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Complete Larval Development of *Hemigrapsus longitarsis* (Miers, 1879) (Crustacea, Decapoda, Grapsidae), with a Key to the Known Grapsid Zoeas of Korea

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Zoea
Key
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Korea

One ovigerous crab of *Hemigrapsus longitarsis* (Miers, 1879) was collected in Jeju Island, Korea and their larvae were reared in the laboratory. Five zoeal and one megalopal stages are described and illustrated in detail. Morphology of the zoeas slightly differs from that in the previous record. Within the genus *Hemigrapsus*, *H. longitarsis* shows similarity closer to *H. sanguineus* and *H. penicillatus* than to *H. sinensis* based on the zoeal morphology. The zoeas of *H. longitarsis* can be distinguished from those of the two other species in having a dorsal carapace spine with minute spinules which is naked in *H. sanguineus* and *H. penicillatus*. A provisional key is provided to aid the identification of the grapsid zoeas in Korea.

The family Grapsidae consists of 30 species of four subfamilies from Korea (Kim, 1973; The Korean Society of Systematic Zoology, 1997; Yang and Ko, 2000). The larval stages of this group are the best known through rearing studies in the families of Brachyura. The larval descriptions have existed for 27 species: Grapsinae, *Pachygrapsus crassipes* Randall, 1840 by Schlotterbeck (1976); Varuninae, *Acmeopleura parvula* Stimpson, 1858 by Kim and Jang (1987); *A. balssi* Shen, 1932 by Ok (2001); *Eriorcheir sinensis* H. Milne Edawards, 1853 by Lee (1982); *E. japonicus* De Haan, 1835 by Kim and Hwang (1990); *E. leptognathus* Rathbun, 1914 by Lee (1988); *Hemigrapsus sanguineus* (De Haan, 1835) by Hwang et al. (1993); *H. penicillatus* (De Haan, 1835) and *H. longtarsis* (Miers, 1879) by Terada (1981); *H. sinensis* Rathbun, 1929 by Kim and Moon (1987); *Gaetice depressus* (De Haan, 1835) by Kim and Lee (1983); Sesarminae, *Nanosesarma gordoni* (Shen, 1935) by Terada (1982); *Sesarma pictum* (De Haan, 1835) by Lee (1988); *S. plicatum* (Latreille, 1806), *S. intermedium* (De Haan, 1835), *S. bidens* (De Haan, 1835), and *S. haematocheir* (De Haan, 1835) by Baba and Fukuda (1976); *S, dehaani* H. Milne Edwards, 1853 by Baba and Miyata (1971); *S. erythrodactyla* (Hess, 1865) by Kim and Ko (1985); *Cyclograpsus intermedius* Ortmann, 1894 by Kim and Jang (1986); *Chasmagnathus convexus* De Haan, 1835 by Baba and Fukuda (1972); *Helice tridens tridens* De Haan, 1835 and *H. t. wuana* Rathbun, 1929 by Baba and Moriyama (1972); *H. t. sheni* Sakai, 1939 by Kim and Ko (1984); *H. t. tientsinensis* Rathbun, 1929 Park (1983); *H. leachi* Hess, 1865 by Baba et al. (1984); Plagusiinae, *Plagusia dentipes* De Haan, 1835 by Lee (1988).

Hemigrapsus longitarsis (Miers, 1879) is found on the weedy and sandy bottoms from littoral to 10-20 m depth (Sakai, 1976). This species is distributed in the coasts of northern China, Korea and Japan (Kim, 1973; Sakai, 1976). Although, the zoeal stage of *H. longitarsis* was first described by Terada (1981), this report was limited to the brief comments and illustrations, with no record on the megalopal stage. Therefore, this paper aims to describe the complete larval stages of *H. longitarsis* in detail including its megalopal stage, to compare its morphology with previously described *Hemigrapsus* zoeas and to provide a key to the known grapsid zoeas in Korea.

Materials and Methods

One ovigerous crab of *Hemigrapsus longitarsis* (Miers, 1879) was collected by us in Jeju Island, Korea, on 5 July 2001 and was transported to a constant temperature chamber in the laboratory. The zoeas of the first stage were hatched on 14 July 2001 and were reared using methods described by Ko (1995) at a constant water temperature of 25℃. Larvae were fixed and preserved in 10% neutral formalin. Appendages were mounted in polyvinyl lactophenol and sealed with clear nail varnish along the margins of the cover slip. Drawings were made with the aid of a camera lucida. Setal counts and measurements were based on *ca.* 10 specimens for each larval stage. The sequence of the larval description is based on the malacostracan somite

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plan and described from anterior to posterior. Setal armature of appendages was described from proximal to distal segments and in order of endopod to exopod (see Clark et al., 1998). The larval series and the spent females were deposited in Silla University, Korea. For the second and subsequent larval stages, only the main differences from the previous stage were described. The long plumose natatory setae of the first and second maxillipeds, the telson fork and the long antennular aesthetascs, were drawn truncated.

Results

Five zoeal stages appeared before metamorphosis to the megalopa. Metamorphosis to megalopa occurred at least 16 days after the first stage zoeas hatched from eggs.

Hemigrapsus longitarsis (Miers, 1879)

Zoea I

Size: Carapace length 0.40±0.01 mm. Distance from tip of dorsal spine to tip of rostral spine 0.82±0.02 mm.

Carapace (Fig. 1A, B, C): Dorsal spine long, slightly curved, with minute spinules and about equal in length to rostral spine; rostral spine straight and slightly longer than antennal protopod; lateral spines present and short; anterodorsal setae absent; 1 pair of posterodorsal setae present; each ventral margin without setae; eyes sessile.

Antennule (Fig. 1D): Uniramous; endopod absent; exopod unsegmented with 3 long (2 stout + 1 thinner) aesthetascs and 1 small seta, all terminal.

Antenna (Fig. 1E): Protopod shorter than rostral spine and spinulate; exopod more than 50% length to protopod, with 1 larger and 1 small medial spines. Endopod absent.

Mandibles (Fig. 1F): Asymmetrical; right molar with 3 teeth and left molar with 1 tooth, confluent with incisor process; endopod palp absent.

Maxillule (Fig. 1G): Coxal epipod absent, coxal endite with 5 terminal setae; basial endite with 5 setal processes; endopod 2-segmented, proximal segment with 1 seta, distal segment with 5 (1 subterminal + 4 terminal) setae; exopod seta absent.

Maxilla (Fig. 1H): Coxal endite bilobed with 4 + 3 setae; basial endite bilobed with 5 + 4 setae; endopod bilobed with 2 + 2 setae; exopod (scaphognathite) margin with 4 plumose setae plus distal stout process.

First maxilliped (Fig. 2A): Coxa without seta; basis with 10 setae arranged 2, 2, 3, 3; endopod 5-segmented with 2, 2, 1, 2, 5 (1 subterminal + 4 terminal) setae, respectively; exopod 2-segmented, distal segment with 4 terminal natatory plumose setae.

Second maxilliped (Fig. 2B): Coxa without seta; basis with 4 setae; endopod 3-segmented, with 0, 1, 6 (3 subterminal + 3 terminal) setae, respectively; exopod 2-segmented, distal segment with 4 terminal natatory plumose setae.

Third maxilliped: Absent.

Abdomen (Fig. 2D): 5 somites; somite 2 with pair of lateral processes directed anteriorly; somite 3 with pair of lateral processes directed posteriorly; somites 2-5 with 1 pair of posterodorsal setae; pleopods absent.

Telson (Fig. 2C, D): Each fork long and spinulate, without seta or spine; posterior margin with 3 pairs of stout spinulate setae.

Zoea II

Size: Carapace length 0.44±0.02 mm. Distance from tip of dorsal spine to tip of rostral spine 1.05±0.04 mm.

Carapace (Fig. 3A, B, C): Two pairs of anterodorsal setae present; ventral margin with seta; eyes stalked.

Antennule (Fig. 3D): Exopod with 5 long (4 stout + 1 thinner) aesthetascs and 1 small seta, all terminal.

Antenna (Fig. 3E): Unchanged.

Mandibles (Fig. 3F): Right molar with 4 teeth and left molar with 1 tooth, confluent with incisor process.

Maxillule (Fig. 3G): Basial endite with 7 setal processes; exopod seta present.

Maxilla (Fig. 3H): Exopod (scaphognathite) margin with 5 + 3 plumose setae.

First maxilliped (Fig. 4A): Exopod with 6 terminal natatory plumose setae.

Second maxilliped (Fig. 4B): Exopod with 6 terminal natatory plumose setae.

Abdomen (Fig. 4D): Somite 1 with a dorsomedial seta.

Telson (Fig. 4C, D): Unchanged.

Zoea III

Size: Carapace length 0.56±0.04 mm. Distance from tip of dorsal spine to tip of rostral spine 1.37±0.06 mm.

