

Abstract—The complete larval development of *Metapenaeopsis dalei* (Rathbun) is described from laboratory-reared larvae. The larvae were reared in a plastic container (20 L). Larvae from the first zoeal stage to the third zoeal stage were fed algae; larvae from the first mysis stage to the first postlarval stage were fed newly hatched nauplii of *Artemia*. The nauplii of *M. dalei* hatched about 20 hours after spawning. The larvae passed through six naupliar, three zoeal, and three mysis stages before the postlarval stage. About 15 days (about 347 hours) were required from hatching to the first postlarval stage. Larval morphology of *M. dalei* is described and compared with those of other *Metapenaeopsis* spp. The first nauplius stage larva of *M. dalei* bears a chitinous conical protuberance on the mediodistal margin of the body. The third protozoeal stage larva has five dorsomedian abdominal spines on the abdomen. The morphological characters of the first postlarva are 43 scaphognathite setae on the maxilla, three scaphocerite spines on the outer margin of antenna, and sternal plate spines: 2,2,0,1,1.

Larval development of the kishi velvet shrimp, *Metapenaeopsis dalei* (Rathbun) (Decapoda: Penaeidae), reared in the laboratory

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The kishi velvet shrimp, *Metapenaeopsis dalei* (Rathbun), inhabits coastal waters of Korea (Kim, 1977) and Japan (Kubo, 1949). Of the 26 penaeid genera comprising 215 species, the genus *Metapenaeopsis* is the largest with 76 species (Pérez Farfante and Kensley, 1997). However, studies on the complete larval development of *Metapenaeopsis* spp. are few.

The mysis and postlarval stages of *Metapenaeopsis mogiensis* (Rathbun) and *Metapenaeopsis andamanensis* (Wood-Mason) and postlarval stages of *Metapenaeopsis barbata* (De Haan) have been partially described by Paulinose (1988) from plankton samples. Jackson et al. (1989) reared *Metapenaeopsis palmenensis* (Haswell) in the laboratory and described all the larval stages of the species except the naupliar stages. From previous works on Indo-west Pacific penaeid larvae, they also described the important morphological characters for identification. Chong and Sasekumar (1994) studied the larval development of *Metapenaeopsis stridulans* (Alcock) from the egg to the first postlarval stage reared in the laboratory and prepared descriptions of all the larval stages. Ronquillo and Saisho (1997) provided descriptions and illustrative figures of the complete larval development of *M. barbata* and compared the morphological characters of the larval stages with those of several penaeid species.

The purpose of the present study is to describe the larval development of *M. dalei* from the egg to the postlarval stage and to compare its larval development with that of other known *Metapenaeopsis* larvae.

Materials and methods

On 22 August 1996, gravid females of *Metapenaeopsis dalei* were caught by shrimp trawl in Oeyondo, Korea, and transported to the laboratory of the Tae-an Fish Hatchery, National Fisheries Research and Development Institute, Korea (NFRDI).

Each of them was kept in a 0.5 t container, containing filtered seawater (22.0°C; 32.2‰), until they spawned. On the night of 22 August 1996, a gravid female spawned, and the eggs hatched on the next day. The larvae were reared in a plastic 20-L container. Half the total volume of rearing water was changed daily with fresh seawater (24.0–26.0°C; 32.2–33.2‰). The larvae were fed with a mixture of algae (*Chaetoceros calcitrans* and *Isochrysis galbana*) from the first zoeal stage to the third zoeal stage and with newly hatched nauplii of *Artemia* from the first mysis stage to the first postlarval stage.

For size measurement and morphological observation, eggs were sampled from the bottom of the rearing tank immediately after having been spawned; the developmental processes of the eggs were observed every 10 minutes, the nauplii were sampled at four hour intervals after hatching, and subsequent larval stages were sampled at least twice a day.

The following measurements were taken from preserved larvae by using an ocular micrometer: total length (TL), from the tip of the rostrum to the tip of the caudal end or telson; carapace length (CL), from the anterior margin of

Table 1

Metapenaeopsis dalei. Chronology of embryonic development under laboratory conditions (24.0–26.0°C; 32.2–33.2‰)

Developmental stages	Duration (hour: min.)	Cumulative (hour: min.)
1 cell	00: 23	00: 00
2 cell	00: 25	00: 23
4 cell	00: 26	00: 48
8 cell	00: 28	01: 14
16 cell	00: 20	01: 42
32 cell	00: 28	02: 02
64 cell	00: 50	02: 30
Gastrula stage	04: 50	03: 20
Early embryonic nauplius	05: 30	08: 10
Late embryonic nauplius	06: 30	13: 40
Embryonic nauplius just before hatching		20: 10

Table 2

Metapenaeopsis dalei. Chronology of larval development under laboratory conditions (24.0–26.0°C; 32.2–33.2‰)

Larval stages	Duration (hour)	Cumulative (hour)
First naupliar stage	06	006
Second naupliar stage	07	013
Third naupliar stage	07	020
Fourth naupliar stage	08	028
Fifth naupliar stage	08	036
Sixth naupliar stage	12	048
First protozoal stage	48	096
Second protozoal stage	60	156
Third protozoal stage	50	206
First mysis stage	46	252
Second mysis stage	26	278
Third mysis stage	49	327
First postlarval stage	119	446

the carapace to the midposterior margin of the carapace for zoeae, from the postorbital margin to the midposterior margin of the carapace for mysis and first postlarvae; body width (BW), the greatest width across the body for nauplii.

Results

Development of larvae and duration of the larval stage

A gravid female of *Metapenaeopsis dalei* spawned for two hours from 22:00 to 24:00. The egg was spherical and greenish grey, with a mean diameter of 0.35 mm ($n=20$). The nauplius hatched about 20 hours after spawning (Table 1). The larvae passed through six naupliar, three zoal, and three mysis stages, before the postlarval stage. About 15 days (about 347 hours) were required from the hatching to the first postlarval stage (Table 2).

Descriptions of larvae

First naupliar stage (Fig. 1, A and B)

Size TL: 0.37 mm (0.35–0.41 mm; SD=0.02; $n=12$)

BW: 0.23 mm (0.21–0.25 mm; SD=0.02; $n=12$)

Body (Fig. 1, A and B): Slightly oval in dorsal or ventral view, convex dorsally; anterodorsal median ocellus; posterior margin rounded; one chitinous conical protuberance on posterodorsal part of body; caudal end with one pair of setae; body unsegmented; three pairs of appendages with naked setae.

Antennule (Fig. 1A): Uniramous; two terminal setae and four lateroventral setae.

Antenna (Fig. 1A): Biramous; endopod with three terminal and two lateroventral setae; exopod with three terminal and three lateroventral setae.

Mandible (Fig. 1A): Biramous; endopod and exopod each with one lateroventral and two terminal setae.

Second naupliar stage (Fig. 1, C and D)

Size TL: 0.43 mm (0.37–0.53 mm; SD=0.04; $n=15$)

BW: 0.23 mm (0.16–0.27 mm; SD=0.03; $n=15$)

Body (Fig. 1, C and D): Elongate oval in dorsal or ventral view; anterodorsal median ocellus; posterior margin rounded; posterodorsal protuberance absent; caudal end with two pairs of setae; three pairs of appendages with bipinnate setae; body unsegmented.

Antennule (Fig. 1C): Unchanged.

Antenna (Fig. 1C): Unchanged.

Mandible (Fig. 1C): Unchanged.

Third naupliar stage (Fig. 1, E and F)

Size TL: 0.44 mm (0.42–0.45 mm; SD=0.02; $n=6$)

BW: 0.24 mm (0.21–0.27 mm; SD=0.03; $n=6$)

Body (Fig. 1, E and F): Form unchanged; anteroventral median ocellus; posterior margin rounded; caudal end with two pairs of setae; body unsegmented.

Antennule (Fig. 1E): Uniramous; three terminal setae, outermost short and four lateroventral setae.

Antenna (Fig. 1E): Biramous; endopod with three terminal and three lateroventral setae; exopod with three terminal and three lateroventral setae.

