumodenticulate setae. Endopodite 3-segmented with 1, 1 and 6 plumodenticulate setae, increasing distally. Exopodite with 4 plumose natatory setae.

Abdomen (Fig. 1A, I) composed of 5 somites; somites 2-5 each with small lateral knobs, a pair of fine short setae and minute spinules on postero-dorsal border.

Telson (Fig. 1A, I) with 3 setae (long lateral, short lateral and short dorsal) on each side at base of fork. Inner margin with 3 pairs of denticulate setae. Fork surface covered with minute spinules.

Chromatophore (Fig. 1A) predominantly orange, but varied from yellow to red with variable brown spots. These occur on bases of antenna, labrum and mandible, behind and between eyes, on abdominal somites 1-4 and telson, on basipodites of first and second maxillipeds and at base of dorsal spine.

Second Zoea (Fig. 2)

Size. Carapace length 0.62 mm. Distance between tip of dorsal spine to tip of rostral spine 0.90 mm.

Carapace (Fig. 2A) with 2 plumose setae on postero-lateral border.

Antennule (Fig. 2B) with 5 aesthetascs, a simple seta and a hair.

Antenna (Fig. 2C). Endopodite as small basal

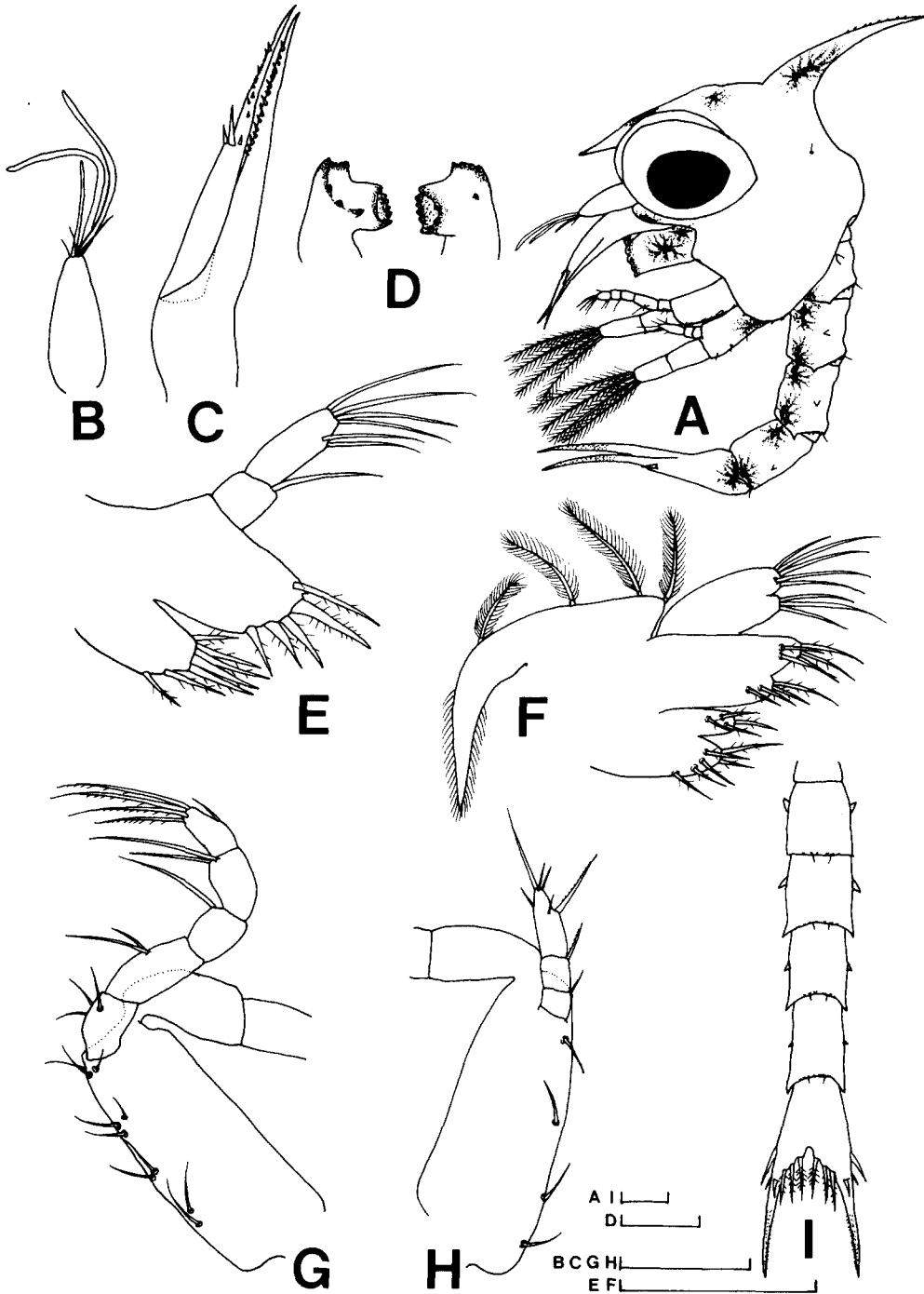


Fig. 1. *Parapilumnus trispinosus* Sakai, first zoeal stage: A, lateral view; B, antennule; C, antenna; D, mandibles; E, maxillule; F, maxilla; G, first maxilliped; H, second maxilliped; I, dorsal view of abdomen and telson. Scale bars=0.1 mm.

