

## Complete larval development of *Pyromaia tuberculata* (Crustacea: Decapoda: Majoidea: Inachoididae)

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The introduced spider crab *Pyromaia tuberculata* was collected from Korea in 2005 and it was ovigerous. After hatching, larvae were reared in the laboratory at 20°C. The larval stage of the species consists of two zoeal and one megalopal stages. The larvae of the Korean species differ somewhat from those from New Zealand described by Webber and Wear (1981; N Z J Mar Freshwat Res. 15:331–383) and from Brazil described by Fransozo and Negreiros-Fransozo (1997; Crustaceana. 70:304–323.) in the setal presence of the antennule, the maxillule, the maxilla and the maxillipeds, and the abdomen. It is found that Fransozo and Negreiros-Fransozo have overlooked some setae on the basis of the zoeal maxillipeds and that re-examination of their larvae is needed. Also, it is found that the Inachoididae is heterogeneous based on the zoeal morphology because two distinct groups exist in the family.

**Keywords:** introduced crab; Inachoididae; *Pyromaia tuberculata*; zoea; megalopa; Korea

### Introduction

The spider crab *Pyromaia tuberculata* (Lockington 1877) lives under the rocks in the intertidal zone of sheltered bays and on pilings (Jensen 1995). It was originally distributed along the American Pacific coast from California to Colombia (Garth 1958). Recently, colonization by introduced populations of this species has been found in Japan (Sakai 1976; Furota and Furuse 1988), New Zealand (Webber and Wear 1981) and Brazil (Melo 1985). In Korean waters two adult specimens were first discovered at Jukbyeon, Uljin in 1982 (Kim 1985).

The family Inachoididae Dana, 1851 contains 38 species of ten genera (Ng et al. 2008); however, larval descriptions of only three species have been reported: *Anasimus latus* Rathbun, 1894, *Pyromaia tuberculata* and *Paradasygyius depressus* (Bell 1835) (see Sandifer and Van Engel 1972; Webber and Wear 1981; Fransozo and Negreiros-Fransozo 1997; Pohle and Marques 2000).

Although the first zoeal and the complete larval stages of *P. tuberculata* have been described by Webber and Wear (1981) and Fransozo and Negreiros-Fransozo (1997), respectively, their reports are limited to brief comments and illustrations of them. Therefore, the aims of this paper are to provide a detailed description of the complete larval stage in

*P. tuberculata* and provide a key for the identification of three known zoeae of the family Inachoididae.

### Materials and methods

An ovigerous female of *Pyromaia tuberculata* was collected from Gijang (35°19'N; 129°17'E), Busan, Korea, on 15 September 2005. The larvae collected from the laboratory were reared using methods described by Ko (1995) at a constant water temperature of 20°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 ten specimens for the larval stage. The sequence of the larval description was based on the malacostracan somite plan and describes from anterior to posterior (Clark et al. 1998). Setal armature on appendages was described from proximal to distal segments and in order of endopod to exopod. The long plumose natatory setae of the first and second maxillipeds were drawn truncated. A micrometer was used for measurements: CL (carapace length) was from the base of the rostral spine to the most posterior carapace margin and CW (carapace width) was across the widest part of the carapace. The classification follows that of Ng et al.

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(2008). The larvae and the spent females were deposited in Silla University, Korea (SUZ Cr103245).

## Results

The larval stage of *Pyromaia tuberculata* consists of two zoeal and one megalopal stages. The minimum durations of the zoeal stages I and II at 20°C were 5 and 8 days, respectively. Metamorphosis to the megalopa occurred from 14 days after the first-stage zoeae 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 (Figure 1)

Size. CL  $0.71 \pm 0.05$  mm.

Carapace (Figure 1A,E). Dorsal spine long; rostral and lateral spines absent; pairs of anterodorsal and posterodorsal setae present; each ventral margin with five setae; eyes stalked.

Antennule (Figure 1B). Endopod bud absent; exopod with four (two long and two shorter) terminal aesthetascs and one short terminal seta.

