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Zoeal Development of *Telmessus acutidens* (Crustacea: Decapoda: Brachyura: Atelecyclidae) Reared in the Laboratory

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ABSTRACT

An ovigerous hair crab, *Telmessus acutidens*, was collected in South Korean waters and its larvae were reared in the laboratory. The larval development consists of four zoeal (including an extra zoeal stage) and one megalopal stages. Four zoeal stages are described and illustrated in detail. The zoeas of the present material show some differences from Kurata (1963)'s plankton-collected zoea of *T. acutidens* in the characteristics of the carapace spines, an endopod and an exopod of the antenna, and the posterolateral process of the abdominal somite. Kurata's zoea agreed well with that of *T. cheiragonus*. So, it is suggested that Kurata's zoea may be the second zoea of *T. cheiragonus*.

Key words: Atelecyclidae, *Telmessus acutidens, T. cheiragonus,* zoea, carapace spines, antenna, Korea

INTRODUCTION

The family Atelecyclidae is represented by four species in Korea (Kim, 1973): *Telmessus acutidens* (Stimpson, 1858), *T. cheiragonus* (Tilesius, 1812), *Erimacrus isenbeckii* (Brandt, 1848), and *Trachycarcinus balssi* Rathbun, 1932. The hair crab, *T. acutidens*, commercially important as a fishing resource, has been reported from the south-eastern coast of Korea and the west coast of Hokkaido, Japan, to south of Sakhalin. It is distributed more southward than the other three species and is known to live in the sand or the mud from the littoral to a depth of 50 m (Kim, 1973; Sakai, 1976).

The larvae of the family Atelecyclidae have been described for *Atelecyclus rotundatus* (Olivi, 1792) by Lebour (1928), Bourdillon-Casanova (1960), Hong and Ingle (1987), and Ingle (1991); *Peltarion spinosulum* (White, 1843) by Irio (1983); *Erimacrus isenbeckii* by Marukawa and Yasunari (1931), Marukawa and Chong (1933), Aikawa (1937), Kurata (1963), Sasaki and Mihara (1993), and Lee et al. (unpublished); *Telmessus cheiragonus* by Kurata (1963) and Rice (1980); and *T. acutidens* by Kurata (1963). Although Kurata (1963) described the second zoea and a megalopa of *T. acutidens* from plankton-caught material, his description was incomplete for current comparative morphological studies.

It is the objective of this paper to describe the zoeal stages of *T. acutidens* in detail and to compare their morphology with previously described zoeas from the same family.

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MATERIALS AND METHODS

An ovigerous *Telmessus acutidens* was collected from a Jagalchi fish market in the southern part of Korea on 4 January 2003 and transported to a constant temperature chamber at Silla University, Busan. Zoeas hatched on 11 January 2003 were reared using methods described by Ko (1995) at a constant water temperature of 15°C. Larvae were preserved in 10% neutral formalin. Zoeal specimens were dissected using a Leitz zoom stereomicroscope and appendages were examined under a Leitz Laborlux S microscope. Appendages were mounted in polyvinyl lactophenol, cover slips were sealed with clear nail varnish and drawings were made with the aid of a *camera lucida*. Setal counts and measurements were based on about 10 specimens for each zoeal stage. The sequence of the zoeal description is based on the malacostracan somite plan and described from anterior to posterior. Setal armatures of appendages are described from proximal to distal segments and in order of endopod to exopod (Clark et al., 1998). Samples of the zoeal series and the spent female were deposited in Silla University, Korea (accession number, SUZ CR 103243). The zoeal stages are described and fully illustrated. For the second and subsequent zoeal stages, only the main differences from the previous stage are described. The long plumose natatory setae of the first and second maxillipeds, the telson fork, and the long antennular aesthetascs, are drawn truncated. A micrometer was used for

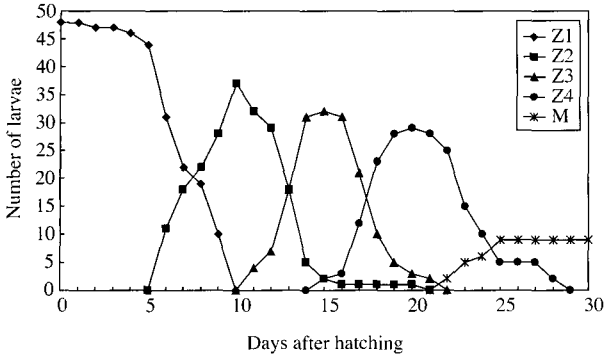

Fig. 1. Life span and survival of larvae of *Telmessus acutidens* reared in the laboratory at 15°C and 33.3‰ salinity.

measurement of zoeal carapace length, measured from the base of the rostral spine to the most posterior carapace margin. The approximate measurement of the antennal exopod (for its ratio with the protopod) was taken from the base to the tip excluding the terminal setae.

RESULTS

Four zoeal stages occurred before metamorphosis to the megalopa. The minimum durations of the zoeal stages I-IV at 15°C were 5, 5, 4, and 7 days, respectively. Metamorphosis to the megalopa occurred from 21 days after the first stage zoeas hatched from eggs (Fig. 1). Only nine megalopae were obtained, however, the moult to megalopa was not entirely successful because they were unable to extricate themselves from the zoeal exoskeleton and consequently this phase could not be properly described and illustrated.

DESCRIPTION

Telmessus acutidens (Stimpson, 1858) (Figs. 2-7)

Zoea I

Size: Carapace length 0.84±0.09 mm. Distance from tip of dorsal spine to tip of rostral spine 2.18±0.10 mm.

Carapace (Fig. 2A, B). Dorsal spine twice longer than rostral spine; rostral spine slightly longer than antennal protopod; lateral spines present; one pair of anterodorsal setae present; one pair of posterodorsal setae present; each ventral margin with 9 setae; eyes stalked.

Antennule (Fig. 2C). Uniramous; endopod absent; exopod unsegmented with 5 (4 long and 1 shorter) terminal aesthetascs, short terminal seta and shorter subterminal aesthetasc.

Antenna (Fig. 2D). Protopod slightly shorter than rostral spine and distally spinulate; endopod bud about 53% length of exopod; exopod about 30% length of protopod with 2 (1 long and 1 shorter) terminal setae.

Mandibles (Fig. 2E). Asymmetrical; right molar with 3 unequal sized teeth and left molar with tooth, confluent with incisor process; endopod palp absent.

Maxillule (Fig. 2F). Epipod seta absent; coxal endite with 9 terminal setae; basial endite with 8 terminal setae; endopod 2-segmented: proximal segment with a seta; distal segment with 6 (2 subterminal+4 terminal) setae.