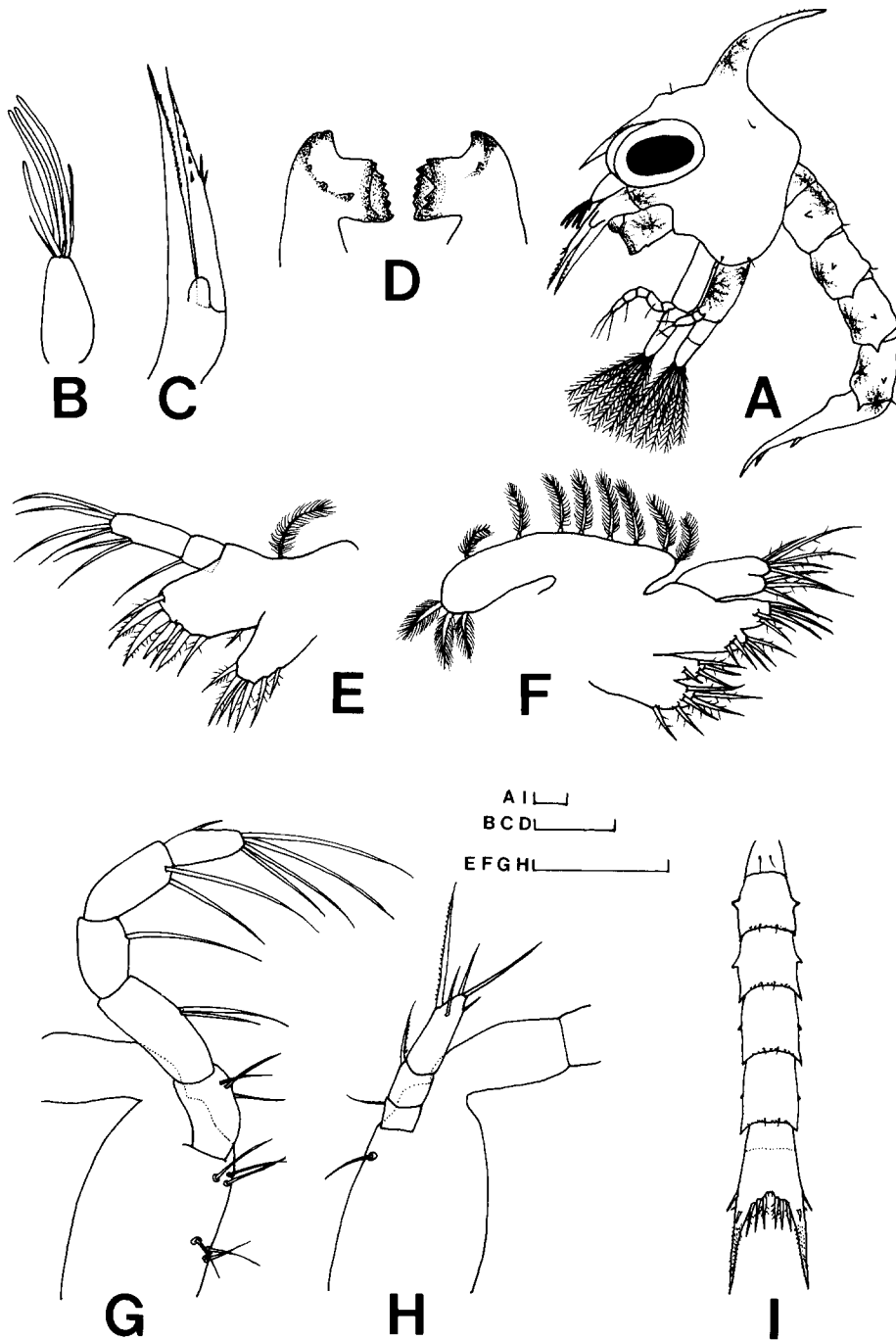


Fig. 2. *Parapilumnus trispinosus* Sakai, second zoal stage: A, lateral view; B, antennule; C, antenna; D, mandibles; E, maxillule; F, maxilla; G, first maxilliped; H, second maxilliped; I, dorsal view of abdomen and telson. Scale bars=0.1 mm.

protuberance.

Maxillule (Fig. 2E). Basal endite with 8 plumodenticulate setae.

Disto-lateral margin with a plumose seta.

Maxilla (Fig. 2F). Basal endite with 10 plumodenticulate setae. Scaphognathite with 8 marginal and 3 terminal plumose setae.

First and second maxillipeds (Fig. 2A) both with 6 plumose natatory setae.

Abdomen (Fig. 2A, I). First somite with 2 dorsal setae. Sixth somite incompletely segmented.

Telson (Fig. 2I). Inner margin with 4 pairs of denticulate setae.

Third Zoea (Fig. 3)

Size. Carapace length 0.75 mm. Distance between tip of dorsal spine to tip of rostral spine 1.05 mm.

Carapace (Fig. 3A) with 5 plumose setae on postero-lateral carapace border. Buds of thoracic appendages underneath carapace visible through.

Antennule (Fig. 3B) with 4 aesthetascs (1 + 3 aesthetascs, increasing distally) and a terminal seta.

Antenna (Fig. 3C). Endopodite more developed than that of previous stage.

Maxillule (Fig. 3E). Basal endite with 9 plumodenticulate setae. A seta present on proximo-lateral margin.