Antenna (Figure 1C). Endopod bud present; protopod long, without spinules, its tip blunt; exopod about 2/3 in length to protopod, with two medial setae.

Mandibles (Figure 1D). Asymmetrical; right molar and left molar processes each with three teeth, confluent with incisor process; palp absent.

Maxillule (Figure 1F). Coxal endite with seven setae; basal endite with seven setae; endopod 2-segmented, proximal segment without seta, distal segment with four terminal setae.

Maxilla (Figure 1G). Coxal endite bilobed, with 4 + 4 setae; basal endite bilobed, with 5 + 4 setae; endopod with three setae; scaphognathite with 11 marginal plumose setae.

First maxilliped (Figure 1H). Coxa without seta; basis with nine setae arranged as 2, 2, 2, 3; endopod 5-segmented, with 3, 2, 1, 2, 5 (1 subterminal + 4 terminal) setae; exopod 2-segmented, distal segment with four terminal natatory setae.

Second maxilliped (Figure 1I). Coxa without seta; basis with three setae; endopod 2-segmented, with 1, 4 (2 subterminal + 2 terminal) setae; exopod 2-segmented, distal segment with four terminal natatory setae.

Pereopods (Figure 1J) present as buds.

Abdomen (Figure 1K). Five somites; somite 1 with two dorsomedial setae; somite 2 with pair of acicular lateral processes directed anteriorly; somites 2–5 each

with pair of posterodorsal setae; pleopod buds present as buds.

Telson (Figure 1K). Each fork long, with dorsomedial spine; each posterior margin with three serrated setae.

### Second zoea (Figure 2)

Size. CL  $0.80 \pm 0.04$  mm.

Carapace (Figure 2A, E). Two pairs of anterodorsal setae present; each ventral margin with 6 setae.

Antennule (Figure 2B). Exopod with six terminal aesthetascs and two short terminal setae.

Antenna (Figure 2C). Endopod bud longer than in previous stage.

Mandibles (Figure 2D). Palp present.

Maxillule (Figure 2F). Epipod plumose seta now present; basal endite with nine setae.

Maxilla (Figure 2G). Basal endite with 5 + 5 setae; scaphognathite with 18 marginal plumose setae.

First maxilliped (Figure 2H). Coxa with seta; exopod 2-segmented, distal segment with six terminal natatory setae.

Second maxilliped (Figure 2I). Exopod 2-segmented, distal segment with six terminal natatory setae.

Third maxilliped (Figure 2J) developing as bud.

Pereopods (Figure 2K). Bilobed cheliped and four buds.

Abdomen (Figure 2L). Six somites, somite 1 with three dorsomedial setae; pleopod buds more developed, endopods present.

### Megalopa (Figure 3)

Size. CL  $1.03 \pm 0.02$  mm. CW  $0.64 \pm 0.03$  mm.

Carapace (Figure 3A). Subquadrated shape, with frontal spine, pair of protogastric tubercles and cardiac spine.

Antennule (Figure 3B). Last segment of peduncle with seta; endopod with subterminal seta and two terminal setae; exopod 3-segmented, segment 1 without seta, segment 2 with eight aesthetascs and two short setae, segment 3 with four aesthetascs, one long and three shorter setae.

Antenna (Figure 3C). Seven-segmented, with 1, 2, 3, 0, 0, 4, 4 setae.

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

Maxillule (Figure 3E). Coxal endite with eight setae; basal endites with 15 setae; endopod without seta; epipod seta present.

Maxilla (Figure 3F). Coxal and basal endites each with 10 and 14 setae, respectively; endopod without; scaphognathite with 28 marginal plumose setae and three surface setae.