Maxilla (Fig. 2G). Coxal endite bilobed, with 5+4 setae; basial endite bilobed, with 5+6 setae; endopod bilobed, with 3+5 setae; exopod (scaphognathite) margin with 28 plumose setae.

First maxilliped (Figs. 2A, 3A). Coxa with seta; basis with 10 setae arranged 2, 2, 3, 3; endopod 5-segmented, with 3, 2, 1, 2, 5 (1 proximal+4 terminal) setae respectively; exopod 2-segmented, distal segment with 4 terminal natatory plumose setae.

Second maxilliped (Figs. 2A, 3B). Coxa without seta; basis with 4 setae; endopod 3-segmented, with 1, 1, 5 (2 subterminal+3 terminal) setae, respectively; exopod 2-segmented, distal segment with 4 terminal natatory plumose setae.

Third maxilliped (Fig. 3C). Biramous.

Pereopods (Fig. 3D). Developing as buds; 1st pereopod present as biramous bud.

Abdomen (Fig. 3E). Five somites; somite 2 with pair of lateral processes directed laterally; somites 3-5 with short posterolateral processes, distally spinulate; somites 2-5 with pair of posterodorsal setae and pleopod buds.

Telson (Fig. 3E, F). Each fork long and distally spinulate, with one lateral long and spinulate, one lateral smaller and one smaller dorsomedial spines; posterior margin with 3 pairs of spinulate setae.

Zoea II

Size: Carapace length 1.08±0.04 mm. Distance from tip of dorsal spine to tip of rostral spine 2.32±0.06 mm.

Carapace (Fig. 4A). Two pairs of anterodorsal setae present; each ventral margin with 12 setae; each ventral margin with 12 setae; otherwise unchanged.

Antennule (Fig. 4B). Exopod now with 7 long (6 stout+1 thinner) terminal aesthetascs, terminal seta, and 6 shorter subterminal aesthetascs; otherwise unchanged.

Antenna (Fig. 4C). Endopod bud about 60% length of exopod; otherwise unchanged.

Mandibles: Unchanged.

Maxillule (Fig. 4D). Coxal endite with 9 setae; basial endite with 10 setae; exopodal plumose seta now present; otherwise unchanged.

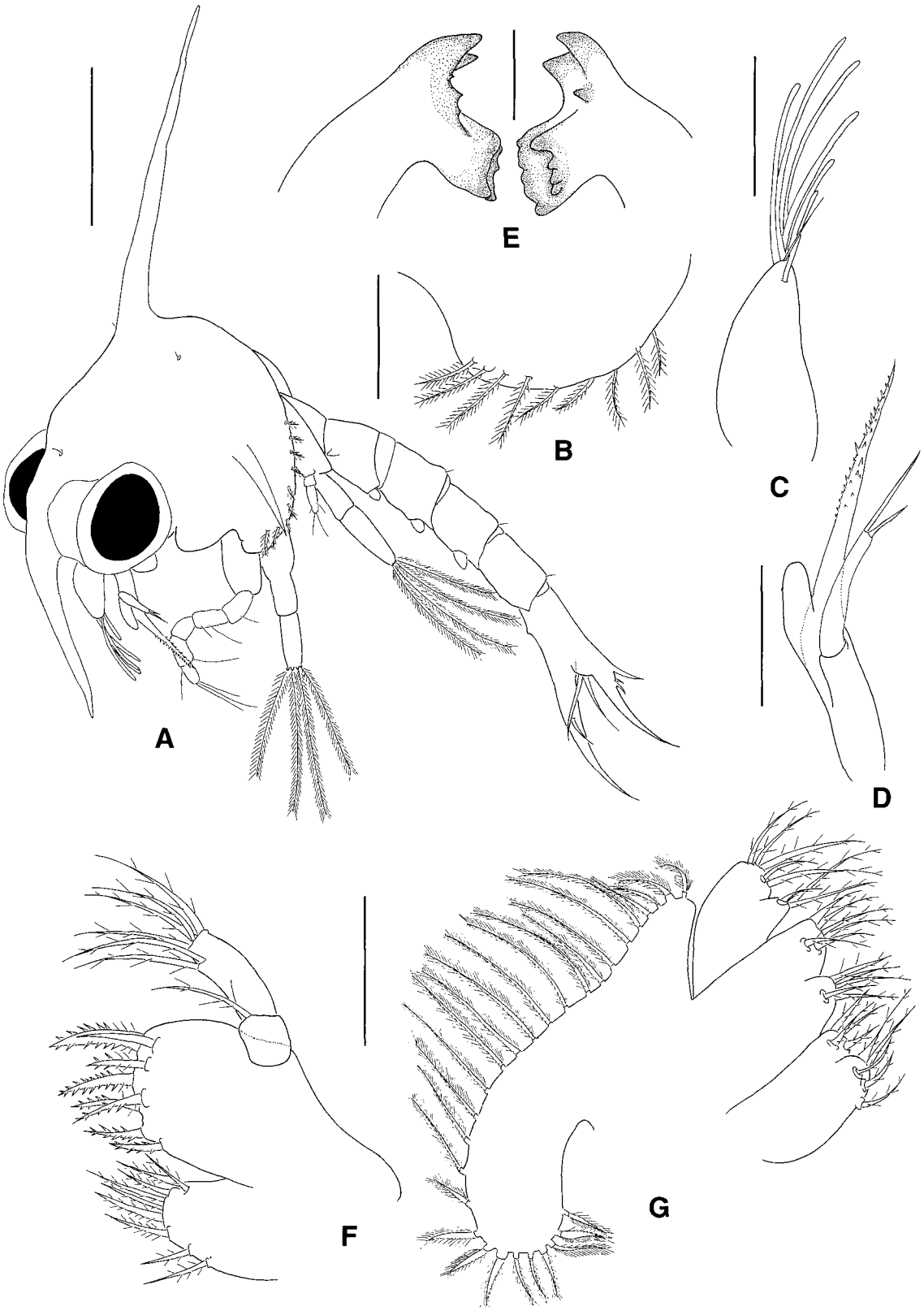

Fig. 2. *Telmessus acutidens*, first zoeal stage. A, lateral view; B, lateral expansion of carapace; C. antennule; D, antenna; E, mandibles; F, maxillule; G, maxilla. Scale bars=0.5 mm (A), 0.1 mm (B-G).