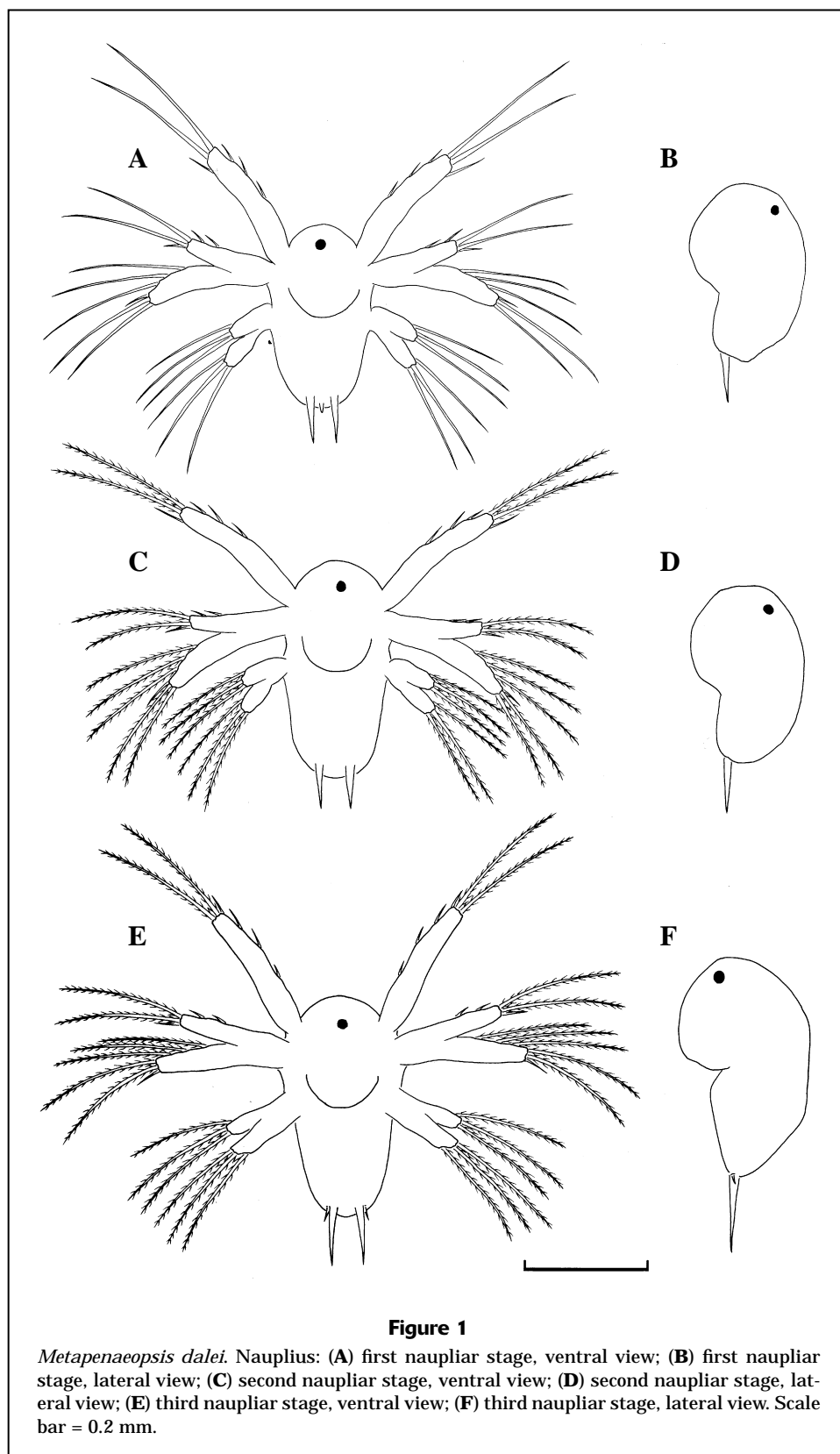
Mandible (Fig. 1E): Unchanged.

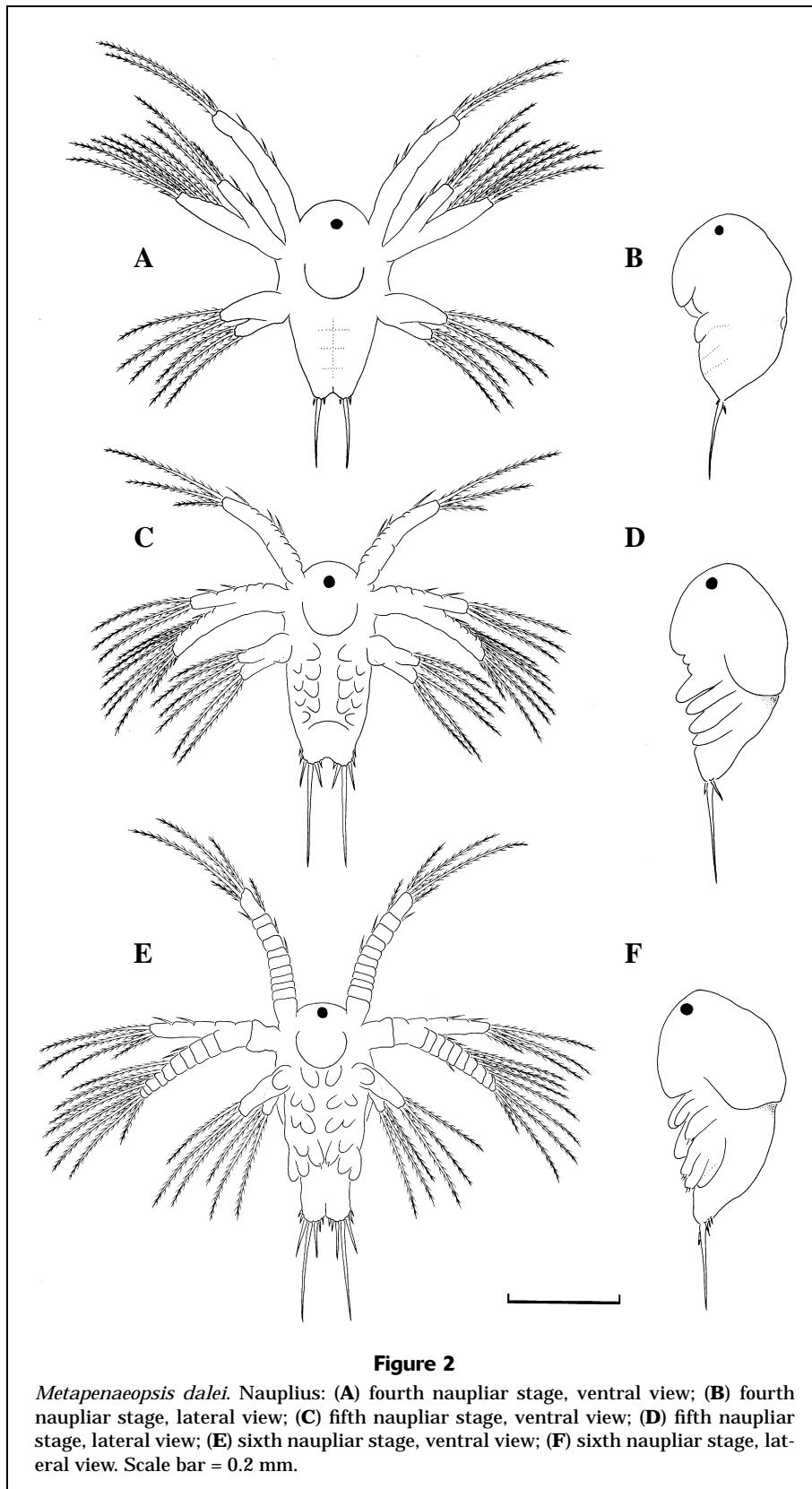
Fourth naupliar stage (Fig. 2, A and B)

Size TL: 0.43 mm (0.40–0.47 mm; SD=0.03; $n=4$)

BW: 0.23 mm (0.22–0.24 mm; SD=0.01; $n=4$)

Body (Fig. 2, A and B): Slightly elongate; anteroventral median ocellus; medial notch dividing posterior end into two symmetrical lobes each with 3+3 setae; thoracic part with some rudimentary segmentation ventrally.





Antennule (Fig. 2A): Uniramous; three terminal and three lateroventral setae.

Antenna (Fig. 2A): Biramous; endopod with three terminal and two lateroventral setae; exopod with three terminal and four lateroventral setae.

Mandible (Fig. 2A): Biramous; protopodal part swollen; endopod and exopod each with two terminal and one lateroventral setae; coxal part enlarged.

Fifth naupliar stage (Fig. 2, C and D)

Size TL: 0.41 mm (0.34–0.54 mm; SD=0.07; $n=10$)

BW: 0.18 mm (0.14–0.23 mm; SD=0.03; $n=10$)

Body (Fig. 2, C and D): Slightly more elongate, tapering towards telson lobes; anteroventral median ocellus; carapace rudimentary; buds of the oral appendages appeared.

Antennule (Fig. 2C): Uniramous; segmentation rudimentary; two terminal and two lateroventral setae.

Antenna (Fig. 2C): Biramous; segmentation rudimentary; endopod with three terminal and two lateroventral setae; exopod with four terminal and five lateroventral setae.

Mandible (Fig. 2C): Biramous; protopod bulbous; setation unchanged.

Telson (Fig. 2C): Bilobed with 6+6 setae.

Sixth naupliar stage (Fig. 2, E and F)

Size TL: 0.56 mm (0.53–0.58 mm; SD=0.01; $n=15$)

BW: 0.24 mm (0.23–0.26 mm; SD=0.01; $n=15$)

Body (Fig. 2, E and F): Elongate with distinct waist; anteroventral median ocellus; carapace developed; rudimentary maxillae and maxillipeds bearing numerous short setae.

Antennule (Fig. 2E): Uniramous; 11-segmented with 0, 0, 0, 0, 1, 0, 1, 0, 2, 4 setae.

Antenna (Fig. 2E): Biramous; peduncle two-segmented; endopod four-segmented with 0, 1, 1, 4 setae; exopod 10-segmented with 0, 0, 1, 2, 1, 1, 1, 1, 1, 3/4 setae.