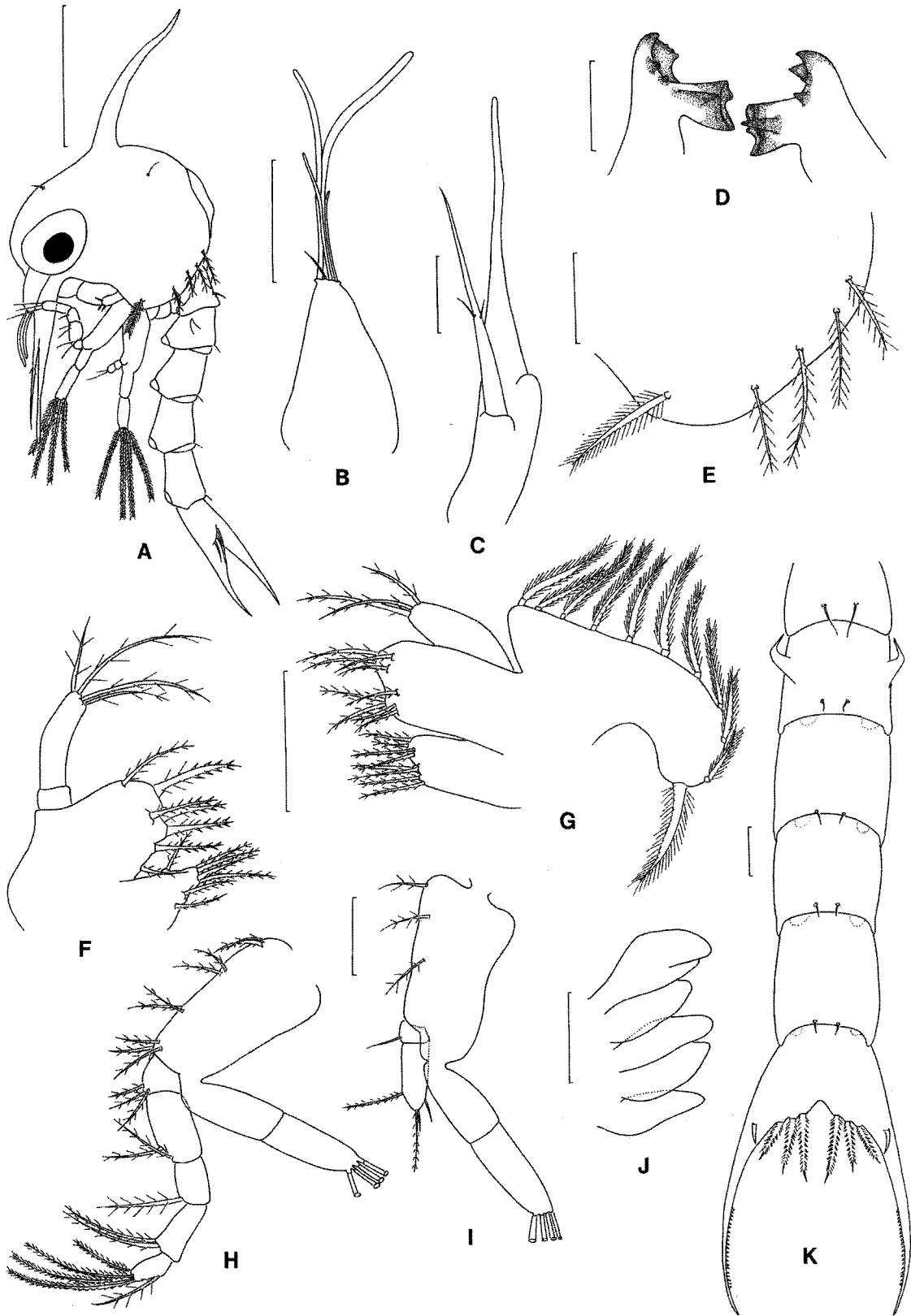


Figure 1. *Pyromaia tuberculata*, first zoeal stage. A, lateral view; B, antennule; C, antenna; D, mandibles; E, lateral expansion of carapace; F, maxillule; G, maxilla; H, first maxilliped; I, second maxilliped; J, chela and pereopods; K, dorsal view of abdomen and telson. Scale bars = 0.5 mm (A) and 0.1 mm (B-K).