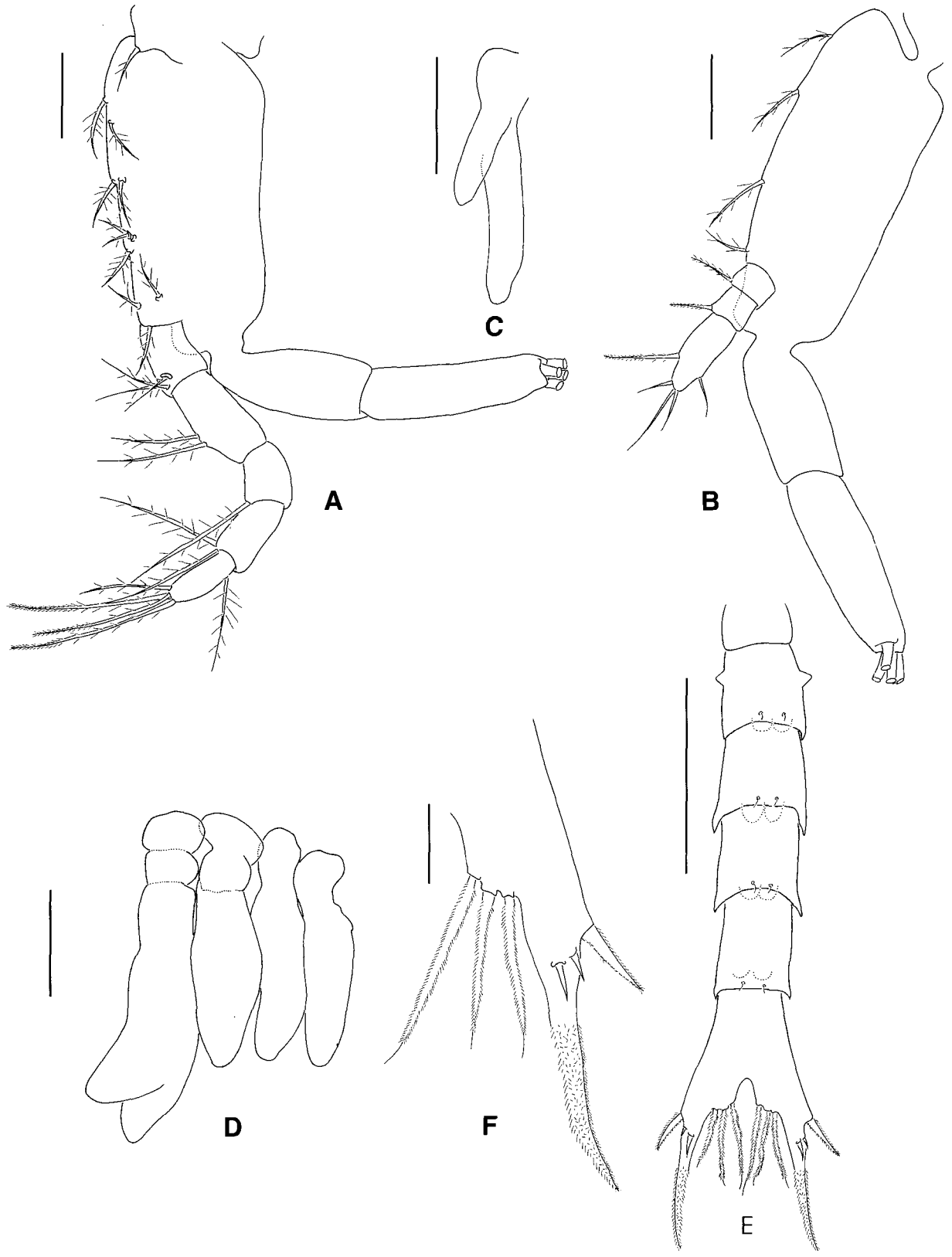

Fig. 3. *Telmessus acutidens*, first zoeal stage. A, first maxilliped; B, second maxilliped; C, third maxilliped; D, pereopods; E, dorsal view of abdomen and telson; F, fork of telson. Scale bars=0.1 mm(A-D, F), 0.5 mm(E).