Mandible (Fig. 2E): Unchanged.

Telson (Fig. 2E): Bilobed with 7+7 setae of varying sizes.

First protozoal stage (Fig. 3, A–I)

Size TL: 1.07 mm (0.97–1.23 mm; SD=0.09; $n=10$)

Cephalothorax (Fig. 3A): Incompletely and loosely covered by unarmed carapace; carapace round to oval, with shallow posterior median notch, anterior margin with one pair of orbital spines; rostrum absent; paired sessile compound eyes.

Antennule (Fig. 3B): Uniramous; six-segmented with 0, 0, 0, 0, 4, 6 (three aesthetascs) setae.

Antenna (Fig. 3C): Biramous; protopod two-segmented; endopod two-segmented with 5, 5 setae; exopod 10-segmented with 0, 0, 1, 2, 1, 2, 1, 1, 1, 3 setae.

Mandible (Fig. 3D): Endopod and exopod absent; asymmetrical; masticatory surface with lower molar processes and upper curved incisor processes; molar with many small teeth; incisor with 2–4 larger teeth; left and right mandible each with one denticulated tooth.

Maxillule (Fig. 3E): Biramous; protopod two-lobed, coxal endite with eight setae, basal endite with two stout setae and two setae; endopod three-segmented with 3, 2, 5 setae; small exopod with four plumose setae.

Maxilla (Fig. 3F): Biramous; protopod five-lobed, endites with 8, 3, 3, 3, 3 setae; endopod four-segmented with 2, 2, 2, 3 setae; exopod with five plumose setae.

First maxilliped (Fig. 3G): Biramous; protopod partially divided, coxa with six setae, basis with nine setae; endopod four-segmented with 3, 2, 2, 5 setae; exopod with seven plumose setae.

Second maxilliped (Fig. 3H): Biramous; protopod two-segmented, coxa without setae, basis with four setae; endopod four-segmented with 2, 2, 2, 5 setae; exopod with five plumose setae.

Third maxilliped (Fig. 3I): Undeveloped biramous; exopod with two plumose setae.

Post-carapacial region (Fig. 3A): Six thoracic and one free abdominal somites; unsegmented abdomen with forked telson.

Telson (Fig. 3A): Broadly bifurcated in two lobes with seven pairs of plumose setae.

Second protozoal stage (Fig. 4, A–I)

Size TL: 1.58 mm (1.44–1.83 mm; SD=0.14; $n=17$)

CL: 0.50 mm (0.40–0.60 mm; SD=0.05; $n=17$)

Cephalothorax (Fig. 4A): Loosely covered by carapace; carapace armed with long acute rostrum and two pairs of supraorbital spines; rostrum present and exceeding eye; eyes stalked.

Antennule (Fig. 4B): Uniramous; seven-segmented with 0, 0, 0, 0, 1, 4, 6 (three aesthetascs) setae.

Antenna (Fig. 4C): Biramous; protopod two-segmented with 0, 1 setae; unchanged; exopod 10-segmented with 0, 1, 2, 1, 2, 1, 1, 1, 1, 3 setae.

Mandible (Fig. 4D): Form unchanged; left mandible with four denticulate setae; right mandible with one denticulate seta.

Maxillule (Fig. 4E): Biramous; coxal endite with eight setae, basal endite with five stout setae and one seta; endopod three-segmented with 2, 2, 5 setae; exopod with four plumose setae.

Maxilla (Fig. 4F): Biramous; endites with 10, 4, 4, 5, 3 setae; endopod four-segmented with 3, 2, 2, 3 setae; exopod unchanged.

First maxilliped (Fig. 4G): Biramous; coxa with six setae, basis with 12 setae; endopod with 3, 2, 2, 4 setae; exopod unchanged.

Second maxilliped (Fig. 4H): Biramous; coxa with one seta, basis with nine setae; endopod four-segmented with 2, 2, 2, 5 setae; exopod with six plumose setae.

Third maxilliped (Fig. 4I): Undeveloped biramous; exopod with three plumose setae.

Post-carapacial region (Fig. 4A): Six thoracic and six abdominal somites; unsegmented abdomen with forked telson.

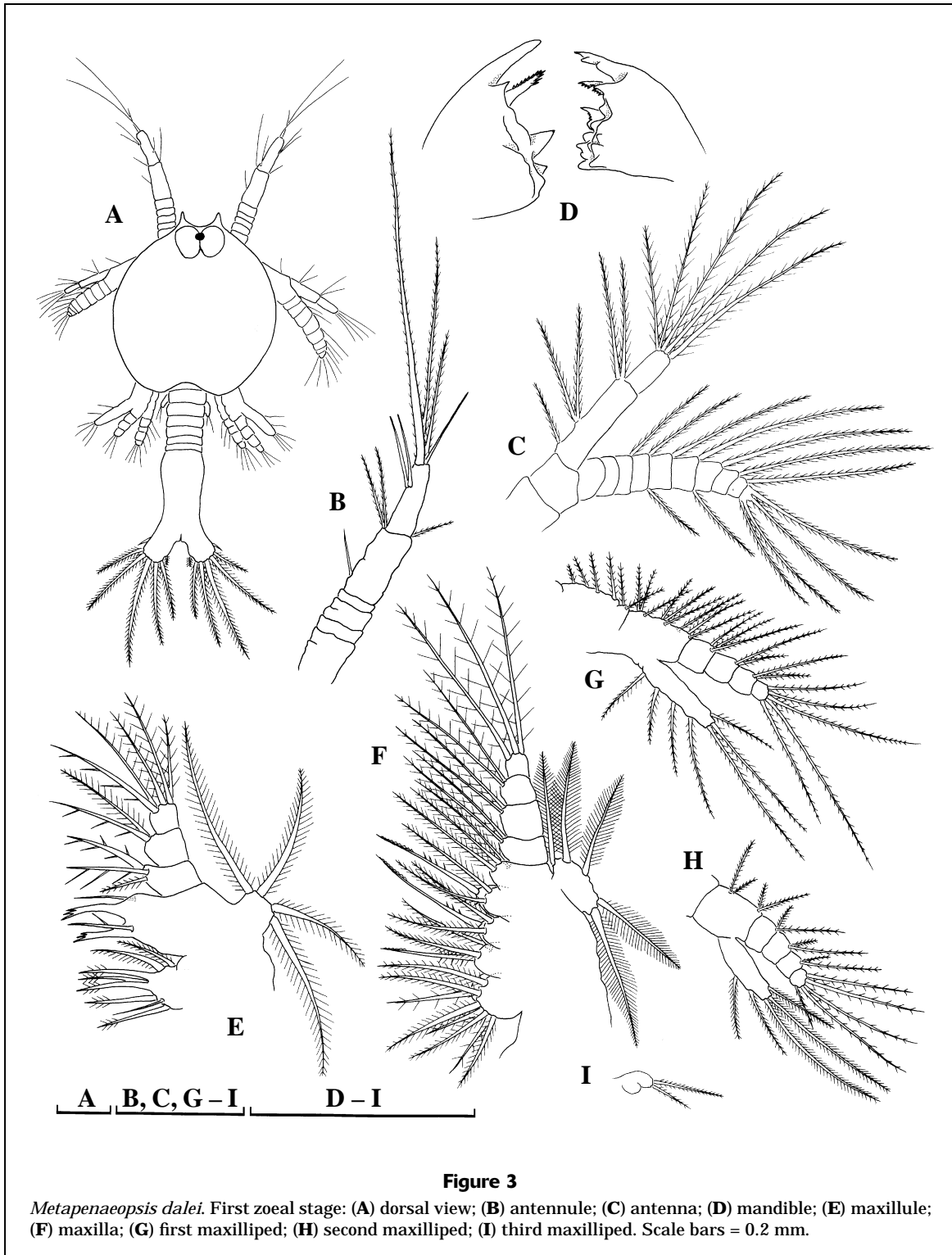
Telson (Fig. 4A): Unchanged.

Third protozoal stage (Fig. 5, A–K)

Size TL: 2.22 mm (1.80–2.43 mm; SD=0.18; $n=11$)

CL: 0.60 mm (0.50–0.70 mm; SD=0.06; $n=11$)

Cephalothorax (Fig. 5A): Incompletely covered by carapace; carapace armed with long rostrum and two pairs of supraorbital spines; rostrum long.