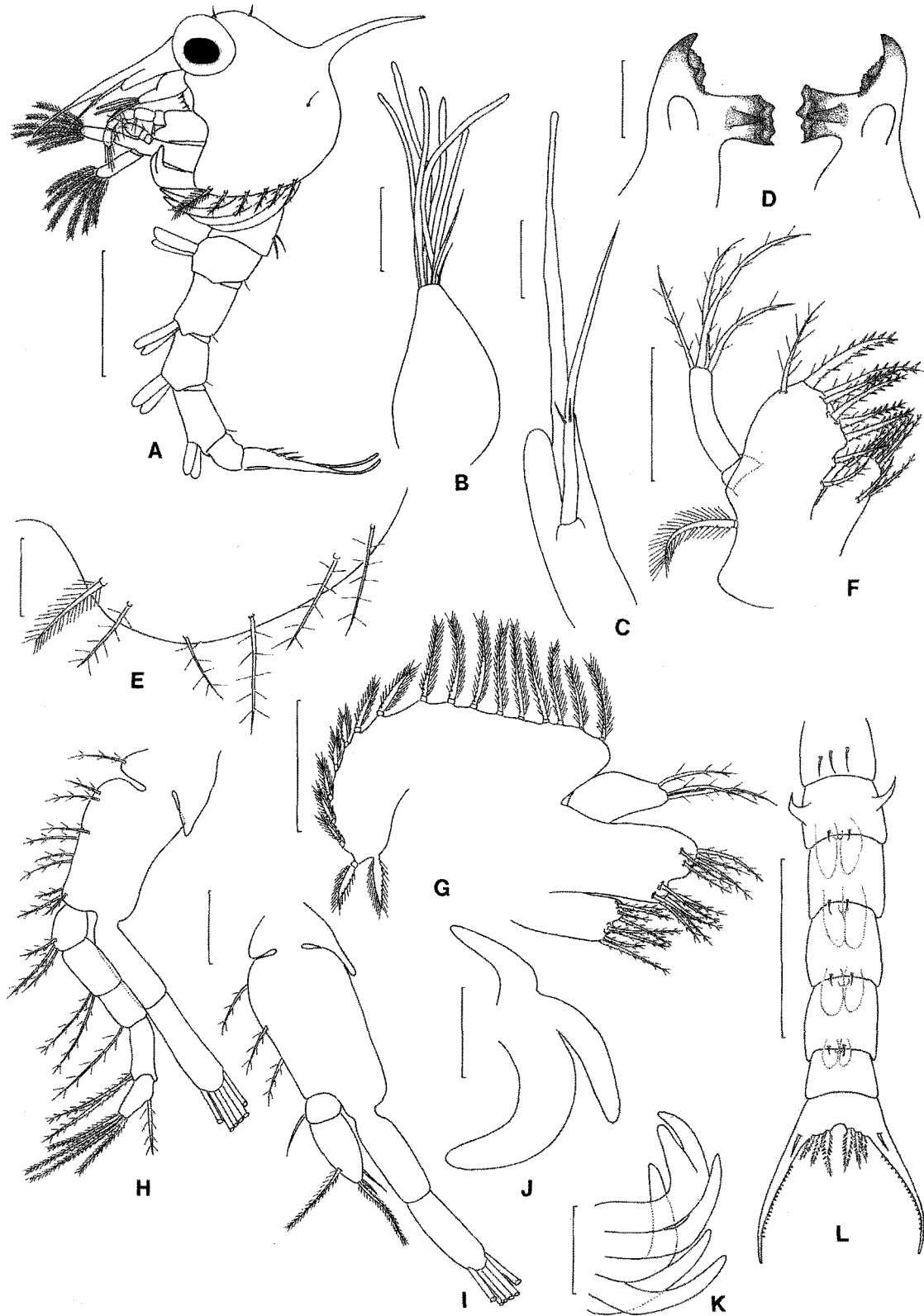


Figure 2. *Pyromaia tuberculata*, second zoeal stage. A, lateral view; B, antennule; C, antenna; D, mandibles; E, lateral expansion of carapace; F, maxillule; G, maxilla; H, first maxilliped; I, second maxilliped; J, third maxilliped; K, chela and pereopods; L, dorsal view of abdomen and telson. Scale bars = 0.5 mm (A, L), 0.1 mm (B–J) and 0.25 mm (K).