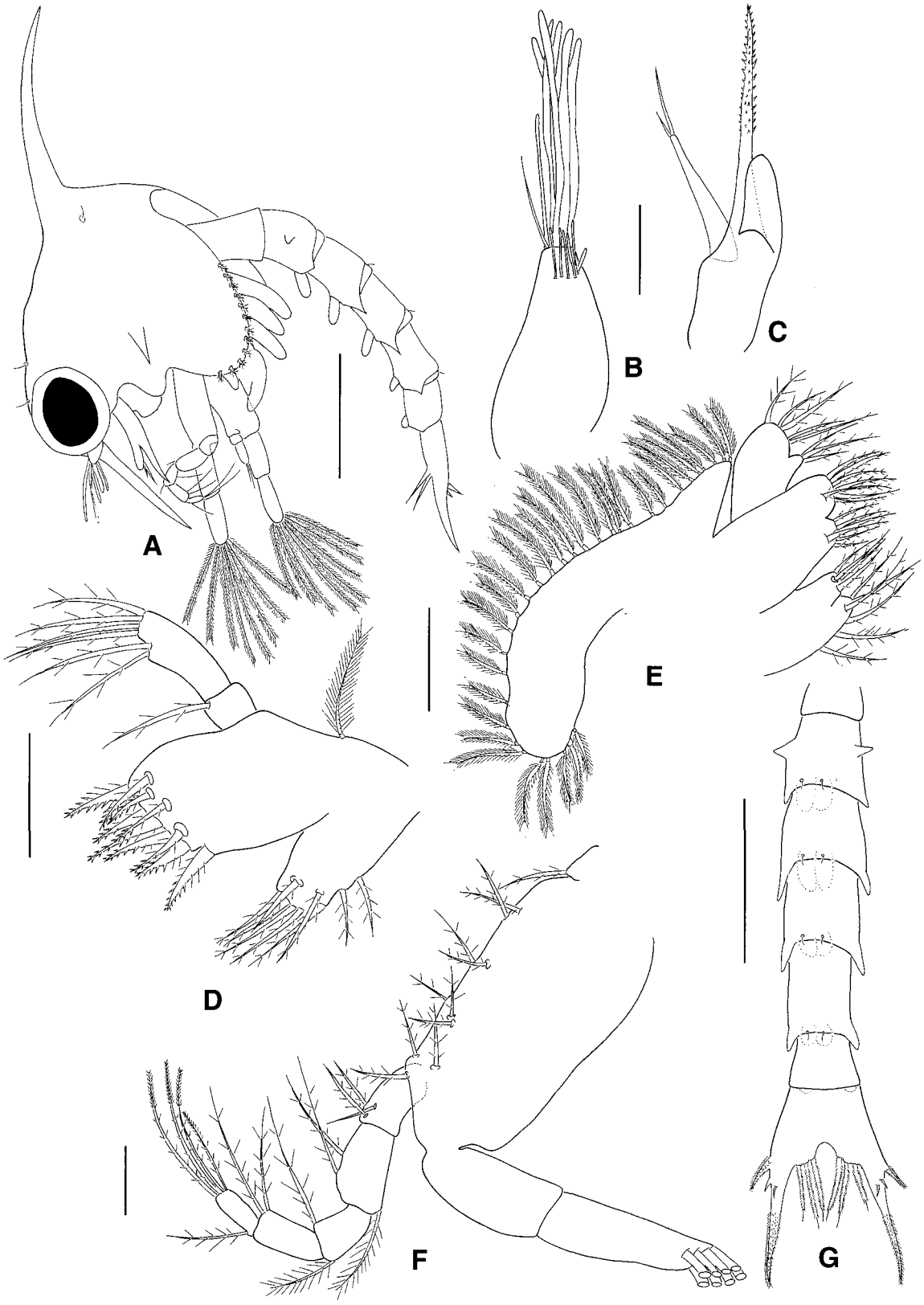

Fig. 4. *Telmessus acutidens*, second zoeal stage. A, lateral view; B, antennule; C, antenna; D, maxillule; E, maxilla; F, first maxilliped; G, dorsal view of abdomen and telson. Scale bars=0.5 mm (A, C-E, G), 0.1 mm (B, D, F).

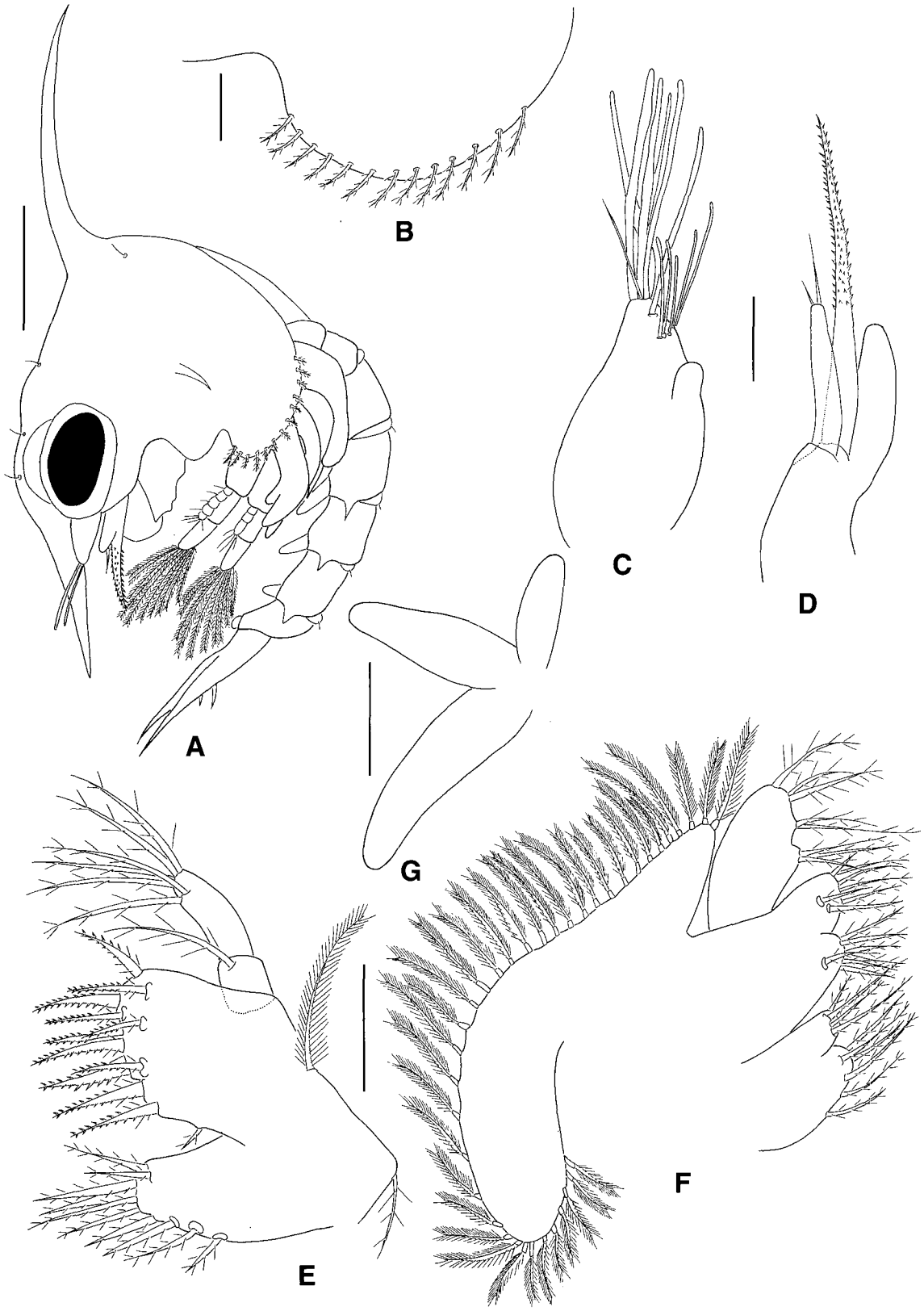

Fig. 5. *Telmessus acutidens*, third zoeal stage. A, lateral view; B, lateral expansion of carapace; C, antennule; D, antenna; E, maxillule; F, maxilla; G, third maxilliped. Scale bars=1.0 mm (A), 0.05 mm (B), 0.1 mm (C-G).