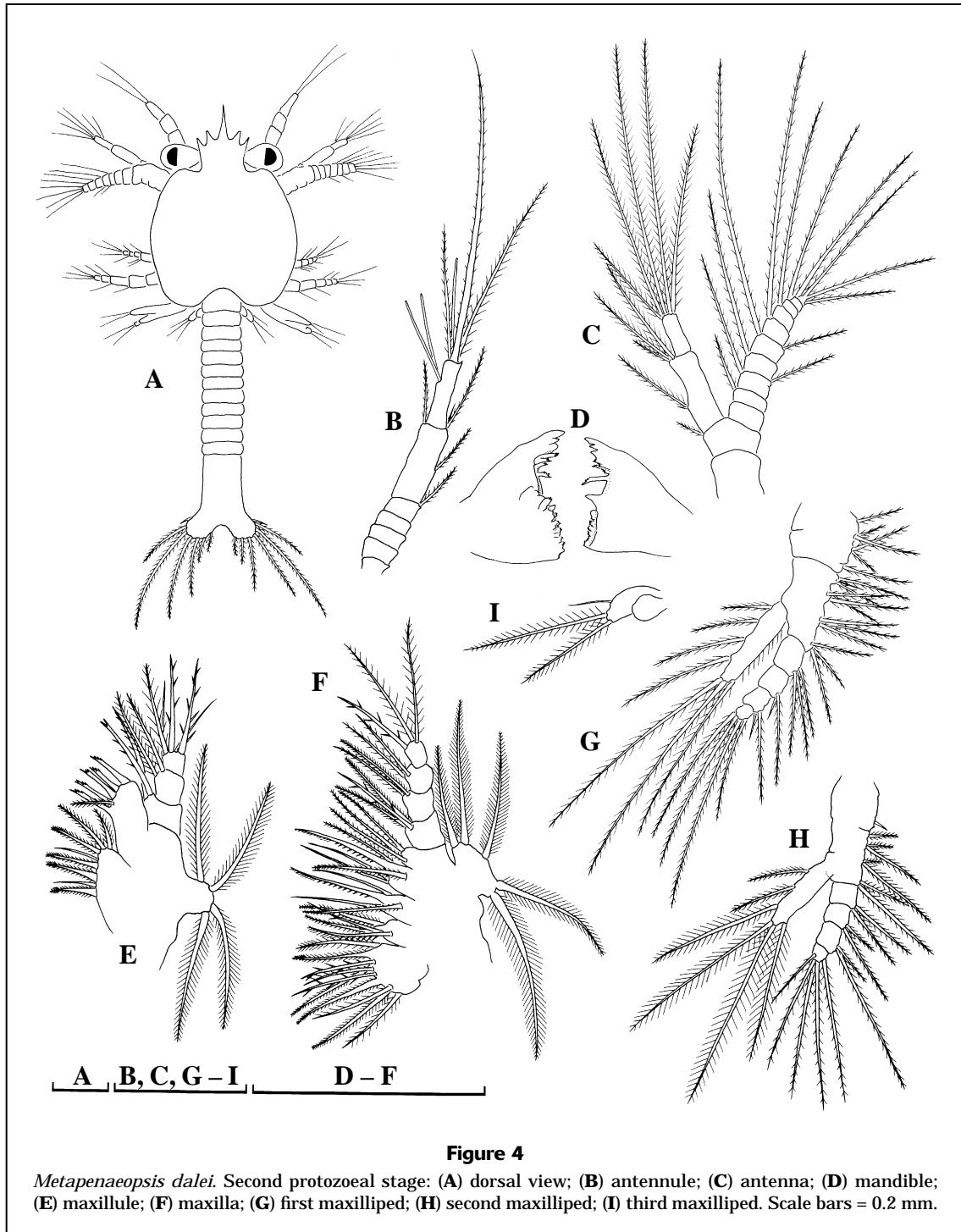


Antennule (Fig. 5B): Uniramous; four-segmented with 1, 1, 2, 8 (three aesthetascs).

Antenna (Fig. 5C): Unchanged.

Mandible (Fig. 5D): Left mandible with six denticulate setae; right mandible with two denticulate setae.

Maxillule (Fig. 5E): Biramous; coxal endite with eight setae, basal endite with seven stout setae and three setae;



endopod three-segmented with 3, 2, 5 setae; exopod with four plumose setae.

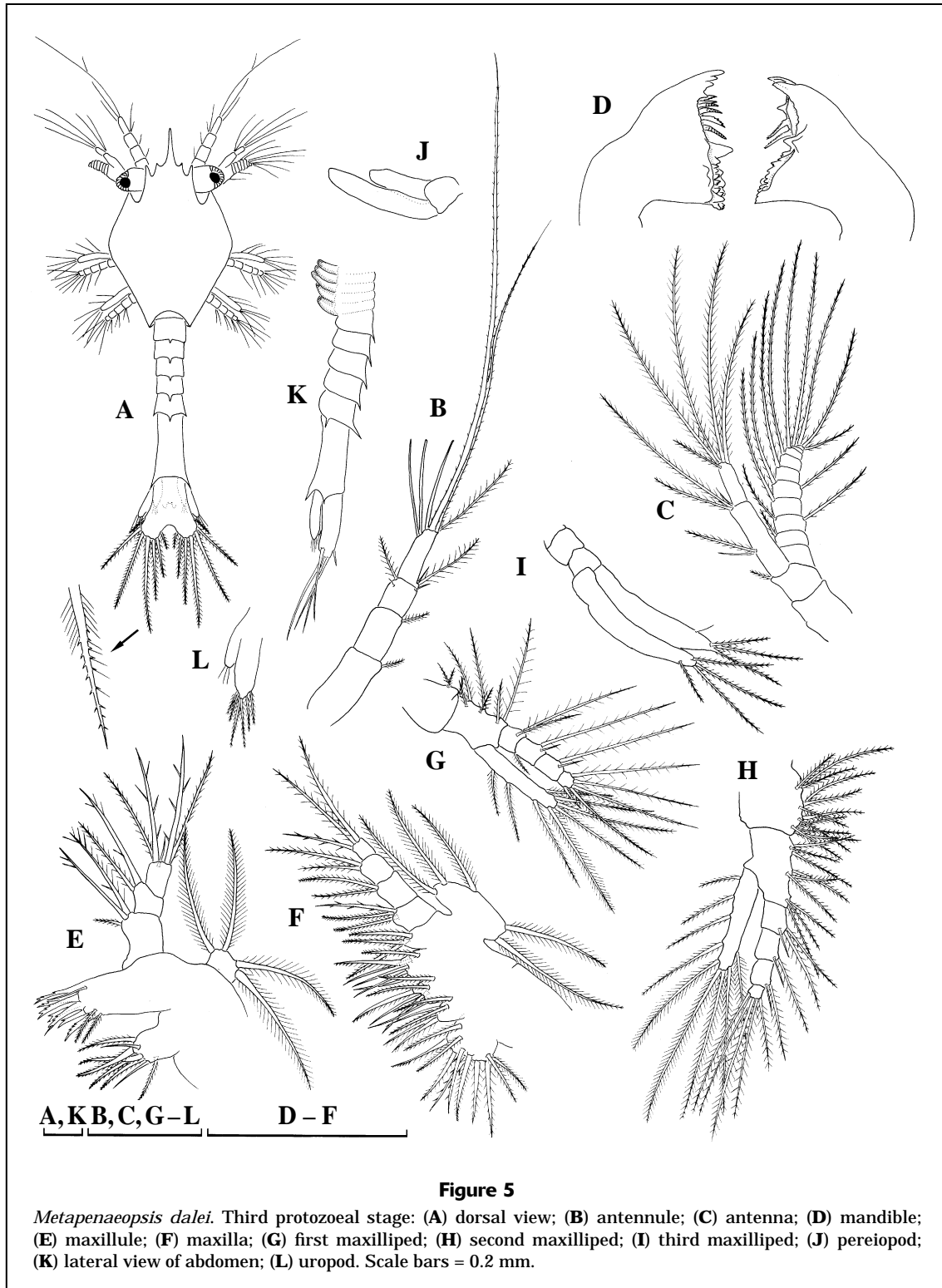
Maxilla (Fig. 5F): Biramous; endites with 11, 5, 6, 6, 4 setae; endopod four-segmented with 3, 2, 2, 3 setae; exopod unchanged.

First maxilliped (Fig. 5G): Biramous; coxa with two setae, basis with seven setae; endopod four-segmented with 3, 2, 2, 5 setae; exopod with nine plumose setae.

Second maxilliped (Fig. 5H): Biramous; coxa with 11 setae, basis with nine setae; endopod four-segmented with 3, 2, 2, 5 setae; exopod with eight plumose setae.

Third maxilliped (Fig. 5I): Biramous; protopod two-segmented, endopod and exopod elongate; endopod with three and exopod with four plumose setae.

Pereiopod (Fig. 5J): Rudimentary and biramous; protopod present.



Postcarapacial region (Fig. 5, A and K): Abdomen six-segmented; dorsomedian spines on posterior margin of the 1st-5th abdominal somites; one pair of spines on postero-lateral margins of 5th and 6th abdominal somites; 6th ab-

dominal somite also with one pair of spines on lateroventral margin; pereiopods appeared.

Uropod (Fig. 5L): Biramous; endopod with three setae; exopod with six setae.