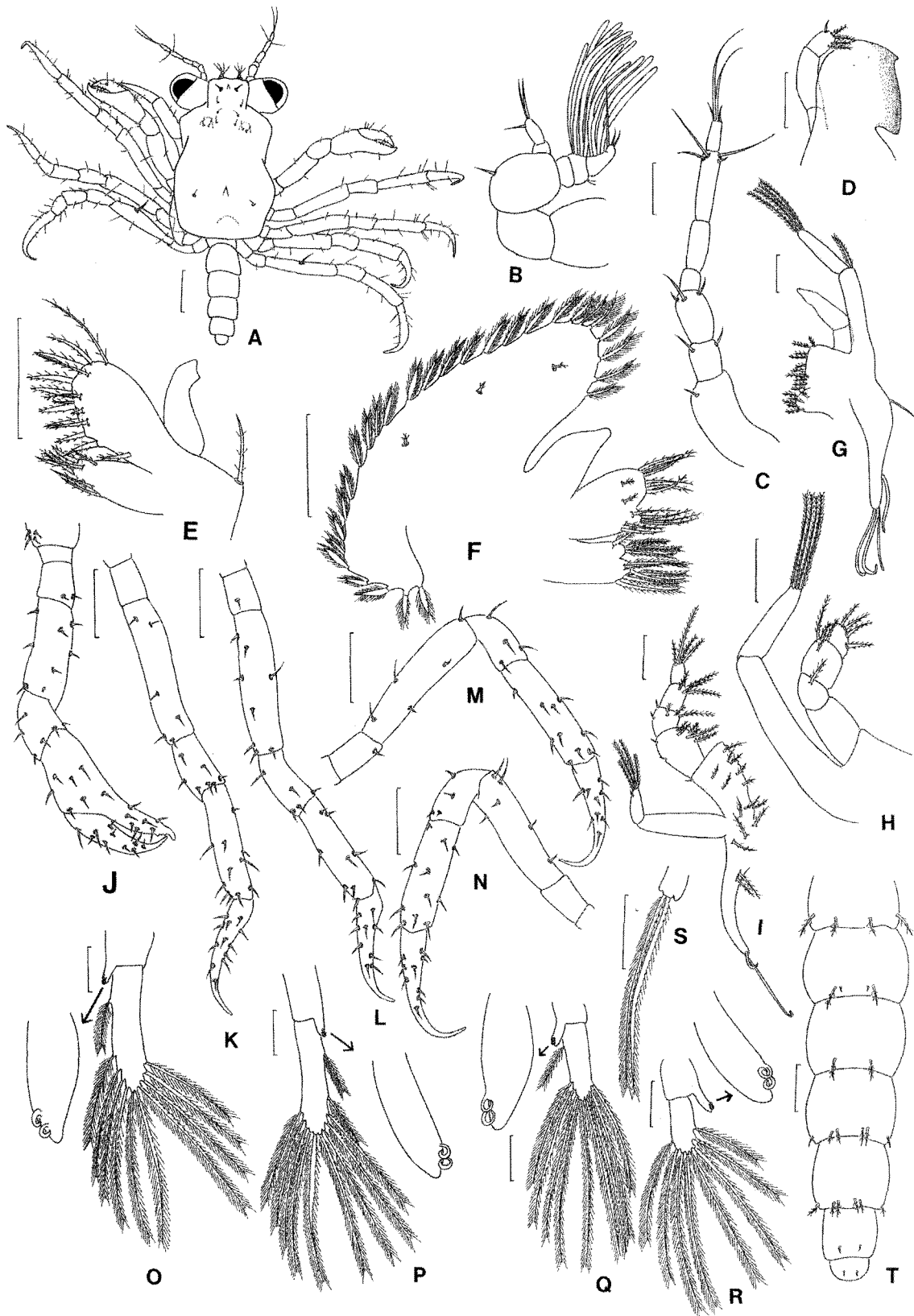


Figure 3. *Pyromaia tuberculata*, megalopal stage. A, dorsal view; B, antennule; C, antenna; D, mandible; E, maxillule; F, maxilla; G, first maxilliped; H, second maxilliped; I, third maxilliped; J, chela; K-N, pereopods 2-5; O-S, pleopods 1-5; T, dorsal view of abdomen and telson. Scale bars = 0.25 mm (A, J-N) and 0.1 mm (B-I, O-T).