Maxilla (Fig. 3F). Basal endite with 11 plumodenticulate setae. Scaphognathite with 18 plumose setae.

First maxilliped (Fig. 3A, G). Endopodite with 3, 2, 1, 2 and 2+4 plumodenticulate setae. Exopodite with 8 plumose natatory setae.

Second maxilliped (Fig. 3A). Exopodite with 8 plumose natatory setae.

Abdomen and telson (Fig. 3I). Abdomen composed of 6 somites, somites 2-6 with pleopod buds.

Fourth Zoea (Fig. 4)

Size. Carapace length 0.89 mm. Distance between tip of dorsal spine to tip of rostral spine 1.21 mm.

Carapace (Fig. 4A) with 6 plumose setae on postero-lateral border. Thoracic appendage more developed than that of previous stage.

Antennule (Fig. 4B) with 10 aesthetascs (1, 5 and 4 aesthetascs increasing distally) and a terminal seta. Endopodite present.

Maxillule (Fig. 4E). Basal and coxal endites each with 10 and 9 plumodenticulate setae, respectively.

Maxilla (Fig. 4F). Basal endite with 12 plumodenticulate setae. Scaphognathite with 24 plumose setae.

First and second maxillipeds (Fig. 4A). Exopodites with 10 plumose natatory setae.

Abdomen (Fig. 4A, I). Pleopod buds more developed than those of previous stage.

Megalopa (Fig. 5)

Size. Carapace length 1.06 mm. Carapace width 0.80 mm.