Carapace (Fig. 5A, B, C): Dorsal spine with pair of medial setae; four pairs of anterodorsal setae present; ventral margin with 5 marginal setae.

Antennule (Fig. 5D): Exopod with 3 long (2 stout + 1 thinner) aesthetascs and 1 small seta.

Antenna (Fig. 5E): Unchanged.

Mandibles (Fig. 5F): Unchanged.

Maxillule (Fig. 5G): Basial endite with 8 setal processes.

Maxilla (Fig. 5H): Exopod (scaphognathite) margin with 7 + 5 plumose setae.

First maxilliped (Fig. 6A): Endopod 5-segmented with 2, 2, 2, 2, 5 setae respectively; exopod with 8 terminal natatory plumose setae.

Second maxilliped (Fig. 6B): Exopod with 8 terminal natatory plumose setae.

Pereiopod (Fig. 6C): Uniramous bud.

Abdomen (Fig. 6E): 6 somites.

Telson (Fig. 6D, E): Posterior margin with 4 pairs of stout spinulate setae.

Zoea IV

Size: Carapace length 0.77±0.01 mm. Distance from

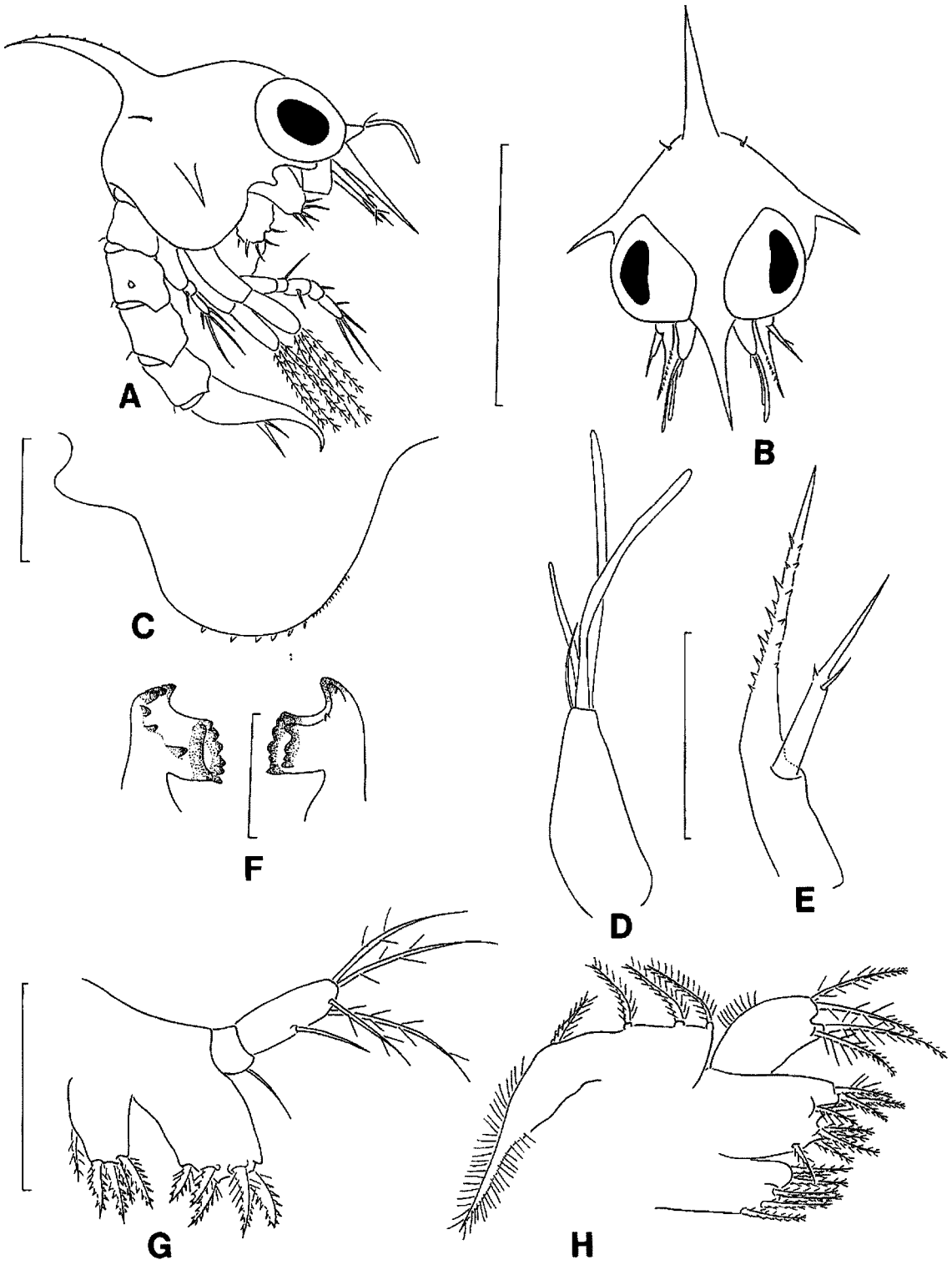

Fig. 1. *Hemigrapsus longitarsis*, first zoeal stage. A, Lateral view. B, Anterodorsal view of carapace. C, Lateral expansion of carapace. D, Antennule. E, Antenna. F, Mandibles. G, Maxillule. H, Maxilla. Scale bars = 0.1 mm (C-H) and 0.5 mm (A, B).

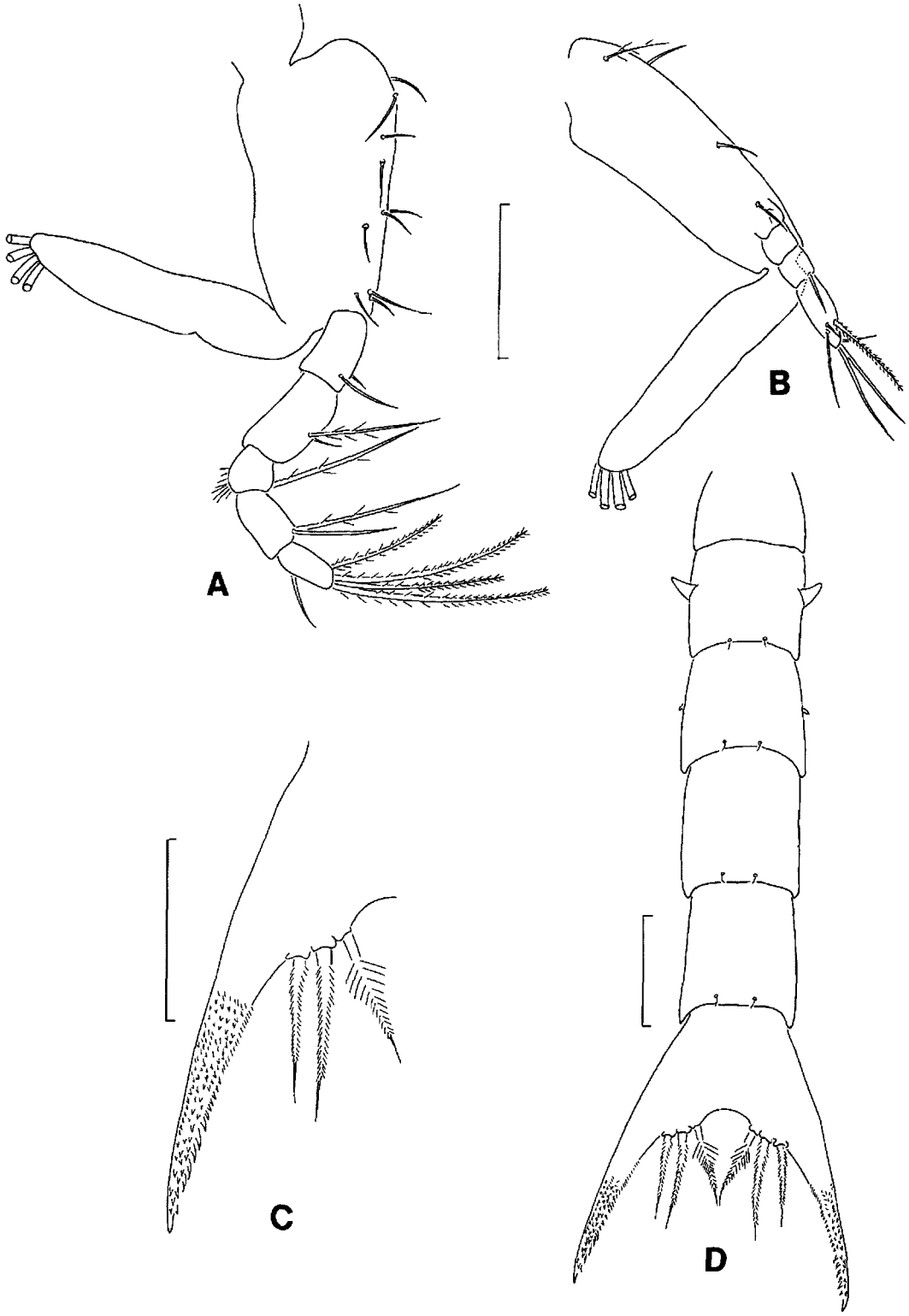

Fig. 2. *Hemigrapsus longitarsis*, first zoeal stage. A, First maxilliped. B, Second maxilliped. C, Fork of telson. D, Dorsal view of abdomen and telson Scale bars = 0.1 mm.