First maxilliped (Figure 3G). Epipod with five long simple setae; coxal and basal endites each with 6 and 11 setae, respectively; endopod 2-segmented, without seta; exopod 2-segmented, proximal segment with terminal seta, distal segment with four long terminal plumose setae.

Second maxilliped (Figure 3H). Coxa and basis not differentiated; endopod 4-segmented, with 0, 1, 5, 4 setae; exopod 2-segmented, distal segment with four long terminal plumose setae.

Third maxilliped (Figure 3I). Epipod with two simple terminal and 5 proximal shorter setae; coxa and basis not differentiated; endopod 5-segmented, with 11, 8, 5, 4, 4 setae; exopod 2-segmented, distal segment with four long terminal plumose setae and small seta.

Chela (Figure 3J) covered with a few small setae; tip slightly hooked; inner margin of immovable finger with three elevations.

Pereopods 2–5 (Figure 3K–N). All segments well differentiated, sparsely armed with setae; dactylus hooked, sharp-pointed.

Pleopods (Figure 3O–S). Endopods of pleopods 1–4 with two hooks; pleopods 1–5 each with 11, 11, 10, 8, 2 plumose setae on distal segment, respectively.

Abdomen and telson (Figure 3T). Abdomen 6-segmented, with a few of small setae on surface; telson rounded, with two posterodorsal setae.

## Discussion

Kim (1985) reported that the introduced spider crabs *Pyromaia tuberculata* were collected for the first time from Korea in 1982. In the present study, one ovigerous crab was collected from Gijang in September 2005 and recently two ovigerous and four male crabs were

collected in Geoje in June 2008 by the second author. This fact indicates the crabs have ecologically adapted to the Korean waters and female crabs produce larvae during summer or early autumn.

Webber and Wear (1981) described only the first zoeal stage of *P. tuberculata* and Fransozo and Negreiros-Fransozo (1997) described two zoeal stages and a megalopal stage of it. By comparison of the two previous studies with the present study, it is found that an antennal endopod and two dorsal setae of the first abdominal somite are present in the first zoeal stage (Table 1). Also, a cardiac spine on the carapace and a seta on the proximal segment of the first maxillipedal exopod are found in the megalopal stage (Table 2). Therefore, it is considered that an improved and more accurate larval description of *P. tuberculata* is provided as compared with the two previous descriptions.

Rice (1980) considered that zoeal mouthpart setations (the endopods of maxillule and maxilla and the endopods and basis of maxillipeds) were important characters and reflected brachyuran classification at the family and subfamily level. As comparing the setations between the present study and the two previous studies (Webber and Wear 1981; Fransozo and Negreiros-Fransozo 1997), this study's and Webber and Wear's zoeae have 2, 2, 2, 3 and 1, 1, 1 setations in the first and the second maxillipedal basis, whereas Fransozo and Negreiros-Fransozo's zoea has 2, 2, 2, 2 and 1, 1, 1, 1 setations (Table 1). In the same family the zoeae of *Anasimus latus* and *Paradasygyius depressus* show the same characteristics (Sandifer and Van Engel 1972; Pohle and Marques 2000) as we described, therefore it is considered that Fransozo and Negreiros-Fransozo have overlooked some setae on the zoeal maxillipeds. In addition, a cardiac spine was found in the present megalopa (Table 2). With respect to the

Table 1. Comparison of the first zoeal stages of *Pyromaia tuberculata* as given by Webber and Wear (1981) and Fransozo and Negreiros-Fransozo (1997) with those obtained in the present study.