Carapace (Fig. 5A) subquadrate, with 2 anterior-gastric lateral carapace and 2 posterior-gastric lateral tubercles. On anterior border with 2 preorbital spines.

Abdomen (Fig. 5A) composed of 6 somites.

Antennule (Fig. 5B). Exopodite 4-segmented with total of 8 aesthetascs, segment 3 with 3 setae and segment 4 with 2 terminal setae. Endopodite with 4 terminal and a subterminal setae.

Antenna (Fig. 5C) composed of 10 segments, with 2, 1, 1, 0, 0, 0, 5, 0, 3, and 4 setae, increasing distally.

Mandible (Fig. 5D). Palp 2-segmented with 8 setae on distal segment.

Maxillule (Fig. 5E). Endopodite 2-segmented bearing 4 terminal and 2 subterminal plumodenticulate setae. Basal and coxal endites with 18 and 14 plumodenticulate setae, respectively.

Maxilla (Fig. 5F). Endopodite with 3 marginal and a terminal plumodenticulate setae. Basal and coxal endites with 15 and 11 plumodenticulate setae, respectively. Scaphognathite bearing 41 marginal plumose setae and 3 plumodenticulate surface setae.

First maxilliped (Fig. 5G). Endopodite with 2 plumodenticulate setae. Basal and coxal endites each with 16 and 8 plumodenticulate setae, respectively. Exopodite 3-segmented, proximal segment with 2 plumose setae and distal segment with 5 plumose setae.