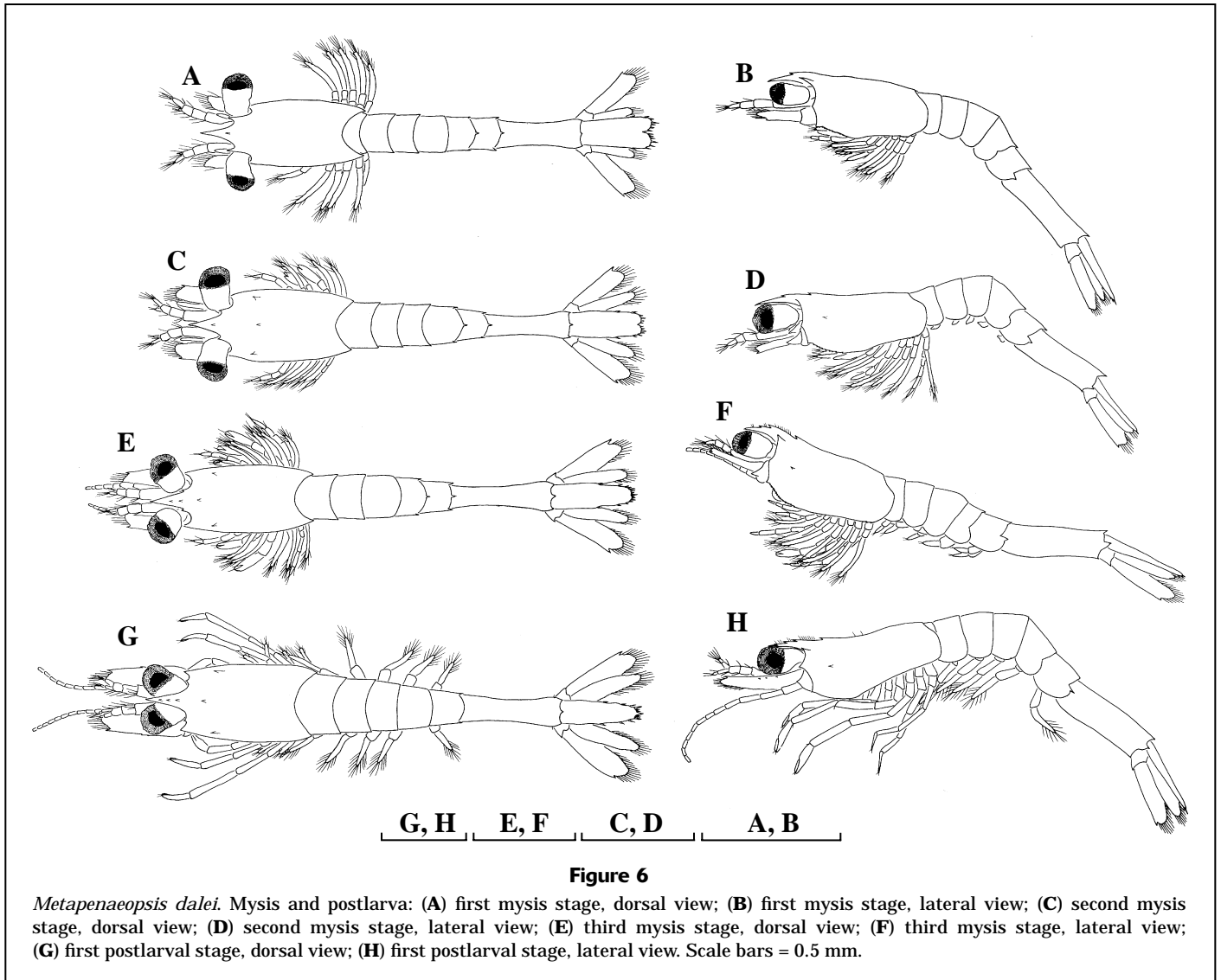


Figure 6

Metapenaeopsis dalei. Mysis and postlarva: (A) first mysis stage, dorsal view; (B) first mysis stage, lateral view; (C) second mysis stage, dorsal view; (D) second mysis stage, lateral view; (E) third mysis stage, dorsal view; (F) third mysis stage, lateral view; (G) first postlarval stage, dorsal view; (H) first postlarval stage, lateral view. Scale bars = 0.5 mm.

Telson (Fig. 5A): Separated from the 6th abdominal somite with seven pairs of setae.

First mysis stage (Fig. 6, A and B, Fig. 7, A–N)

Size TL: 2.79 mm (2.69–3.07 mm; SD=0.14; $n=15$)

CL: 0.75 mm (0.64–0.86 mm; SD=0.06; $n=15$)

Carapace (Fig. 6, A and B): Closely covering thoracic somites; one pair of supraorbital, antennal and pterygostomial spines, 10 anteroventral and three posteroventral spines on each marginal side; rostrum long with one dorsomedian rostral tooth.

Antennule (Fig. 7A): Uniramous; peduncle three-segmented, 1st segment with one large ventral spine, one small proximal spine and 11 setae, 2nd segment with 10 setae, 3rd segment with seven setae; outer ramus with seven aesthetascs; inner ramus with two setae.

Antenna (Fig. 7B): Biramous; protopod two-segmented; endopod and exopod unsegmented; endopod with three na-

ked setae; exopod (scaphocerite) with 12 marginal plumose setae.

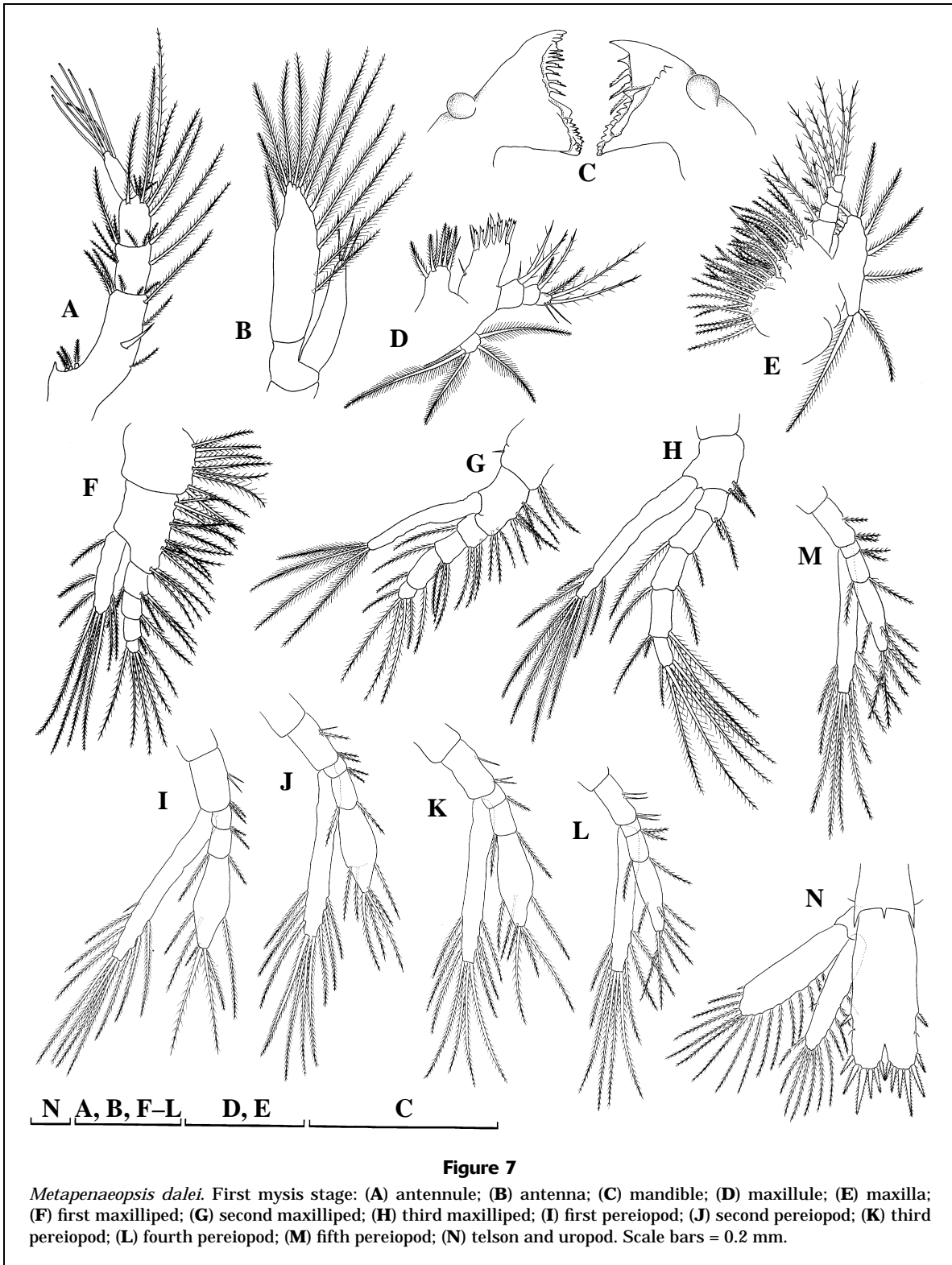
Mandible (Fig. 7C): Left mandible with seven denticulate setae; right mandible with four denticulate setae; mandibular palp present as bud.

Maxillule (Fig. 7D): Biramous; protopod two-lobed, coxal endite with eight setae, basal endite with nine stout setae and three setae; endopod three-segmented with 3, 2, 5 setae; exopod with four plumose setae.