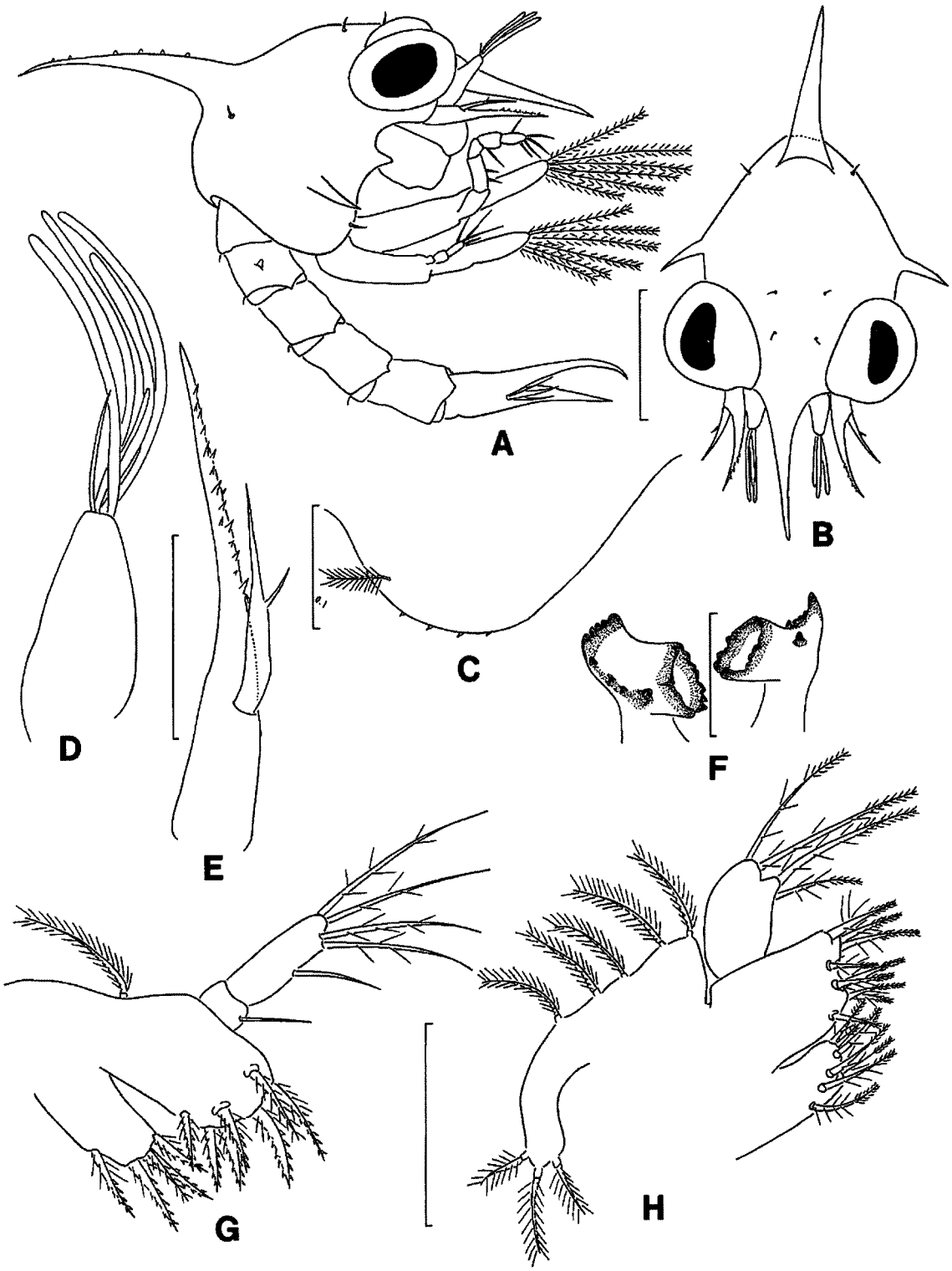

Fig. 3. *Hemigrapsus longitarsis*, second zoeal stage. A, Lateral view. B, Anterodorsal view of carapace. C, Lateral expansion of carapace. D, Antennule. E, Antenna. F, Mandibles. G, Maxillule. H, Maxilla. Scale bars = 0.1 mm (C-H) and 0.25 mm (A, B).

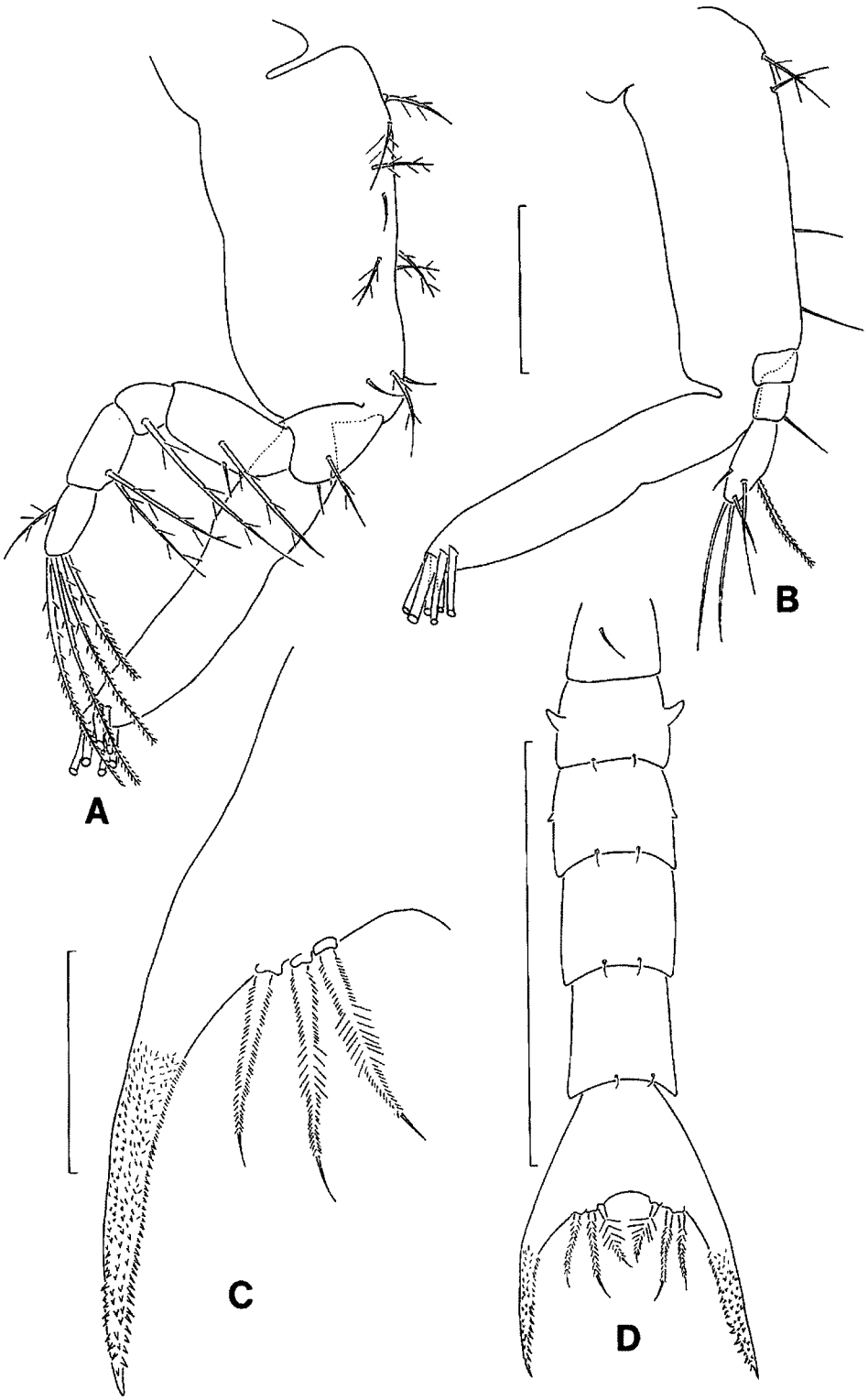

Fig. 4. *Hemigrapsus longitarsis*, second zoeal stage. A, First maxilliped. B, Second maxilliped. C. Fork of telson. D, Dorsal view of abdomen and telson. Scale bars = 0.1 mm (A-C) and 0.5 mm (D).