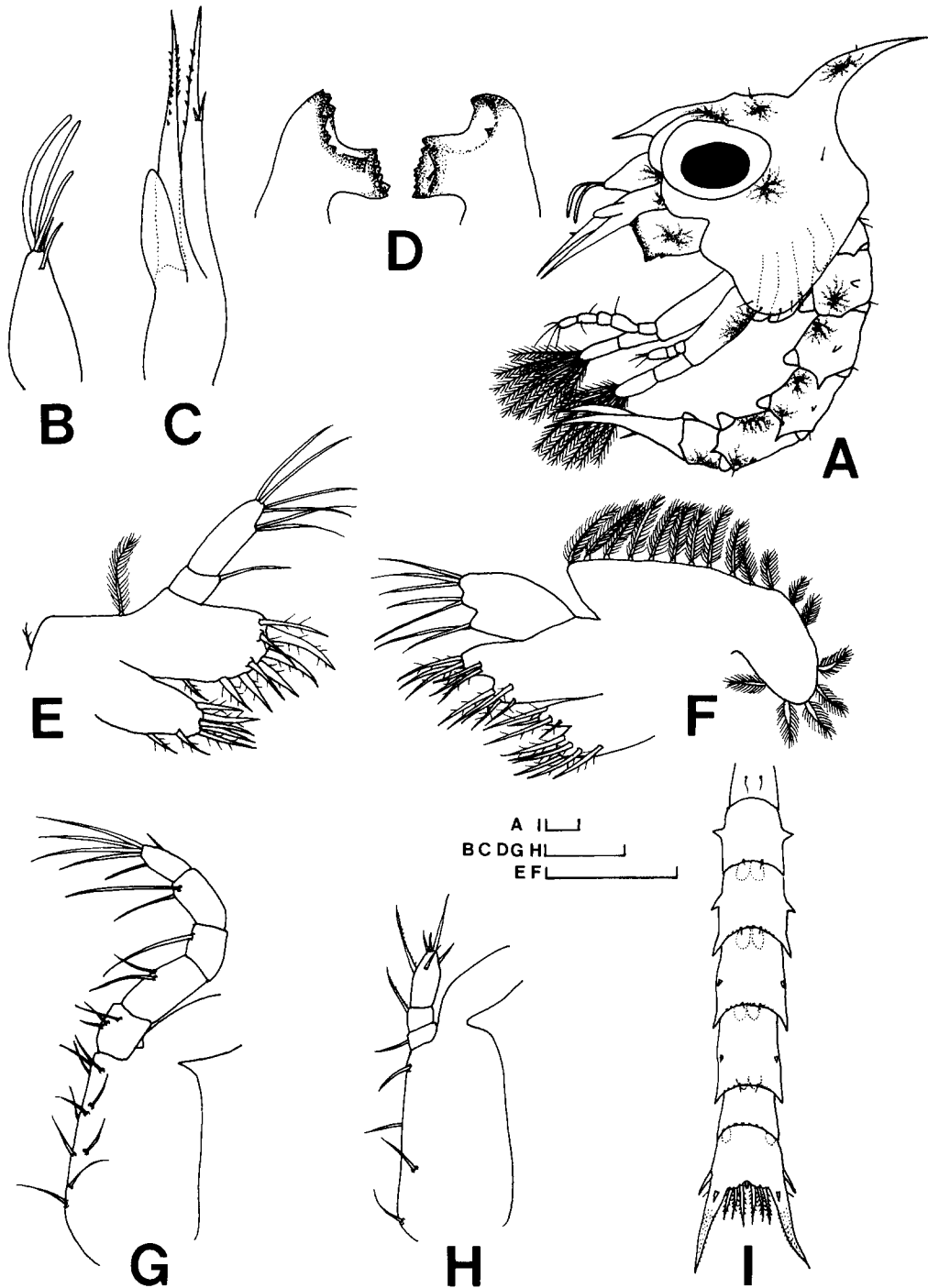


Fig. 3. *Parapilumnus trispinosus* Sakai, third zoeal stage: A, lateral view; B, antennule; C, antenna; D, mandibles; E, maxillule; F, maxilla; G, first maxilliped; H, second maxilliped; I, dorsal view of abdomen and telson. Scale bars=0.1 mm.