Maxilla (Fig. 7E): Biramous; protopod five-lobed, endites with 11, 5, 7, 7, 3 setae; endopod 4-segmented with 2, 2, 2, 3 setae; exopod (scaphognathite) with nine plumose setae.

First maxilliped (Fig. 7F): Biramous; coxa with eight setae, basis with 14 setae; endopod four-segmented with 4, 2, 2, 5 setae; exopod with nine plumose setae.

Second maxilliped (Fig. 7G): Biramous; coxa with three setae, basis with eight setae; endopod four-segmented with 4, 4, 2, 5 setae; exopod with four plumose setae.



Third maxilliped (Fig. 7H): Biramous; coxa naked, basis with three setae; endopod five-segmented with 2, 2, 2, 4, 5 setae; exopod with eight plumose setae.

First pereiopod (Fig. 7I): Biramous; coxa naked, basis with four setae; endopod three-segmented with 2, 2, 7 setae; exopod with 10–11 plumose setae.

Second pereopod (Fig. 7J): Biramous; coxa naked, basis with four setae; endopod three-segmented with 2, 2, 7 setae; exopod with 10 plumose setae.

Third pereopod (Fig. 7K): Biramous; coxa naked, basis with three setae; endopod three-segmented with 2, 2, 7 setae; exopod with 10 plumose setae.

Fourth pereopod (Fig. 7L): Biramous; coxa naked, basis with four setae; endopod three-segmented with 2, 2, 7 setae; exopod with nine plumose setae.

Fifth pereopod (Fig. 7M): Biramous; coxa naked, basis with three setae; endopod three-segmented with 2, 2, 7 setae; exopod with nine plumose setae.

Abdomen (Fig. 6, A and B): Dorsomedian spines on the 4th, 5th and 6th abdominal somites; one pair of lateral spines on 5th and 6th abdominal somites; one pair of lateroventral spines on the 6th abdominal somite.

Uropod (Fig. 7N): Protopod with one spine; endopod with 11 marginal plumose setae; exopod with one marginal spine and 13–15 marginal plumose setae.

Telson (Fig. 7N): Narrow and deep median notch with seven pairs of setae and one pair of plumose setae.

Second mysis stage (Fig. 6, C and D; Fig. 8, A–O)

Size TL: 3.71 mm (3.16–4.54 mm; SD=0.29; $n=19$)

CL: 0.87 mm (0.69–1.10 mm; SD=0.09; $n=19$)

Carapace (Fig. 6, C and D): Covering thoracic somites; one pair of supraorbital, antennal, pterygostomial, and hepatic spines, 10 anteroventral and three ventroposterior spines on each marginal side; rostrum long with one dorsal tooth.

Antennule (Fig. 8A): Uniramous; peduncle three-segmented, 1st segment with one large ventral spine, one small proximal seta and 14 setae, 2nd segment with eight setae, 3rd segment with three setae; outer and inner ramus unchanged.

Antenna (Fig. 8B): Biramous; protopod two-segmented, 2nd segment with one basal spine; endopod three-segmented with 0, 0, 2 setae; scaphocerite with 19 marginal plumose setae.

Mandible (Fig. 8C): Left mandible with three denticulate setae; right mandible with seven denticulate setae; mandibular palp unsegmented.

Maxillule (Fig. 8D): Biramous; coxal endite with six plumed and two naked setae, basal endite with six stout setae and three setae; endopod unchanged; exopod absent.

Maxilla (Fig. 8E): Biramous; endites with 15, 5, 7, 7, 3 setae; endopod four-segmented with 2, 2, 2, 3 setae; scaphognathite with 16 plumose setae.

First maxilliped (Fig. 8F): Biramous; coxa with eight setae, basis with 15 setae; endopod four-segmented with 4, 3, 2, 5 setae; exopod with nine plumose setae.

Second maxilliped (Fig. 8G): Biramous; coxa with two setae, basis with 10 setae; endopod five-segmented with 4, 5, 1, 2, 6 setae; exopod with six plumose setae.

Third maxilliped (Fig. 8H): Biramous; coxa naked, basis with two setae; endopod five-segmented with 2, 3, 3, 3, 4–5 setae; exopod with 8–9 plumose setae.

First pereopod (Fig. 8I): Biramous; endopod chelate; coxa naked, basis with two setae; endopod five-segmented with 1, 2, 2, 4, 2 setae; exopod with 10 plumose setae.

Second pereopod (Fig. 8J): Biramous; endopod chelate; coxa naked, basis with one seta; endopod five-segmented with 2, 3, 3, 3, 3 setae; exopod with 10 plumose setae.

Third pereopod (Fig. 8K): Similar to 1st pereopod.

Fourth pereopod (Fig. 8L): Coxa naked, basis with three setae; endopod five-segmented with 2, 3, 3, 5, 2 setae; exopod with 9–10 plumose setae.

Fifth pereopod (Fig. 8M): Similar to 4th pereopod.

Abdomen (Fig. 6C, D): Similar to 1st mysis stage.

Pleopods (Fig. 8N): Two-segmented and uniramous, without setae.

Uropod (Fig. 8O): Biramous; protopod with one spine; endopod with 14 plumose setae; exopod with one fused spine and 19 plumose setae.

Telson (Fig. 8O): Median notch less deep with seven pairs of plumose setae and one posteromedian spine.

Third mysis stage (Fig. 6, E and F; Fig. 9 A–J; Fig. 10, A–E)

Size TL: 4.45 mm (3.99–4.88 mm; SD=0.25; $n=20$)

CL: 1.13 mm (0.96–1.31 mm; SD=0.10; $n=20$)

Carapace (Fig. 6, E and F): Covering thoracic somites; one pair of supraorbital, antennal, pterygostomial and hepatic spines, 10 anteroventral and three posteroventral spines on each marginal side; rostrum long with two dorsal teeth.

Antennule (Fig. 9A): Uniramous; peduncle three-segmented: 1st segment with one large ventral spine, one small proximal spine, 27 plumose setae and statocyst; 2nd segment with 12 plumose setae; 3rd segment with seven plumose setae; outer ramus with eight aesthetascs; inner ramus unchanged.

Antenna (Fig. 9B): Biramous; protopod unsegmented with one spine; endopod nine-segmented, 1st segment with one spine; scaphocerite with 22 plumose setae and one spine.

Mandible (Fig. 9C): Left mandible with seven denticulate setae; right mandible with three denticulate setae; mandibular palp bud present.

Maxillule (Fig. 9D): Biramous; coxal endite with eight setae, basal endite with eight stout setae and three setae; endopod three-segmented with 2, 2, 5 setae.

Maxilla (Fig. 9E): Biramous; endites with 11, 5, 8, 8, 4 setae; endopod four-segmented with 3, 1, 2, 3 setae; scaphognathite with 24 plumose setae.

First maxilliped (Fig. 9F): Biramous; coxa with 10 setae, basis with 18 setae; endopod four-segmented with 4, 2, 4, 5 setae; exopod with 10 plumose setae.

Second maxilliped (Fig. 9G): Biramous; coxa naked, basis with eight setae; endopod five-segmented with 4, 5, 2, 2, 5 setae; exopod unchanged.