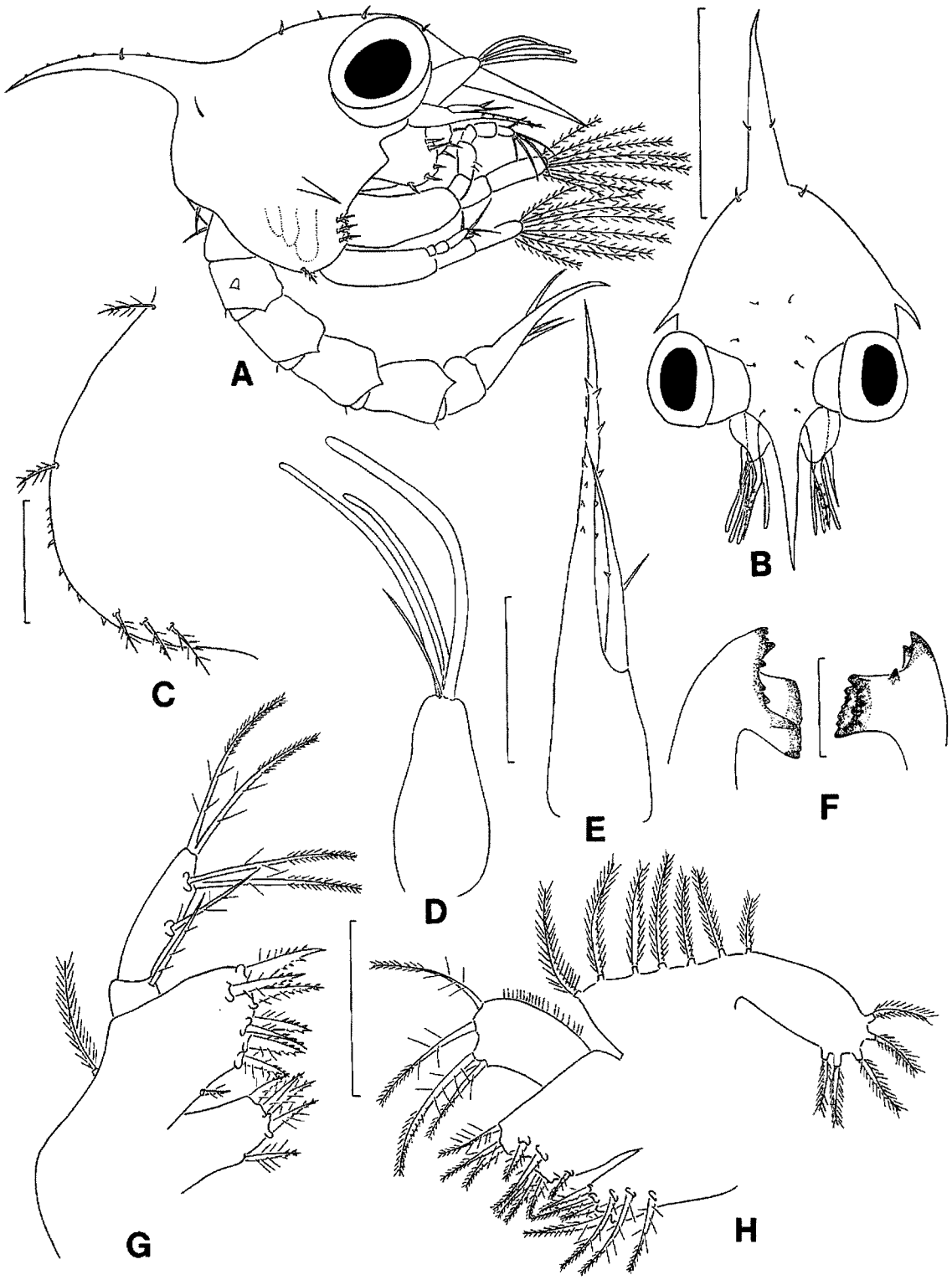

Fig. 5. *Hemigrapsus longitarsis*, third zoeal stage. A, Lateral view. B, Anterodorsal view of carapace. C, Lateral expansion of carapace. D, Antennule. E, Antenna. F, Mandibles. G, Maxillule. H, Maxilla. Scale bars = 0.1 mm (C-H) and 0.5 mm (A, B).

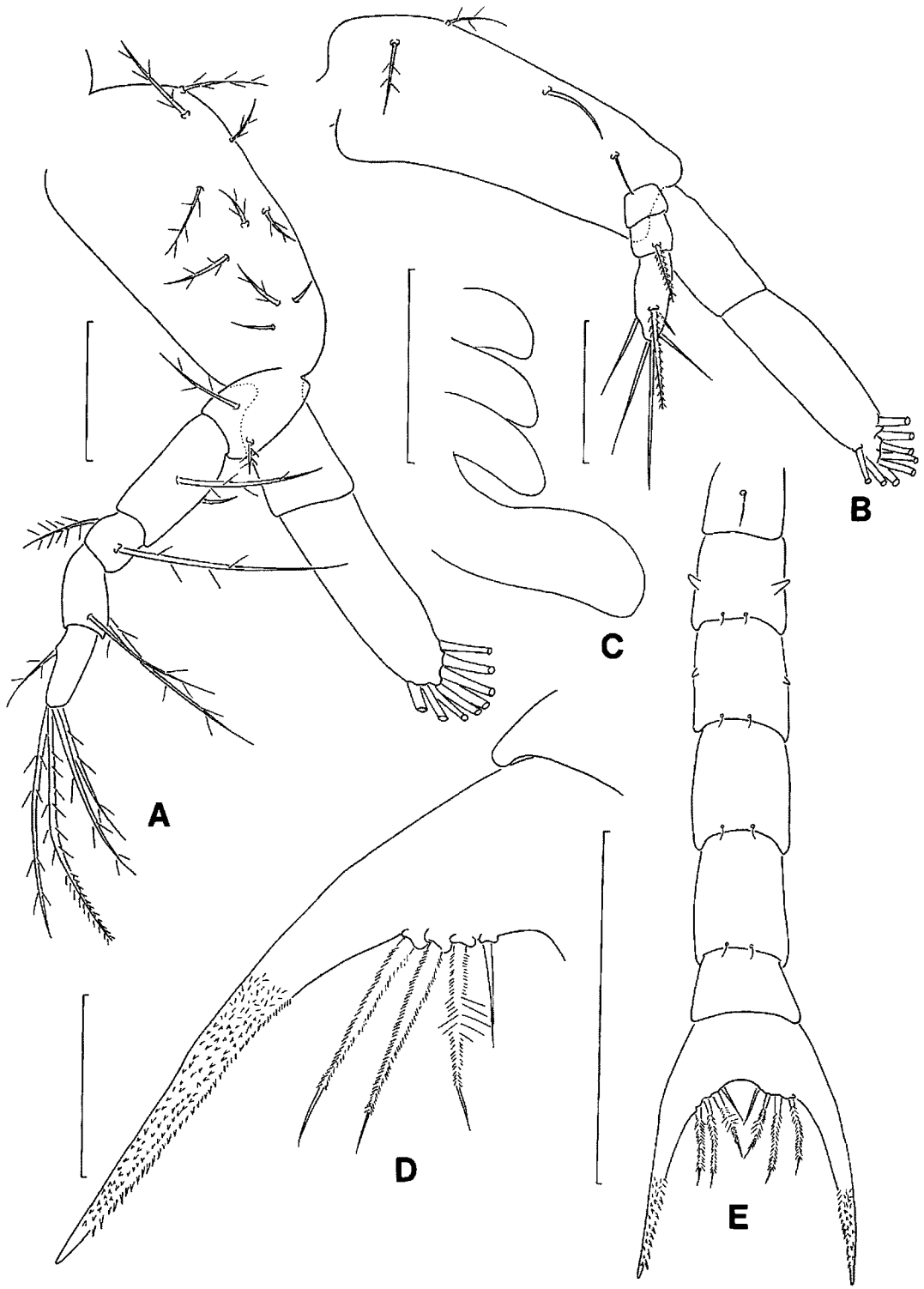

Fig. 6. *Hemigrapsus longitarsis*, third zoeal stage. A, First maxilliped. B, Second maxilliped. C, Pereiopods. D, Fork of telson. E, Dorsal view of abdomen and telson. Scale bars = 0.1 mm (A-D) and 0.5 mm (E).

tip of dorsal spine to tip of rostral spine 1.66±0.08 mm.

Carapace (Fig. 7A, B, C): Dorsal spine with 2 pairs of medial setae; 5 pairs of anterodorsal setae present; ventral margin with 8 setae.

Antennule (Fig. 7D): Exopod with 3 long (2 stout + 1 thinner) aesthetascs and 1 small seta terminally and 2 aesthetascs subterminally.

Antenna (Fig. 7E): Endopod bud present.

Mandibles (Fig. 7F): Right molar with 5 teeth and left molar with 1 tooth, confluent with incisor process.