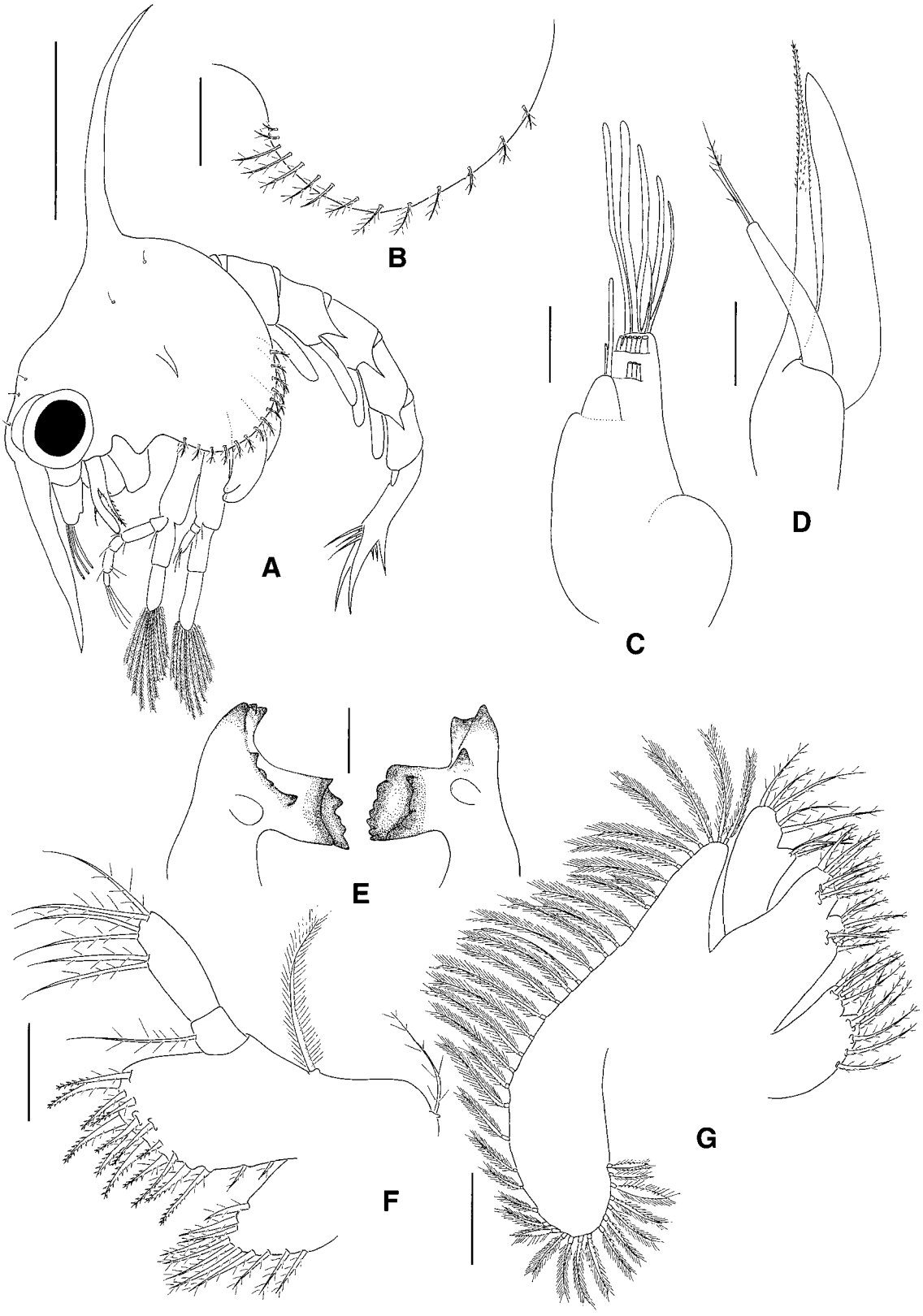

Fig. 6. *Telmessus acutidens*, fourth zoeal stage. A, lateral view; B, lateral expansion of carapace; C, antennule; D, antenna; E, mandibles; F, maxillule; G, maxilla. Scale bars=1.0 mm (A), 0.25 mm (B), 0.1 mm (C-G).

Maxilla (Fig. 4E). Coxal endite bilobed, with 6+4 setae; basial endite bilobed, with 6+7 setae; exopod (scaphognathite) margin with 32 plumose setae and distal, stout process no longer prominent; otherwise unchanged.

First maxilliped (Fig. 4F). Endopod 5-segmented, with 3, 3, 2, 2, 5 (1 proximal+4 terminal) setae respectively; exopodal distal segment now with 8 terminal natatory plumose setae; otherwise unchanged.

Second maxilliped (Fig. 4A). Exopodal distal segment now with 8 terminal natatory plumose setae; otherwise unchanged.

Third maxilliped: Unchanged.

Pereopods: Unchanged.

Abdomen (Fig. 4G). With 6 somites; posterolateral processes of somites 3 and 4 longest, but, not reaching to 1/2 length of next somite; pleopodal buds present on somite 6; otherwise unchanged.

Telson (Fig. 4G). Unchanged.

Zoea III

Size: Carapace length 1.22±0.05 mm. Distance from tip of dorsal spine to tip of rostral spine 2.74±0.12 mm.

Carapace (Fig. 5A, B). Three pairs of anterodorsal setae present; each ventral margin with 13 setae; otherwise unchanged.

Antennule (Fig. 5C). Endopodal bud present; exopod with 2 rows of subterminal aesthetascs arranged 5, 1 and 5 long terminal aesthetascs plus terminal seta.

Antenna (Fig. 5D). Endopodal bud about 97% length of exopod; otherwise unchanged.

Mandibles: Unchanged.

Maxillule (Fig. 5E). Epipod seta now present; coxal endite with 10 setae; basial endite with 12 setae; otherwise unchanged.

Maxilla (Fig. 5F). Basial endite bilobed, with 7+7 setae; exopodal (scaphognathite) margin with 37 plumose setae; otherwise unchanged.

First maxilliped (Fig. 5A). Exopodal distal segment now with 10 terminal natatory plumose setae; otherwise unchanged.

Second maxilliped (Fig. 5A). Exopodal distal segment now with 10 terminal natatory plumose setae; otherwise unchanged.

Third maxilliped (Fig. 5G). Epipod now present.

Pereopods: Unchanged.

Abdomen (Fig. 5A). Six somites fully formed; posterolateral processes of somites 3-5 not reaching to 1/2 length of next somite; pleopodal buds developing; otherwise unchanged.

Telson: Unchanged.

Zoea IV

Size: Carapace length 1.52±0.08 mm. Distance from tip of dorsal spine to tip of rostral spine 3.36±0.23 mm.

Carapace (Fig. 6A, B). Three pairs of anterodorsal and 2 pairs of posterodorsal setae present; each ventral margin with 14 setae; otherwise unchanged.

Antennule (Fig. 6C). Exopod with 2 rows of subterminal aesthetascs arranged 5, 6 and 5 long aesthetascs plus seta terminaly.

Antenna (Fig. 6D). Endopod about twice longer than length of exopod, but, slightly shorter than length of protopod; terminal setae of exopod with a few setule; otherwise unchanged.

Mandibles (Fig. 6E). Right molar now with 4 unequal sized teeth confluent with incisor process; endopodal palp present.