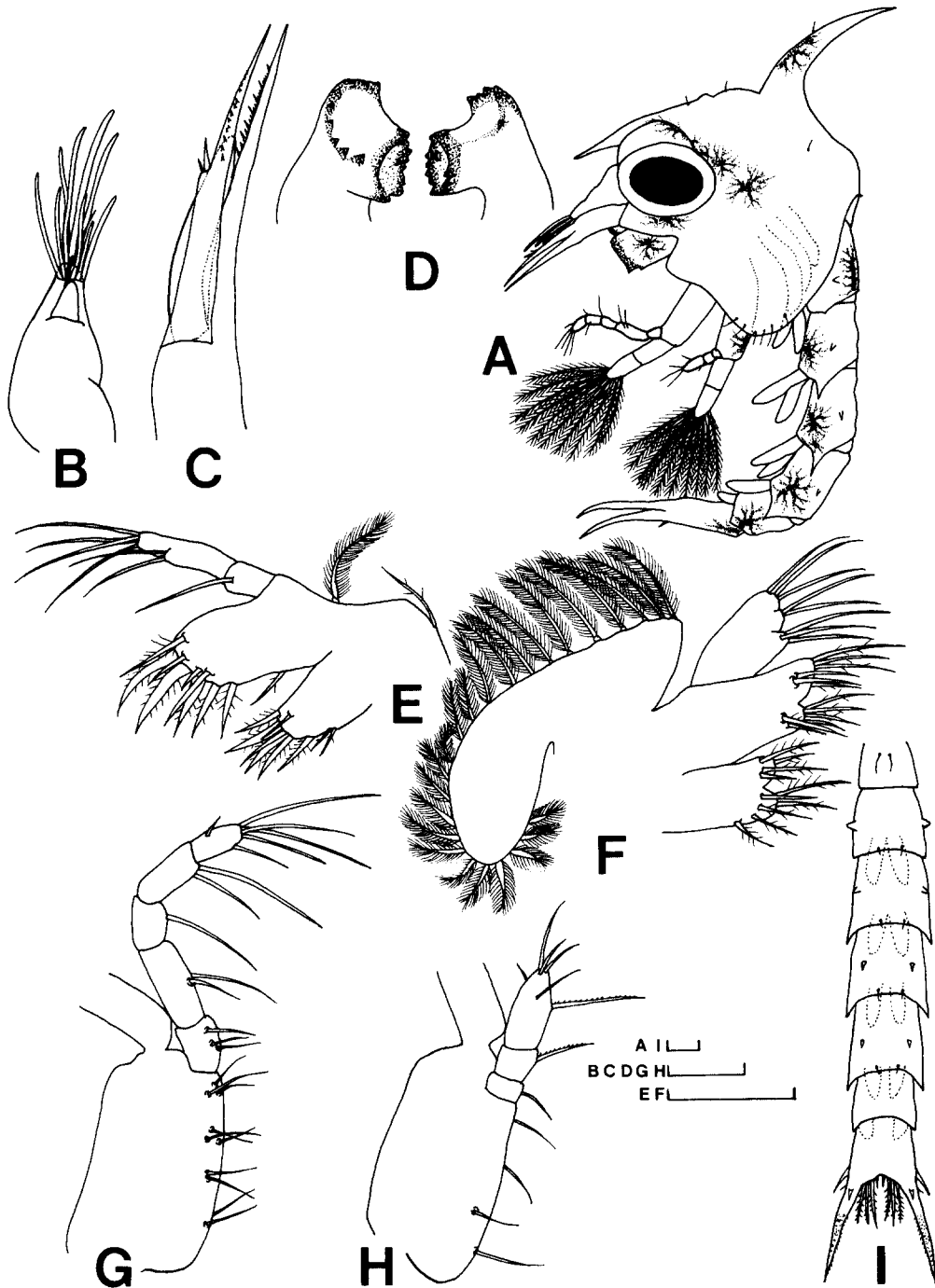


Fig. 4. *Parapilumnus trispinosus* Sakai, fourth zoeal stage: A, lateral view; B, antennule; C, antenna; D, mandibles; E, maxillule; F, maxilla; G, first maxilliped; H, second maxilliped; I, dorsal view of abdomen and telson. Scale bars=0.1 mm.