Maxillule (Fig. 7G): Coxal epipod present as 2 setae, coxal endite with 7 terminal setae; basial endite with 11 setal processes.

Maxilla (Fig. 7H): Coxal endite bilobed with 5 + 3 setae; basial endite bilobed with 6 + 5 setae; exopod (scaphognathite) margin with 20 plumose setae.

First maxilliped (Fig. 8A): Coxa with 1 seta; endopod 5-segmented with 2, 3, 2, 2, 6 (2 subterminal+4 terminal) setae respectively; exopod 2-segmented with 10 terminal natatory plumose setae.

Second maxilliped (Fig. 8B): Exopod 2-segmented with 10 terminal natatory plumose setae.

Third maxilliped (Fig. 8C): Biramous.

Pereiopod (Fig. 8D): Chela biramous.

Abdomen (Fig. 8F): Somite 1 with 3 dorsomedial setae; pleopod buds present.

Telson (Fig. 8E, F): Unchanged.

Zoea V

Size: Carapace length 0.93±0.05 mm. Distance from tip of dorsal spine to tip of rostral spine 2.05±0.16 mm.

Carapace (Fig. 9A, B, C): Dorsal spine with 3 pairs of setae; 6 pairs of anterodorsal setae present; each ventral margin with 13 setae.

Antennule (Fig. 9D): Endopod bud present; exopod with 4 long aesthetascs and 1 small seta terminally and 3 aesthetascs subterminally.

Antenna (Fig. 9E): Endopod enlarged and segmented.

Mandibles (Fig. 9F): Right molar with 6 teeth and left molar with 1 tooth, confluent with incisor process; endopod palp present.

Maxillule (Fig. 9G): Coxal and basial endite each with 8, 16 setal processes, respectively.

Maxilla (Fig. 9H): Coxal endite bilobed with 8 + 3 setae; basial endite bilobed with 8 + 8 setae; exopod (scaphognathite) margin with 29 setae.

First maxilliped (Fig. 10A): Coxa with 2 setae; exopod with 12 terminal natatory plumose setae.

Second maxilliped (Fig. 10B): Exopod with 12 terminal natatory plumose setae.

Third maxilliped (Fig. 10C): Gill present.

Pereiopod (Fig. 10D): More developed.

Abdomen (Fig. 10F): Somite 1 with 5 dorsomedial setae; pleopods 1-3 with endopod buds.

Telson (Fig. 10E, F): Dorsal surface with 1 pair of setae; posterior margin with 5 pairs of stout spinulate setae.

Megalopa

Size. Carapace length 1.47±0.09 mm. Carapace width 1.32±0.05 mm.

Carapace (Fig. 11A, B): Tubercles present; rostrum as a single median process.

Antennule (Fig. 11C): Exopod 4-segmented, with total of 17 aesthetascs plus 2 setae; endopod with 1 subterminal plus 3 terminal setae.

Antenna (Fig. 11D): 11-segmented, with 0, 2, 1, 1, 0, 4, 2, 2, 4, 3 and 3 terminal setae.

Mandible (Fig. 11E): Distal segment palp with 9 setae.

Maxillule (Fig. 11F): Exopod and coxal epipod present as setae; endopod with 1 + 2 + 2 setae; coxal and basial endites each with 28 and 11 setae, respectively.

Maxilla (Fig. 11G): Endopod with 2 proximal setae; coxal and basal endites 2-lobed each with 14 + 9, 4 + 15 setae, respectively; exopod (scaphognathite) margin with 54 setae, surface with 6 setae.

Abdomen (Fig. 11H): 6-somites with numerous setae.

Telson (Fig. 11H): With 3 terminal plumose setae.

Pereiopd (Fig. 12A-E): With numerous setae; dactylus of ambulatory leg 4 with 3 long setae.

First maxilliped (Fig. 12F): Endopod with 2 setae; coxal and basial endites each with 11 and 14 setae, respectively; exopod 2-segmented, proximal with 2 terminal plumose and distal with 4 terminal plumose and simple setae; epipod with 7 and a simple setae.

Second maxilliped (Fig. 12G): Endopod 4-segmented with 2, 1, 8, and 9 setae, respectively; exopod 2-segmented, proximal with middle spine and distal with 5 terminal setae; epipod with 4 simple setae.

Third maxilliped (Fig. 12H): Endopod 5-segmented with 15, 10, 4, 13 and 8 setae; exopod with 2-segmented, proximal with 4 setae and distal with 5 terminal plumose setae; epipod with 30 setae on terminal segment.

Pleopod (Fig. 12I-M). Pleopods 1-4 with 14, 19, 17 and 14 plumose setae on distal segment; pleopod 5 with 10 plumose setae on distal and a plumose seta on proximal segments.

Discussion

Terada (1981) first described the zoeal stages of *Hemigrapsus longtarsis.* This report was limited to the brief comments and illustrations, and therefore he omitted descriptions or illustrations about the setal presence of the mouthpart appendages and the carapace (see Table 1).

The zoeal stages of four *Hemigrapsus* species have been reported from Korea and the adjacent waters: *H. sanguineus* by Hwang et al. (1993), *H. penicillatus* and *H. longtarsis* by Terada (1981), and *H. sinensis* by Kim and Moon (1987). Their common characteristics can be summarized as follows: carapace with all spines; antennal exopod with 2 medial spines more than 40% in length of protopod (except in *H. sinensis*); endopod of maxillule with 1 + 4 setae; endopod of maxilla with 2 +

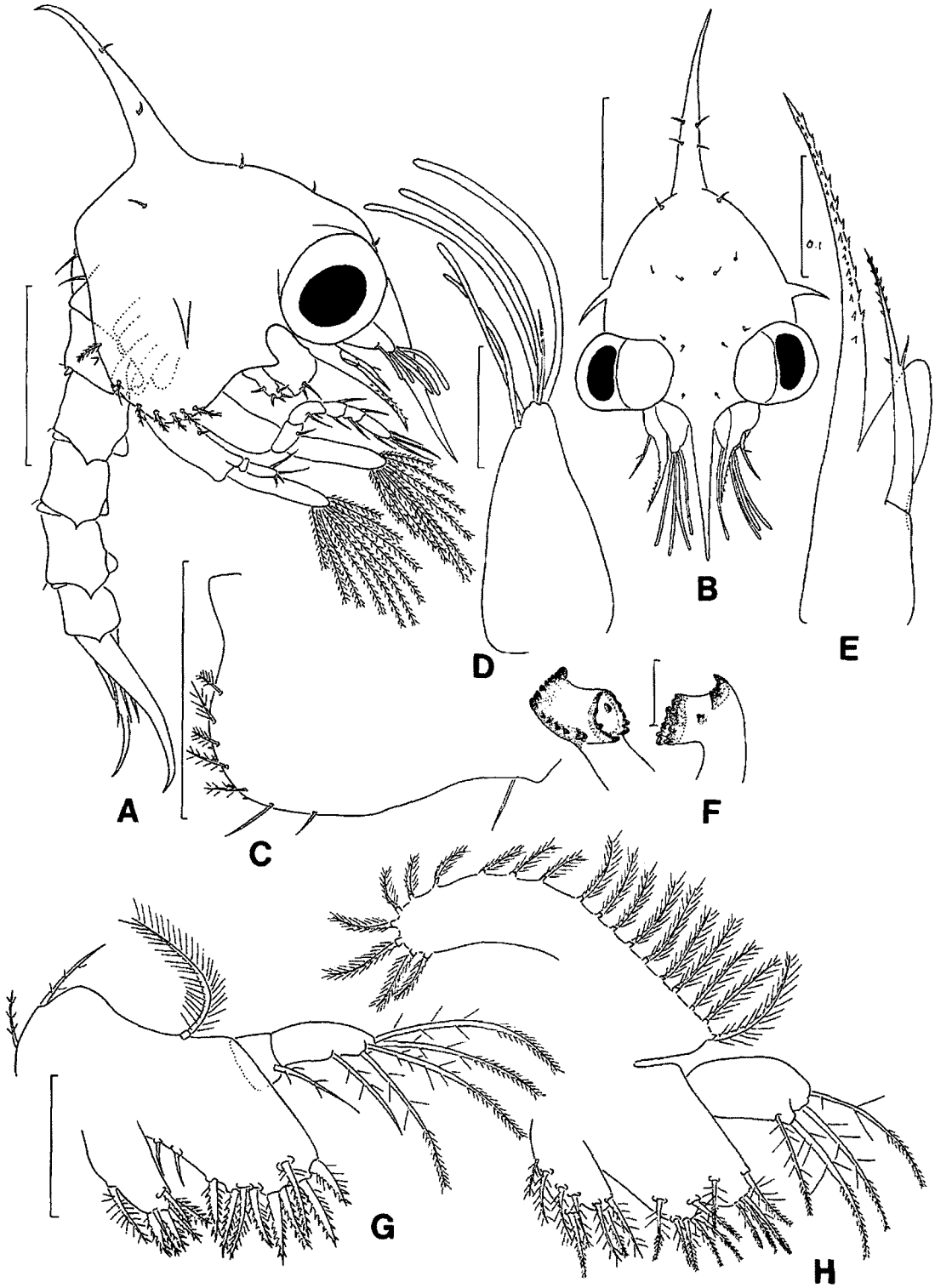

Fig. 7. *Hemigrapsus longitarsis*, fourth zoeal stage. A, Lateral view. B, Anterodorsal view of carapace. C, Lateral expansion of carapace. D, Antennule. E, Antenna. F, Mandibles. G, Maxillule. H, Maxilla. Scale bars = 0.1 mm (D-H) and 0.5 mm (A-C).