Maxillule (Fig. 6F). Coxal endite with 11 setae; basial endite with 16 setae; otherwise unchanged.

Maxilla (Fig. 6G). Basial endite bilobed, with 7+8 setae; exopodal (scaphognathite) margin with 39 plumose setae; otherwise unchanged.

First maxilliped (Fig. 7A). Coxa with epipodal bud bearing arthrobranch gill and now with 2 setae; otherwise unchanged.

Second maxilliped (Fig. 7A). Coxa with epipodal bud bearing arthrobranch gill; distal segment of endopod now with 6 (4 subterminal+2 terminal) setae; otherwise unchanged.

Third maxilliped (Fig. 7C). Endopod slightly segmented.

Pereopods (Fig. 7D). Some segmental differentiation into segments.

Abdomen (Fig. 7E, F). Each of pleopods 1-3 with endopodal bud, pleopods 4 and 5 uniramous; otherwise unchanged.

Telson (Fig. 7E, G). Posterior margin with 3 pairs of spinulate setae and one pair of simple setae; otherwise unchanged.

DISCUSSION

Kurata (1963) described larvae of three species of the family Atelecyclidae; *Telmessus cheiragonus, T. acutidens*, and *Erimacrus isenbeckii*, from Hokkaido, Japan. In his description, larvae of *T. cheiragonus* were obtained from laboratory-reared material, whereas single specimen of the second zoea and five of megalopae of *T. acutidens* were from plankton-collected material. Kurata's second zoea of *T. acutidens* is very similar to that of *T. cheiragonus* and different from the present material, as shown in Table 1. The second and third zoeal stages of *T. acutidens* are easily distinguished from those of *T. cheiragonus* in having

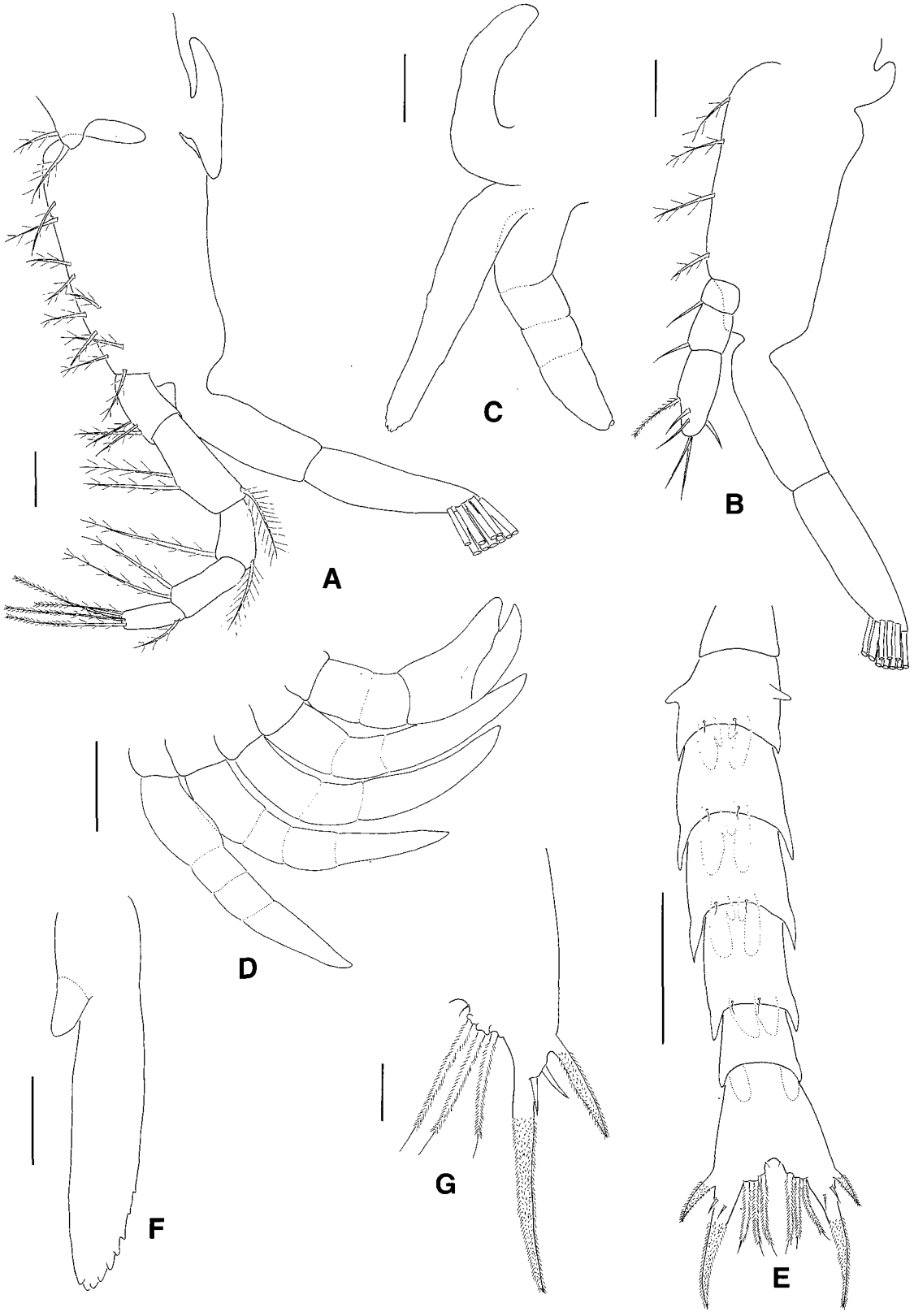

Fig. 7. *Telmessus acutidens*, fourth zoeal stage. A, first maxilliped; B, second maxilliped; C, third maxilliped; D, pereopods; E, dorsal view of abdomen and telson; F, first pleopod; G, fork of telson. Scale bars=0.1 mm (A-C, F, G), 0.25 mm (D), 0.5 mm (E).