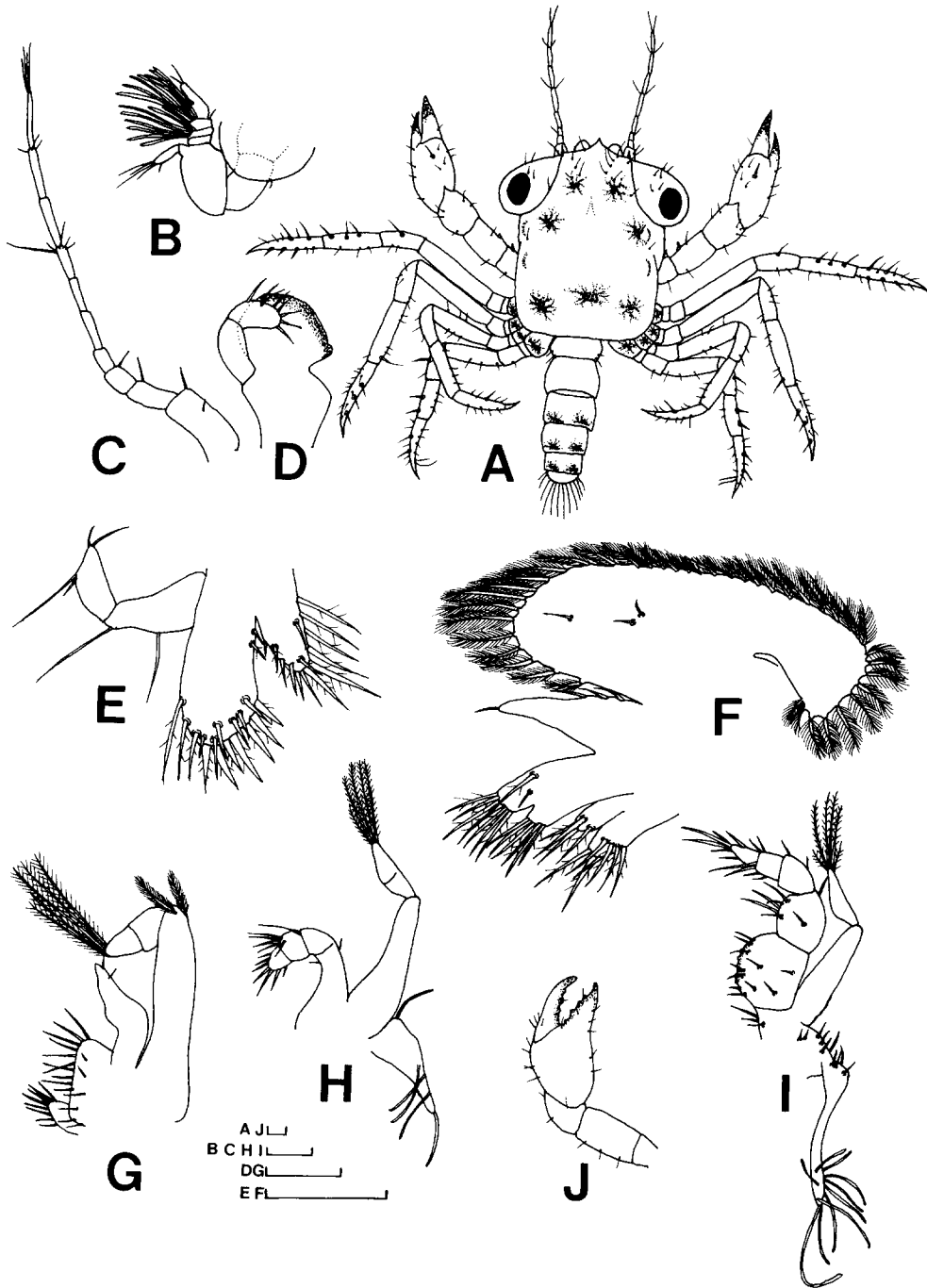


Fig. 5. *Parapilumnus trispinosus* Sakai, megalopal stage: A, dorsal view; B, antennule; C, antenna; D, mandible; E, maxillule; F, maxilla; G, first maxilliped; H, second maxilliped; I, third maxilliped; J, chela. Scale bars=0.1 mm.

Second maxilliped (Fig. 5H). Endopodite 4-segmented with 2,1,5 and 7 plumodenticulate setae, increasing distally. Exopodite incompletely 3-segmented with 5 plumose setae on terminal segment. Epipodite with 5 long, curved simple setae.

Third maxilliped (Fig. 5I). Endopodite 5-segmented with 12,6,6,10 and 6 plumodenticulate setae, increasing distally. Exopodite 2-segmented with 6 plumose setae on distal segment. Epipodite with 10 long, curved simple setae.

Chela (Fig. 5J). Propodus with a few small teeth on cutting edge; tip slightly hooked.

The life span of zoeal stages and survival rate in the cultures are shown in Fig. 6. A small number of megalopa molted into young crab. Completion of larval stages required at least 18 days.

Discussion

The characteristics of the zoeae of Pilumninae are as follows: the exopodite of the antenna is more or less equal in length to the spinous process, armed with a number of small spinules distally and with a prominent outer spine about half-way along its length; the distal segment of the

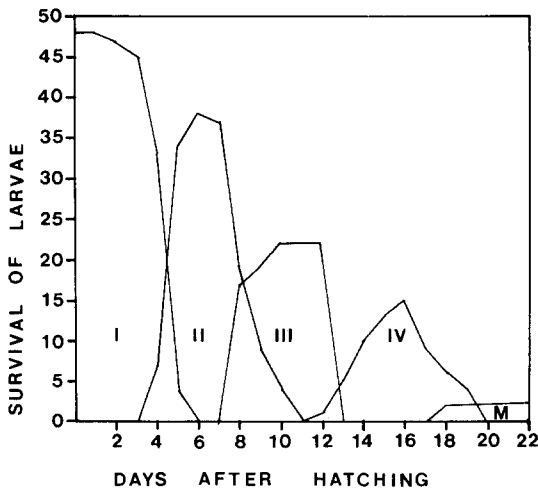


Fig. 6. Life span and survival of larval stages of *Parapilumnus trispinosus* reared in the laboratory at 20-25°C and 33.3‰ salinity. Roman numerals represents zoeal stages I-IV, and M, megalopa.

endopodite of the maxillule always carries six setae of which two are subterminal; the endopodite of the maxilla always bears eight setae; the basal segment of the endopodite of the first maxilliped always carries three setae (with only one exception: it is two setae in *Pilumnus vespertilio*) and that of the second maxilliped a single seta.