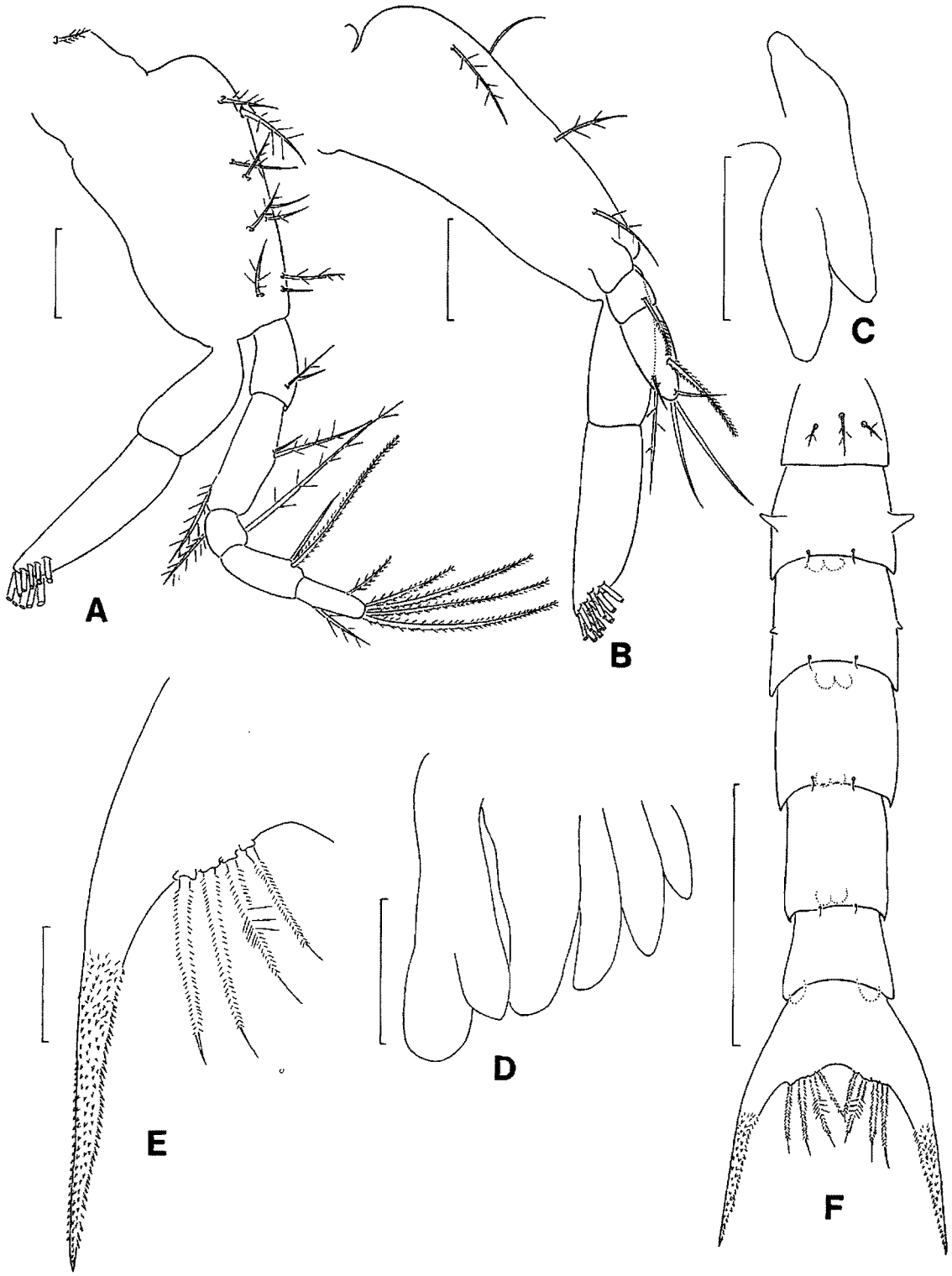

Fig. 8. *Hemigrapsus longitarsis*, fourth zoeal stage. A, First maxilliped. B, Second maxilliped. C. Third maxilliped. D, Pereiopods. E, Fork of telson. F, Dorsal view of abdomen and telson. Scale bars = 0.1 mm (A-E) and 0.5 mm (F).

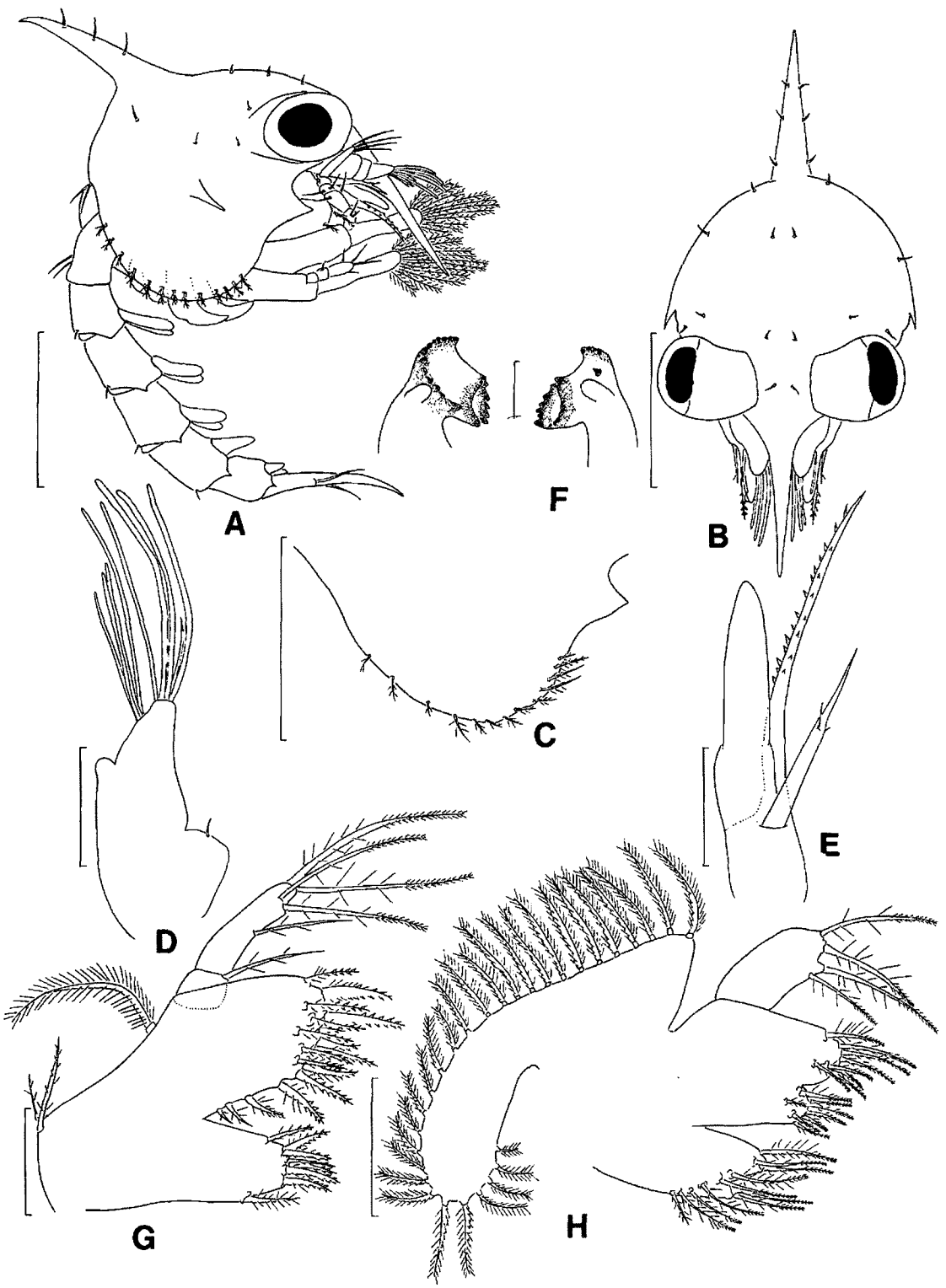

Fig. 9. *Hemigrapsus longitarsis*, fifth zoeal stage. A, Lateral view. B, Anterodorsal view of carapace. C, Lateral expansion of carapace. D, Antennule. E, Antenna. F, Mandibles. G, Maxillule. H, Maxilla. Scale bars = 0.1 mm (D-G) and 0.5 mm (A-C, H).