Table 1. Differences in the zoeal characteristics between two *Telmessus* species described by Kurata (1963) and *T. acutidens* of the present study

Species	*T. cheiragonus*	*T. acutidens*	*T. acutidens*	
Author	Kurata (1963)	Kurata (1963)	Present study	
Zoeal stage	Zoea II	Zoea II	Zoea II	Zoea III
SL	3.2-3.4 mm	3.3 mm	2.32 mm	2.74 mm
Dorsal carapace spine	spinulate	spinulate	smooth	smooth
Antenna				
ratio of endopod to protopod length	about 12%	about 13%	about 22%	about 41%
ratio of exopod to protopod length	about 16%	about 18%	about 37%	about 42%
ratio of endopod to exopod length	about 75%	about 71%	about 59%	about 97%
Exopod of maxillule	as 2 plumose+a setae	as 2 plumose+a setae	as a plumose seta	as a plumose+a seta
Exopod of maxilliped	10 natatory setae	10 natatory setae	8 natatory setae	10 natatory setae
Abdomen				
posterolateral process on somite 4	reaching to 1/2 length of somite 5	reaching to 1/2 length of somite 5	reaching to 1/3 length of somite 5	reaching to 1/3 length ofa somite 5

SL=Distance from tip of dorsal spine to tip of rostral spine

Table 2. A comparison of the zoeal stages, duration of zoeal stages, zoeal size, intermoult period, and survival rate of larvae of *Telmessus acutidens* reared at 15°C between Lee et al. (1993) and the present study

Author	Lee et al. (1993)	Present study
Zoeal stages	5	4
Duration of zoeal stage	at least 23 days	al least 21 days
Carapace length : SL (mm)		
zoea I	1.03 : 2.47	0.84±0.09 : 2.18±0.10
zoea II	1.18 : 2.65	1.08±0.04 : 2.32±0.06
zoea III	1.24 : 3.09	1.22±0.05 : 2.74±0.12
zoea IV	1.87 : 3.76	1.52±0.08 : 3.36±0.23
zoea V	2.21 : 3.98	-
Minimum intermolt period (days)		
zoea I	5	5
zoea II	4	5
zoea III	3	4
zoea IV	3	7
zoea V	5	-
Survival rate of last zoeal stage	18%	60%
Survival rate of megalopal stage	18%	19%

SL=Distance from tip of dorsal spine to tip of rostral spine

smooth carapace spines, approximately twice longer endopod and exopod of the antenna, and the posterolateral process on somite 4 approximately 1/3 length of somite 5. Therefore, it is suggested that Kurata (1963)'s zoea of *T. acutidens* can be referred to *T. cheiragonus*.

Lee et al. (1993) reported the larval rearing and growth of *T. acutidens* fed with *Artemia* nauplii. They recognized five zoeal stages, and the minimum durations of the zoeal stages I-V at 15°C to be 5, 4, 3, 3, and 5 days, respectively (Table 2). On the contrary, only four zoeal stages were observed in the present study. Compared with the data of Lee et al. (1993), the author's zoeas were smaller, but survival rates were higher. The occurrence of extra zoeal stage was considered to be due to stress imposed by a prolonged period of maintaining the ovigerous crabs in the laboratory (Ong and Costlow, 1970; Christiansen and Costlow, 1975; Johns et al., 1980). According to Lee et al. (1993), the ovigerous females were held in running seawater in the laboratory for one year before larvae hatched, while in the present study, larvae hatched only one week after the ovigerous crab was collected. Extra zoeal stage isn't apparently unusual in the laboratory-cultured brachyuran zoeas. For example, Wilson (1980) noted that *Euchirograpsus americanus* possessed either five or six zoeal stages in laboratory conditions. An

Table 3. A comparison of the first stage zoeal characteristics from known descriptions of the family Atelecyclidae

Species	*Atelecyclus rotundatus*	*Peltarion spinosulum*	*Telmessus cheiragonus*	*Telmessus acutidens*	*Erimacrus isenbeckii*
Authors	Hong and Ingle (1987)	Irio (1983)	Kurata (1963)	Present study	Sasaki and Mihara (1993)
Antenna					
terminal setae of exopod	3	3	2	2	2
Maxillule					
setation of endopod	1, 5	1, 6	1, 6	1,6	1, 6
Maxilla					
setation of endopod	4+3 (7)	3+5 (8)	3+5 (8)	3+5 (8)	3+5 (8)
Endopod of first maxilliped					
setae of proximal segment	2	3	3 [as figured by Rice (1980)]	3	3 (Lee et al., unpublished)
Second maxilliped					
setation of endopod	1, 1, 5	1, 1, 6	1, 1, 5	1, 1, 5	1, 1, 5 (Lee et al., unpublished)
Abdomen					
lateral process	somite 2	somite 2	somite 2	somite 2	somites 2, 3
Telson					
lateral spine	1 small+1 minute	2 small	1 long+1 smaller	1 long+1 smaller	1 very long+1 smaller

extra zoea seemed to be found in the present study because ten natatory plumose setae were bearing on exopods of maxillipeds in the third and fourth zoeas. The number of setae on an exopod of maxilliped increases through the moulting in all brachyuran zoeas, so, the number of ten in the third zoeal stage should be changed to 12 in the next zoeal stage. Besides, bud of a zoeal pleopod appears from the first zoeal stage in the present species, whereas in other atelecyclid zoeas it shows at the second zoeal stage (*T. cheiragonus*, *Erimacrus isenbeckii*, *Peltarion spinosulum*) or the fourth zoeal stage (*Atelecyclus rotundatus*) (Kurata, 1963; Irio, 1983; Hong and Ingle, 1987). Therefore, it is suggested that *T. acutidens* may have three zoeal stages in natural conditions.

As shown in Table 3, the zoeas of *Telmessus acutidens* coincide well with those of *T. cheiragonus* (see Rice, 1980) and *Erimacrus isenbeckii* (see Sasaki and Mihara, 1993; Lee et al., unpublished) on the following characteristics, which are consistent throughout all zoeal stages: carapace with all spines, exopod of antenna with 2 setae, endopod of maxillule with 1, 6 setae, endopod of maxilla with 3+5 (8) setae, proximal segment of first maxilliped with 3 setae, endopod of second maxilliped with 1, 1, 5 setae, and fork of telson with a lateral long, a lateral smaller and a smaller dorsomedial spine. However, these zoeas can be easily identified on the basis of the presence of the lateral process of the abdomen and the length of the posterolateral process on abdominal somite 4, as follows:

1. Lateral process on abdominal somites 2 and 3; posterolateral process on abdominal somite 4 spinulate, longer than length of somite 5 ····· *Erimacrus isenbeckii*
   – Lateral process on abdominal somite 2; posterolateral process on abdominal somite 4 reaching to 1/2 length of somite 5 ····· *Telmessus cheiragonus*
   – Lateral process on abdominal somite 2; posterolateral process on abdominal somite 4 reaching to 1/3 length of somite 5 ····· *T. acutidens*

Rice (1981) suggested that the zoeas of *Telmessus* and *Erimacrus* were unlike those of the Atelecyclidae, *sensu stricto*, so they must be separated completely from that family. Further, Stevcic (1988) reexamined the systematic status of the two genera and supported their inclusion in the family Cheiragonidae Ortmann, 1893, based on adult characters. According to Table 3, the zoeas of three species, *T. cheiragonus*, *T. acutidens*, and *Erimacrus isenbeckii*, are significantly different from the zoeas of *Atelecyclus rotundatus*, the type species of the type genus of the Atelecyclidae. Also, they show remarkably different characteristics compared with those of two other species, *Thia scutellata* (Fabricius, 1793) of the Thiidae and *Pirimela denticulate* (Montagu, 1808) of the Pirimelidae, both these latter species possess two setae on the proximal segment of the first maxilliped and 1, 1, 4 setations on the endopod of the second maxilliped (Ingle, 1984; Paula, 1987). Thus, the author supports the contentions of Rice (1981) and Stevcic (1988)

that these two genera should be removed from the Atelecyclidae.