	Webber and Wear (1981)	Fransozo and Negreiros-Fransozo (1997)	Present study
ZOEAI			
Antennule	4 aesthetascs	3 aesthetascs and 1 seta	4 aesthetascs and 1 seta
Antenna	no data	no endopod	an endopod
Maxillule			
coxal endite	6 setae	8 setae	7 setae
Maxilla			
basial endite	5 + 4 setae	3 + 4 setae	5 + 4 setae
coxal endite	3 + 4 setae	5 + 4 setae	4 + 4 setae
Maxilliped 1			
basis	2, 2, 2, 3 setae	2, 2, 2, 2 setae	2, 2, 2, 3 setae
Maxilliped 2			
basis	1, 1, 1 setae	1, 1, 1, 1 setae	1, 1, 1 setae
Abdomen			
somite 1	no data	no seta	2 dorsal setae

Table 2. Comparison of the second zoeal and megalopal stages of *Pyromaia tuberculata* as given by Fransozo and Negreiros-Fransozo (1997) with those obtained in the present study.

	Fransozo and Negreiros-Fransozo (1997)	Present study
ZOEAL		
Antennule	5 aesthetascs and 1 seta	6 aesthetascs and 2 setae
Maxillule		
basial endite	8 setae	9 setae
coxal endite	8 setae	7 setae
Maxilla		
scaphognathite	20 setae	18 setae
basial endite	4 + 4 setae	5 + 5 setae
coxal endite	4 + 5 setae	4 + 4 setae
Abdomen		
somite 1	2 setae	3 setae
MEGALOPA		
Carapace	no cardiac spine	1 cardiac spine
Antennule		
exopod	1 terminal seta	3 terminal setae
Antenna	2, 1, 3, 0, 0, 3, 3 setae	1, 2, 3, 0, 0, 4, 4 setae
Mandible		
palp	4 terminal setae	5 terminal setae
Maxilliped 1		
proximal segment of exopod	no seta	1 seta
distal segment of exopod	3 setae	4 setae

spine, Ingle (1992) reported that in the larval stages of northeastern Atlantic brachyurans the majoid megalopa has a cardiac spine which when present is always accompanied by other spines or processes on the carapace. As a pair of carapacial protuberances were drawn in the figure of Fransozo and Negreiros-Fransozo's megalopa, it is concluded that re-examination of Fransozo and Negreiros-Fransozo's larvae is needed. Other differences in numbers of setae or aesthetascs on the antennule, the coxal and the basial endites of the maxillule and the maxilla, and the abdomen may be due to geographical variation in zoeae of the introduced spider crabs *Pyromaia tuberculata* from New Zealand, Brazil and Korea.

Although the larval descriptions of the Inachoididae are limited to three species (*Anasimus latus*, *Paradasygyius depressus* and *Pyromaia tuberculata*), overall similarities of zoeal characteristics of the family were suggested by Guinot and Richer de Forges (1997) as follows: (1) absence of lateral and rostral carapace spines on the carapace, (2) presence of ocular spines (except in *P. tuberculata*), and (3) presence of a pair of acicular processes on the abdominal somite 2. Despite these similarities, it is found that there are two groups based on setal number of the endopods of the maxillule and the maxilla, which are the characteristics used by Rice (1980) for finding distinctions between subfamilies or families. The first group is *A. latus*, having three setae and five setae on the endopods of the maxillule and the maxilla, whereas the second one

includes *P. depressus* and *P. tuberculata*, having four and three setae in the positions. The existence of two such larval groups suggests that the Inachoididae are a heterogeneous group.

For the identification of three species of inachoidid zoeae, the following provisional key is provided.

- (1) Endopod of maxillule with three setae; endopod of maxilla with five setae – *Anasimus latus*  
Endopod of maxillule with four setae; endopod of maxilla with three setae – 2
- (2) Antennal protopod spinulate – *Paradasygyius depressus*  
Antennal protopod naked, tip blunt – *Pyromaia tuberculata*

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