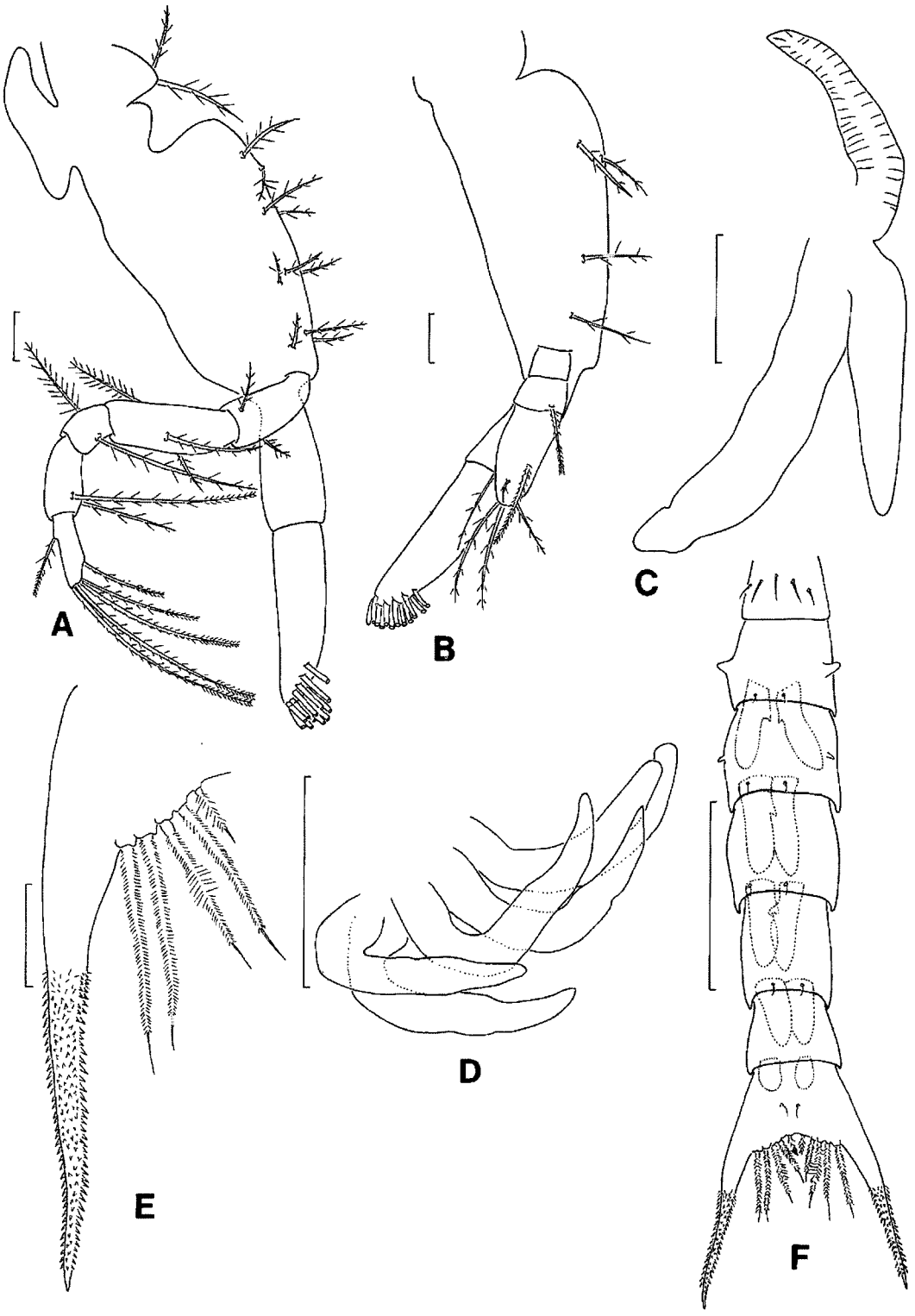

Fig. 10. *Hemigrapsus longitarsis*, fifth zoeal stage. A, First maxilliped. B, Second maxilliped. C, Third maxilliped. D, Pereiopods. E, Fork of telson. F, Dorsal view of abdomen and telson. Scale bars = 0.1 mm (A-C, E) and 0.5 mm (D, F).

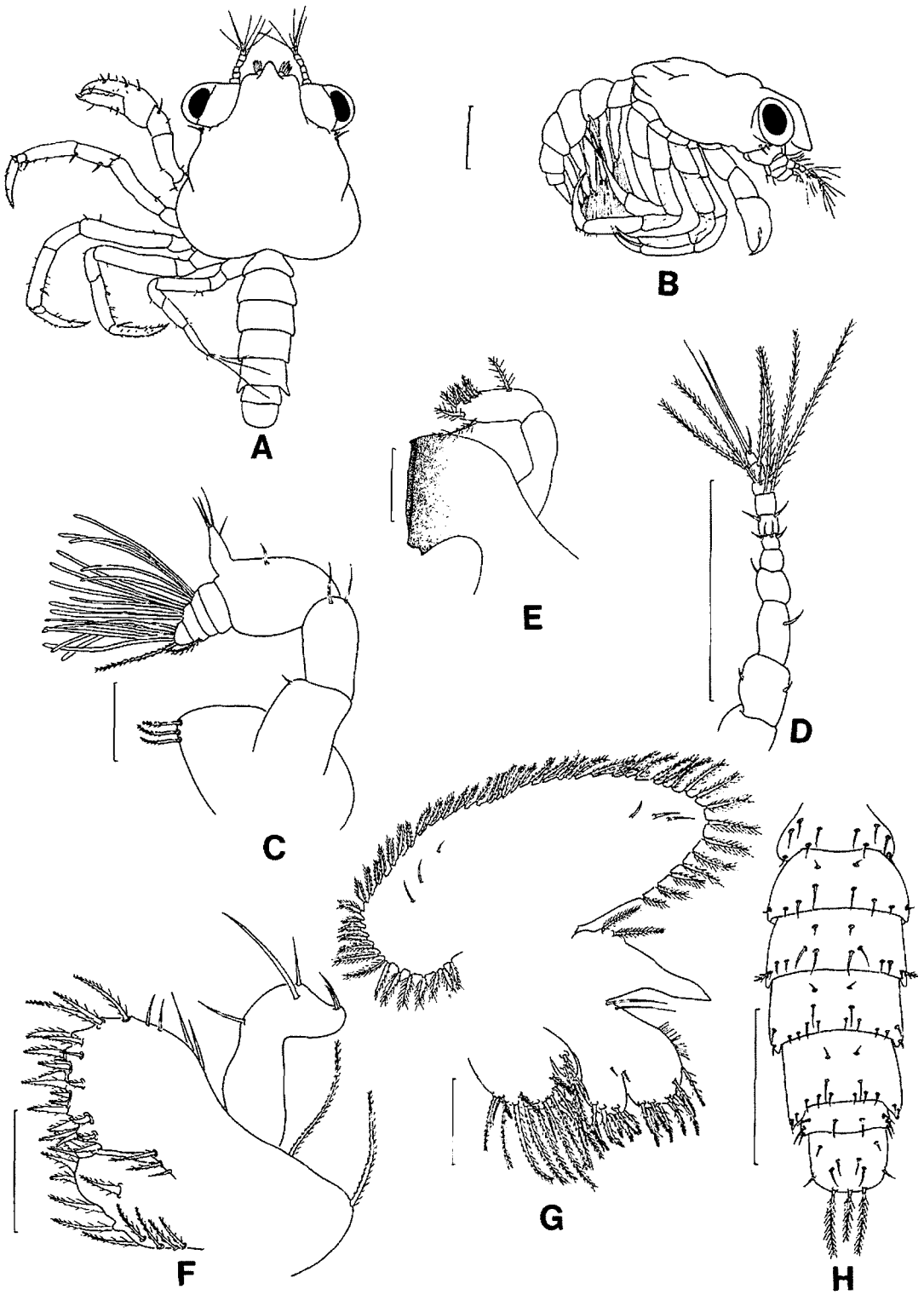

Fig. 11. *Hemigrapsus longitarsis*, megalopal stage. A, Dorsal view. B, Lateral view. C, Antennule. D, Antenna. E, Mandible. F, Maxillule. G, Maxilla H, Dorsal view of abdomen and telson. Scale bars = 0.1 mm (C, E, F, G) and 0.5 mm (A, B, D, H).