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REFERENCES

Aikawa, H., 1937. Further notes on brachyuran larvae. Rec. oceanogr. Wks. Japan, 9: 87-162.

Bourdillon-Casanova, L., 1960. Le méroplancton du golfe de Marseille: les larves de Crustacés Décapodes. Rec. Trav. Sta. mar. Endoume, 30: 1-286.

Christiansen, M.E. and J.D. Costlow, Jr., 1975. The effect of salinity and cyclic temperature on larval development of the mud crab *Rhithropanopeus harrisii* (Brachyura: Xanthidae) reared in the laboratory. Mar. Biol., 32: 215-221.

Clark, P.F., D.K. Calazans and G.W. Pohle, 1998. Accuracy and standardisation of brachyuran larval descriptions. Invert. Reprod. Develop., 33: 127-144.

Hong, S.Y. and R.W. Ingle, 1987. Larval development of the circular crab, *Atelecyclus rotundatus* (Olivi) (Crustacea: Brachyura: Atelecyclidae) reared in the laboratory. J. Nat. Hist., 21: 1539-1560.

Ingle, R.W., 1984. The larval and post-larval development of the thumb-nail crab, *Thia scutellata* (Fabricius) (Decapoda: Brachyura). Bull. British Mus. (nat. Hist.) (Zool.), 47: 53-64.

Ingle, R.W., 1991. Larval stages of northeastern Atlantic crabs. An illustrated key. (London: nat. Hist. Mus. Publ. Chapman and Hall), pp. 1-363.

Irio, M.I., 1983. Estadios larvales del cangrejo *Pellatrion spinosulum* (White) (Crustacea, Decapoda, Brachyura, Atelecyclidae). Physis (Buenos Aires), 41: 143-156.

Johns, D.M., M.E. Peters and A.D. Beck, 1980. International study on *Artemia*. VI. Nutritional value of geographical and temporal strains of *Artemia*: effects on survival and growth of two species of brachyuran larvae. pp. 291-304. *In* The brine shrimp *Artemia*. Vol. 3. Ecology, Culturing, Use in Aquaculture. Persoone G., P. Sorgeloos, O. Roels, and E. Jaspers (Eds). Universa Press, Wetteren, Belgium, pp. 1-456.

Kim, H.S., 1973. Anomura, Brachyura. Illustrated Encyclopedia of Fauna and Flora of Korea, (Seoul: Sam Wha) pp. 1-506 [In Korean].

Ko, H.S., 1995. Larval development of *Benthopanope indica* (De Man, 1887) (Decapoda: Brachyura: Pilumnidae) in the Laboratory. J. Crust. Biol., 15: 280-290.

Kurata, H., 1963. Larvae of Decapoda Crustacea of Hokkaido 1. Atelecyclidae (Atelecyclinae). Bull. Hokkaido Reg. Fish. Res. Lab., 27: 13-24.

Lebour, M.V., 1928. The larval stages of the Plymouth Brachyura. Proc. Zool. Soc. London, 1928: 473-560.

Lee, H.Y., Y.G. Rho and M.W. Park, 1993. Larval rearing and growth of Hair crab, *Telmessus acutidens* (Stimpson). Bull. nat. Fish. Res. Develop. Agency, 47: 117-131.

Lee, J., Y.B. Moon, I.G. Jeon, J.M. Shim and H.S. Ko, Early zoeal satges of *Erimacrus isenbeckii* (Brandt, 1848) (Crustacea: Decapoda: Brachyura: Atelecyclidae) and a comparison with other zoeal larvae [unpublished].

Marukawa, H. and H. Chong, 1933. [Oh-kurigani *Erimacrus isenbeckii* (Brandt), Larval stage ni tsuite]. Rakusuikai-shi, 28: 1-11 [In Japanese].

Marukawa, H. and K. Yasunari, 1931. [Kegani matawa Oh-kurigani *Erimacrus isenbeckii* (Brandt), Megalopa oyobi sono Chokugo-yosei ni tsuite]. Suisan-Kenkyu-shi, 26: 1-11 [In Japanese].

Ong, K.S. and J.D. Costlow, Jr., 1970. The effect of salinity and temperature on the larval development of the stone crab *Menippe mercenaria* (Say), reared in the laboratory. Chesapeake Sci., 11: 16-29.

Paula, J., 1987. Planktonic stages of brachyuran crabs from the south-western Iberian coast (Crustacea, Decapoda, Brachyura). J. nat. Hist., 21: 717-756.

Rice, A.L., 1980. Crab zoeal morphology and its bearing on the classification of the Brachyura. Trans. zool. Soc. London, 25: 271-424.

Rice, A.L., 1981. The megalopa stage in brachyuran crabs: The Podotremata Guinot. J. nat. Hist., 15: 1003-1011.

Sakai, T., 1976. Crabs of Japan and adjacent Seas, (Tokyo: Kodansha Ltd), [*In* 3 volumes: (1) English text, pp. 1-773. (2) Plates volume, pp. 1-251. (3) Japanese text, pp. 1-461].

Sasaki, J. and Y. Mihara, 1993. Early larval stages of the hair crab *Erimacrus isenbeckii* (Brandt) (Brachyura: Atelecyclidae), with special reference to its hatching process. J. Crust. Biol., 13: 511-522.

Stevcic, Z., 1988. Family Cheiragonidae. Oebalia, 14: 33-41.

Wilson, K.A., 1980. Studies on decapod Crustacea from the Indian river region of Florida. XV. The larval development under laboratory conditions of *Euchirograpsus americanus* A. Milne Edwards, 1880 (Crustacea: Decapoda: Grapsidae) with notes on grapsid subfamilial larval characters. Bull. Mar. Sci., 30: 756-775.

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