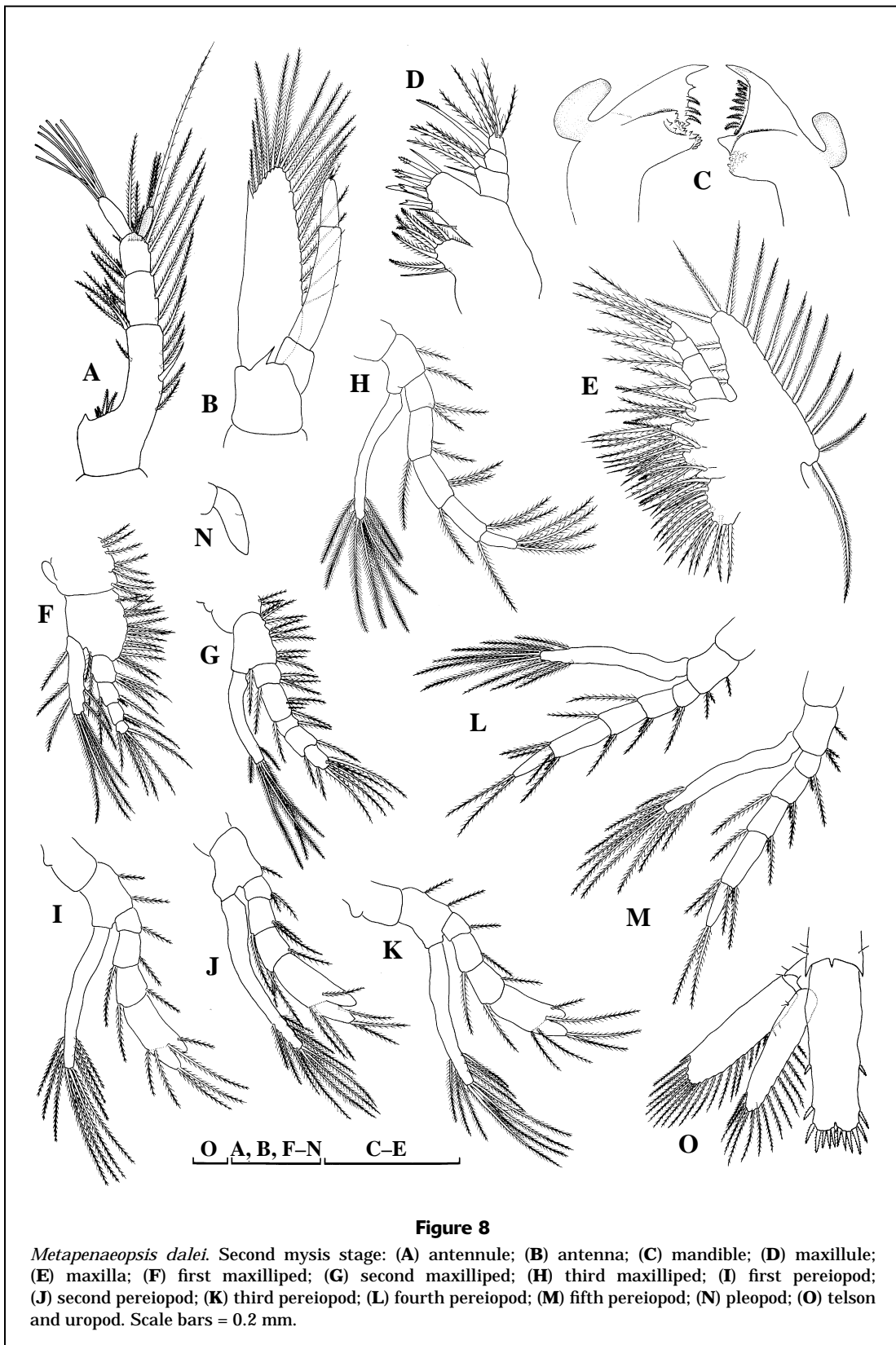
Third maxilliped (Fig. 9H): Biramous; coxa naked, basis with two setae; endopod five-segmented with 2, 3, 3, 3, 5 setae; exopod with nine plumose setae.

First pereopod (Fig. 10A): Biramous; coxa naked, basis with three setae; endopod five-segmented with 2, 3, 2, 4, 2 setae; exopod unchanged.

Second pereopod (Fig. 10B): Similar to 1st pereopod.

Third pereopod (Fig. 10C): Similar to 1st pereopod.

Fourth pereopod (Fig. 10D): Biramous; coxa naked, basis with two setae; endopod five-segmented with 2, 2, 2, 4, 2 setae; exopod with 10 plumose setae.



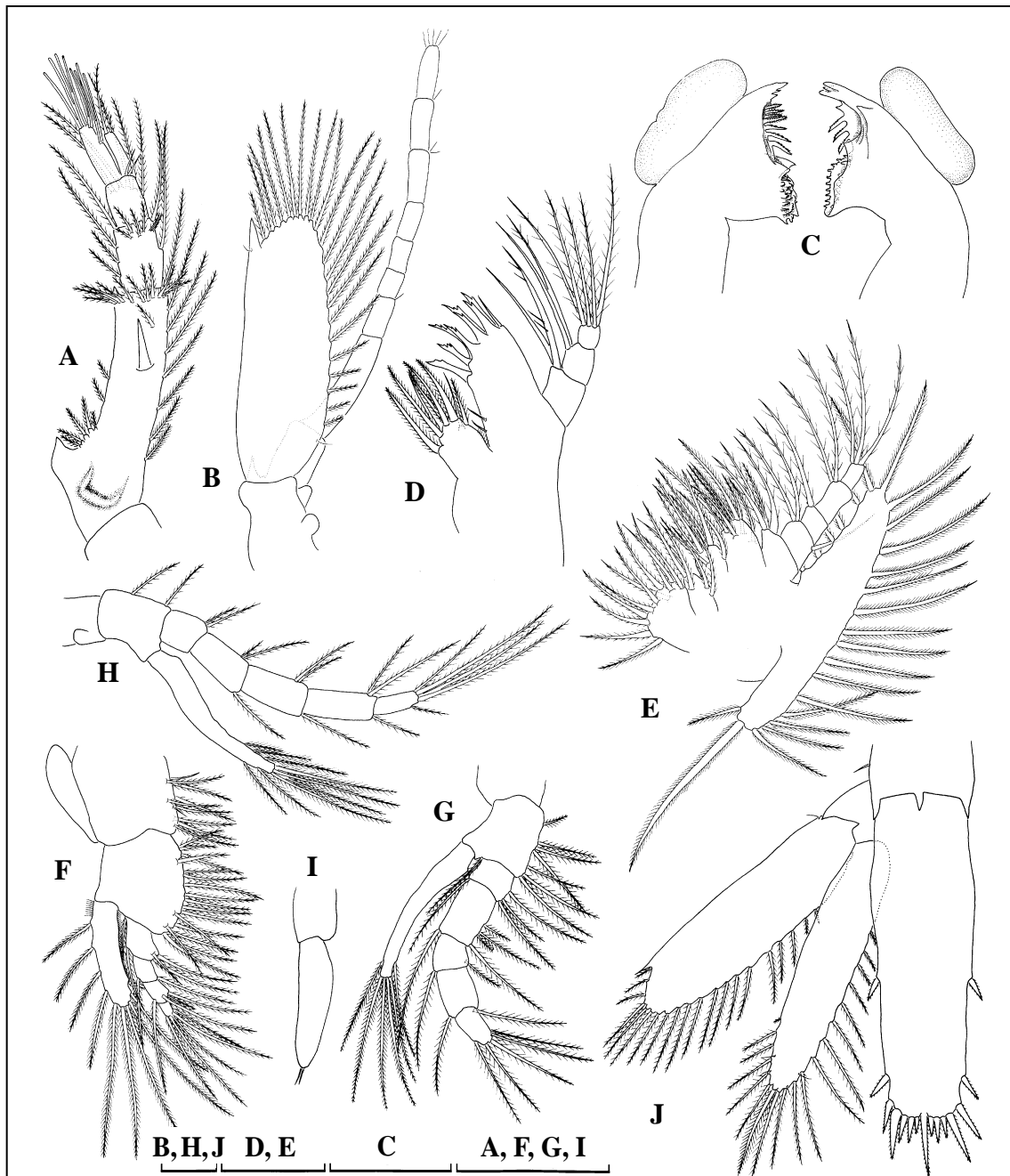


Figure 9

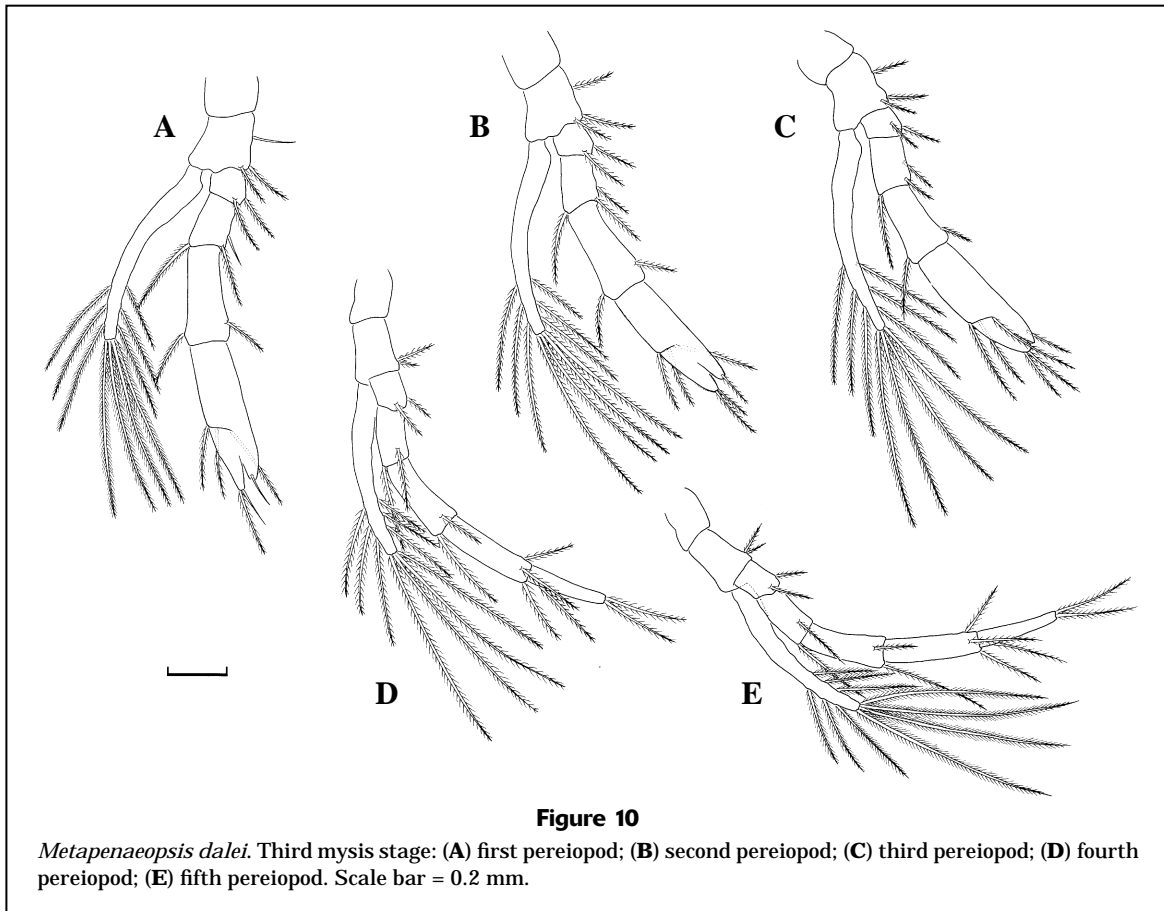
Metapenaeopsis dalei. Third mysis stage: (A) antennule; (B) antenna; (C) mandible; (D) maxillule; (E) maxilla; (F) first maxilliped; (G) second maxilliped; (H) third maxilliped; (I) pleopod; (J) telson and uropod. Scale bars = 0.2 mm.