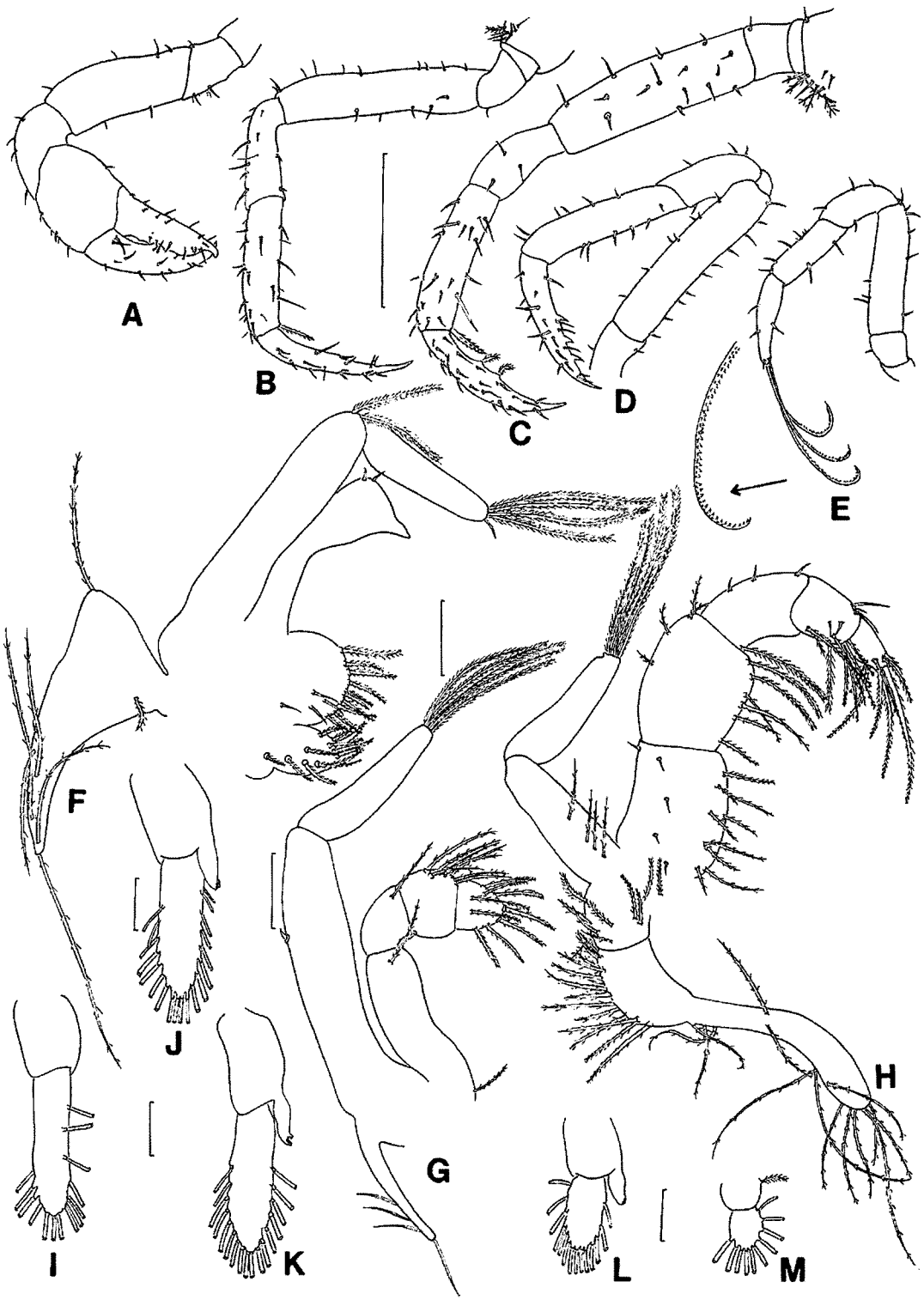

Fig. 12. *Hemigrapsus longitarsis*, megalopal stage. A-E, Pereiopods 1-5. F, First maxilliped. G, Second maxilliped. H, Third maxilliped. I-M, Pleopods 1-5. Scale bars = 0.1 mm (F-M) and 0.5 mm (A-E).

Table 1. Differences in the first zoeas of *Hemigrapsus longitarsis* as described by Terada (1981) and in the present study

Characters	Terada (1981)	Present study
First zoea		
Antennule	unknown	exopod with 3 aesthetascs and a seta
Coxal endite of maxilla	with 4+2 setae	with 4+3 setae
Second zoea		
Antennule	unknown	exopod with 5 aesthetascs and a seta
First abdominal somite	without seta	with a dorsomedial seta
Third zoea		
Antennule	unknown	exopod with 3 aesthetascs and a seta
First abdominal somite	without seta	with a dorsomedial seta
Fourth zoea		
Antennule	unknown	exopod with 3 terminal, 2 subterminal aesthetascs and a seta
Coxal epipod of maxillule	absent	present as 2 setae
Third maxilliped	absent	present
First abdominal somite	without seta	with 3 dorsomedial setae
Fifth zoea		
Coxal epipod of maxillule	absent	present as 2 setae
Third maxilliped	absent	present with gill
First abdominal somite	without setae	with 5 dorsomedial setae
Dorsal surface of telson	smooth	with a pair of setae

2 setae; endopod of second maxilliped with 0, 1, 6 setae; lateral processes almost on abdominal somites 2 and 3 (except in *H. sinensis*); telson fork without outer spine. The *H. sinensis* is somewhat different from other three species by having an antennal exopod less than 40% in length of the protopod and lateral processes on the abdominal somites 2 to 4. However, the other three species are so similar to each other that it is difficult to identify each. However, the zoea of *H. longitarsis* can be distinguished from those of the other two *Hemigrapsus* in having a dorsal carapace spine with minute spinules, whereas in *H. sanguineus* and *H. penicillatus* it is naked.

The Korean grapsid crabs have been reported for 30 species (Kim, 1973; The Korean Society of Systematic Zoology, 1997; Ko, 2000) and the larval descriptions are available for 27 species. The following provisional key is provided for rapid identification of the grapsid zoeas. The characters employed are usually consistent during the zoeal development.

A key to the known grapsid zoeas in Korea.

1. Endopod of maxillule with 1, 1+4 setae; endopod of first maxilliped with 1, 2, 1, 2, 5 setation ..... *Pachygrapsus crassipes*
   - Endopod of maxillule with 1, 1+4 setae; endopod of first maxilliped with 2, 2, 1, 2, 5 setation 2
2. Endopod of maxilla with 2+3 setae 3
   - Endopod of maxilla with 2+2 setae 6
3. Lateral carapace absent 4
   - Lateral carapace present ..... *Plagusia dentipes*
4. Antennal exopod about 20% length of protopod .. 5
   - Antennal exopod more than 40% length of protopod ..... *Sesarma*
   S. bidens, S. pictum, S. haematocheir, S. plicatum, Nanosesarma gordoni
5. Rostral carapace spine longer than antenna ..... *Sesarma dehaani*
   - Rostral carapace spine shorter than antenna ..... *Sesarma intermedium*
6. Lateral processes on abdominal somites 2-3 7
   - Lateral processes on abdominal somites 2-4 15
7. Lateral carapace spine present 8
   - Lateral carapace spine absent 12
8. Antennal exopod small or rudimentary 9
   - Antennal exopod not small 10
9. Rostral carapace spine less than 50% length to antennal protopod ..... *Acmeopleura balssi*
   - Rostral carapace spine about 50% length to antennal protopod ..... *Eriocheir leptognathus*
10. Antennal exopod less than 40% length of protopod ..... *Helice tridens wuana*
    - Antennal exopod more than 50% length of protopod 11
11. Dorsal carapace spine with minute spinules ..... *Hemigrapsus longitarsis*
    - Dorsal carapace spine without minute spinules ..... *Hemigrapsus sanguineus, H. penicillatus*
12. Antennal exopod more than 60% length of protopod 13
    - Antennal exopod less than 60% length of protopod 14
13. Antennal exopod with 2 middle setae ..... *Gaetice depressus*
    - Antennal exopod with 1 middle seta ... *Helice leachi*
14. Antennal exopod less than 40% length of protopod ..... *Acmeopleura parvula*
    - Antennal exopod about 50% length of protopod ..... *Cyclograpsus intermedius*
15. Endopod setation of second maxilliped 0. 1. 6 16
    - Endopod setation of second maxilliped 0. 1. 5 ..... *Helice tridens tientsinensis*
16. Antennal exopod less than 40% length of protopod 17
    - Antennal exopod about 40% length of protopod 19
17. Antennal exopod with 2 middle setae 18
    - Antennal exopod with 1 middle seta ..... *Helice tridens sheni, H. t. tridens*

18. Rostral carapace spine without minute spinules ..... *Hemigrapsus sinensis*
    - Rostral carapace spine with minute spinules ..... *Eriocheir japonicus*
19. Lateral process of abdominal somite 3 as small as that of abdominal somite 2 ..... *Eriocheir sinensis*
    - Lateral process of abdominal somite 3 larger than that of abdominal somite 2 ..... *Chasmagnathus convexus*

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