In other zoeal characters, such as the carapace spines and the lateral abdominal knobs, the Pilumninae zoeae are much more variable than the other xanthids as shown in Table 1: the dorsal spines are long and straight, slightly curved or hook shape; the rostral spines are long, short or vestigial; the lateral spines are present or absent; the abdominal lateral knobs are on somite 2 and occasionally on somites 3, 4, and 5.

Wear (1970) divided the xanthid zoeae into two groups: those with a vestigial antennal exopodite (subfamily Xanthinae), and those with a well-developed antennal exopodite (subfamilies Menippinae, Pilumninae and Trapeziinae). Also, he suggested the third group, which was characterized by the reduced rostral carapace spines, including the genera *Heteropanope* and *Pilumnopeus*. According to Wear's viewpoint, the genus *Parapilumnus* may belong to the Wear's third group because of having a short rostral spine. However, the rostral spine seems to be inadequate for a zoeal character in Pilumninae. This feature is much variable with the species even within the genus *Pilumnopeus*.

The present author suggests the five groups of Pilumninae zoeae in the characteristics of the carapace spines and abdominal lateral knobs:

- (1) the genera *Heteropanope* and *Heteropilumnus*,
- (2) the genera *Actumnus* and *Pilumnus*,
- (3) *Pilumnopeus makiana* and *P. serratifrons*,
- (4) *Parapilumnus trispinosus*, and
- (5) *Pilumnopeus eucratodes* and *P. indica*.

Rice (1980) reported that the genus *Pilumnopeus* should be recognized as advanced members of Pilumninae because of short or lack of carapace spines and reduced abdominal lateral knobs. In fact this subfamily includes a wide range of zoeal evolutionary development. But, it was revealed that the present author's fifth group (*Pilumnopeus eucratoides* and *P. indica*) is more

6. Abdominal somites 3 and 4 with lateral knobs
*Pilumnus minutus*
 –Abdominal somites 2 and 3 with lateral knobs
7
7. Rostral spine nearly as long as antenna
*Pilumnus hirtellus*
 –Rostral spine about half as long as antenna
*Pilumnus dasypodus*
8. Carapace with slightly curved or hooked dorsal spine; no lateral spine; abdominal somites 2,3,4 and 5 with lateral knobs

Parapilumnus trispinosus
 –Carapace with slightly curved or hooked dorsal spine; no lateral spine; abdominal somite 2 with lateral knobs9
9. Rostral spine vestigial*Pilumnopeus indica*
 –Rostral spine shorter or nearly as long as antenna*Pilumnopeus eucratoides*

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세가지부채계(갑각강, 단미목, 부채계과)의 유생발생
고현숙(부산여자대학교 자연과학대학 생물학과)

실험실에서 사육된 세가지부채계의 유생은 4 zoea기와 1 megalopa기를 가졌고, 유생기를 완료하는데 20-25°C 수온에서 최저 18일이 걸렸다. 각 유생기의 형태적 특징을 상세히 기록, 도시하고 Pilumninae 아과의 이미 보고된 11종의 제 1 zoea유생과 그 특징을 비교하였다.

Pilumninae 아과의 zoea들은 구부부속지의 특징에서 별차이가 없었으나 갑각극과 복부의 측돌기에 의거하여 5무리로 나눌수가 있었다.

- (1) *Heteropanpope* 와 *Heteropilumnus* 속
- (2) *Actumnus* 와 *Pilumnus* 속
- (3) *Pilumnopeus makiana* 와 *P. serratifrons*
- (4) *Parapilumnus trispinosus*
- (5) *Pilumnopeus eucratodes* 와 *P. indica*.

(*Pilumnopeus*) *serratifrons* (Kinnahan 1856). New Zealand Journ. Mar. Freshwater Res. **2**: 293-332.

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