Fifth pereopod (Fig. 10E): Similar to 4th pereopod.
 Abdomen (Fig. 6F): Similar to 2nd mysis stage.
 Pleopods (Fig. 9I): Two-segmented with 0, 2 minute terminal setae.
 Uropod (Fig. 9J): Protopod with one spine; endopod with 19 plumose setae; exopod with one fused spine and 20 plumose setae.

Telson (Fig. 9J): Posterior margin straight, with seven pairs of plumose setae and one posteromedian spine.

First postlarval stage (Fig. 6, G and H; Fig. 11, A–J; Fig. 12, A–J)

Size TL: 5.07 mm (4.68–5.64 mm; SD=0.31; $n=20$)
 CL: 1.21 mm (1.03–1.51 mm; SD=0.14; $n=20$)



Body contour (Figs. 6G, 11I): Adult-like; pleopod developed; thorax completely covered by carapace; last five thoracic sternal plates with 2, 2, 0, 1, 1 spines.

Carapace (Fig. 6, G and H): Long rostrum with one epigastric tooth and three dorsal teeth; one pair of supraorbital, antennal, pterygostomial and hepatic spines anteroventral and posteroventral spines absent.

Antennule (Fig. 11A): Peduncle three-segmented, 1st segment with one large ventral spine, one small proximal spine, 40 plumose setae and a statocyst, 2nd segment with 10 plumose setae, 3rd segment with seven plumose setae; outer ramus two-segmented with 2, 6 aesthetascs; inner ramus two-segmented with 1, 3 plumose setae.

Antenna (Fig. 11B): Protopod unsegmented with two spines and one seta; endopod 23-segmented, 1st segment with two spines; scaphocerite with 34 marginal plumose setae, four spines on outer margin and 21 setae on surface.

Mandible (Fig. 11C): Denticulate setae absent; mandibular palp three-segmented, distal segment ovate; left mandible with 1, 10, 20 plumose setae; right mandible with 2, 11, 21 plumose setae.

Maxillule (Fig. 11D): Protopod two-lobed, coxal endite with nine plumose setae, basal endite with 22 naked setae; endopod four-segmented with 2, 2, 2, 3 setae.

Maxilla (Fig. 11E): Protopod four-lobed, endites with 11, 4, 10, 8 setae; endopod two-segmented with 8, 3 setae; scaphognathite with 43 plumose setae.

First maxilliped (Fig. 11F): Protopod two-lobed, coxal endite with nine setae and no spinules, basal endite with 36 setae; endopod four-segmented with 2, 0, 1, 5 setae; exopod with 10 plumose setae.

Second maxilliped (Fig. 11G): Naked podobranch, basis with 16 setae; endopod five-segmented with 8, 15, 1, 9, 10 setae; exopod with six plumose setae.

Third maxilliped (Fig. 11H): Coxa with three setae, basis with six setae; endopod five-segmented with 13, 12, 9, 13, 9 setae; exopod with eight plumose setae.

First pereopod (Fig. 12A): Coxa with four setae, basis with four setae; endopod 5-segmented and fully chelate with numerous setae; exopod with 8 plumose setae.

Second pereopod (Fig. 12B): Coxa with one seta, basis with two setae; endopod five-segmented and fully chelate with numerous setae; exopod with 8 plumose setae.

Third pereopod (Fig. 12C): Coxa naked, basis with five setae; endopod five-segmented and fully chelate with numerous setae; exopod with 10 plumose setae.

Fourth pereopod (Fig. 12D): Coxa naked, basis with four setae; endopod five-segmented with numerous fine setae; exopod with 11–12 plumose setae.

Fifth pereopod (Fig. 12E): Similar to 4th pereopod in form; exopod with 7–8 plumose setae.

First pleopod (Fig. 12F): Uniramous; two-segmented, proximal segment with 3–5 setae, distal segment with 10–14 plumose setae.

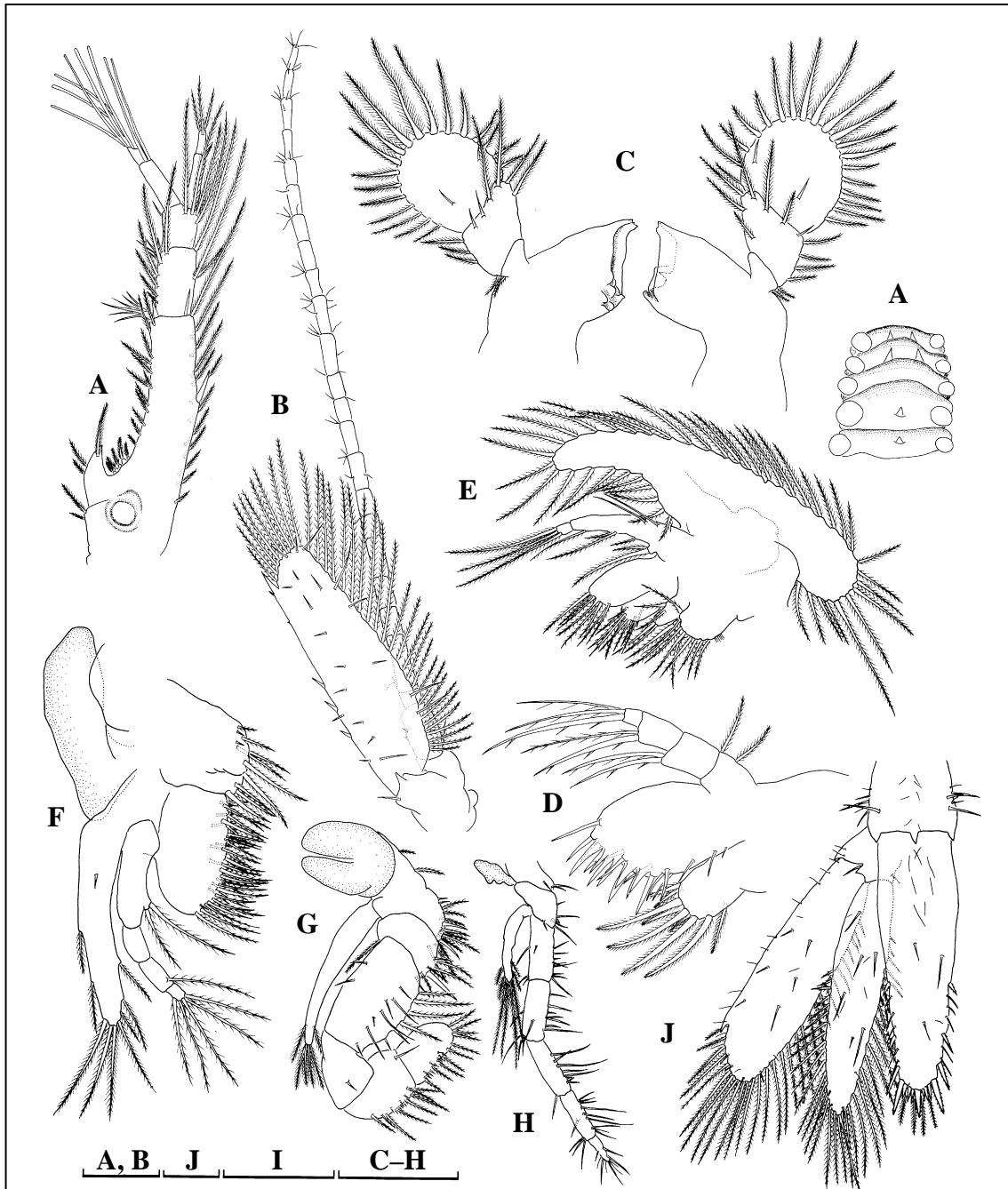


Figure 11

Metapenaeopsis dalei. First postlarval stage: (A) antennule; (B) antenna; (C) mandible; (D) maxillule; (E) maxilla; (F) first maxilliped; (G) second maxilliped; (H) third maxilliped; (I) thoracic sternal plate; (J) telson and uropod. Scale bars = 0.2 mm.

Second pleopod (Fig. 12G): Similar to 1st pleopod.

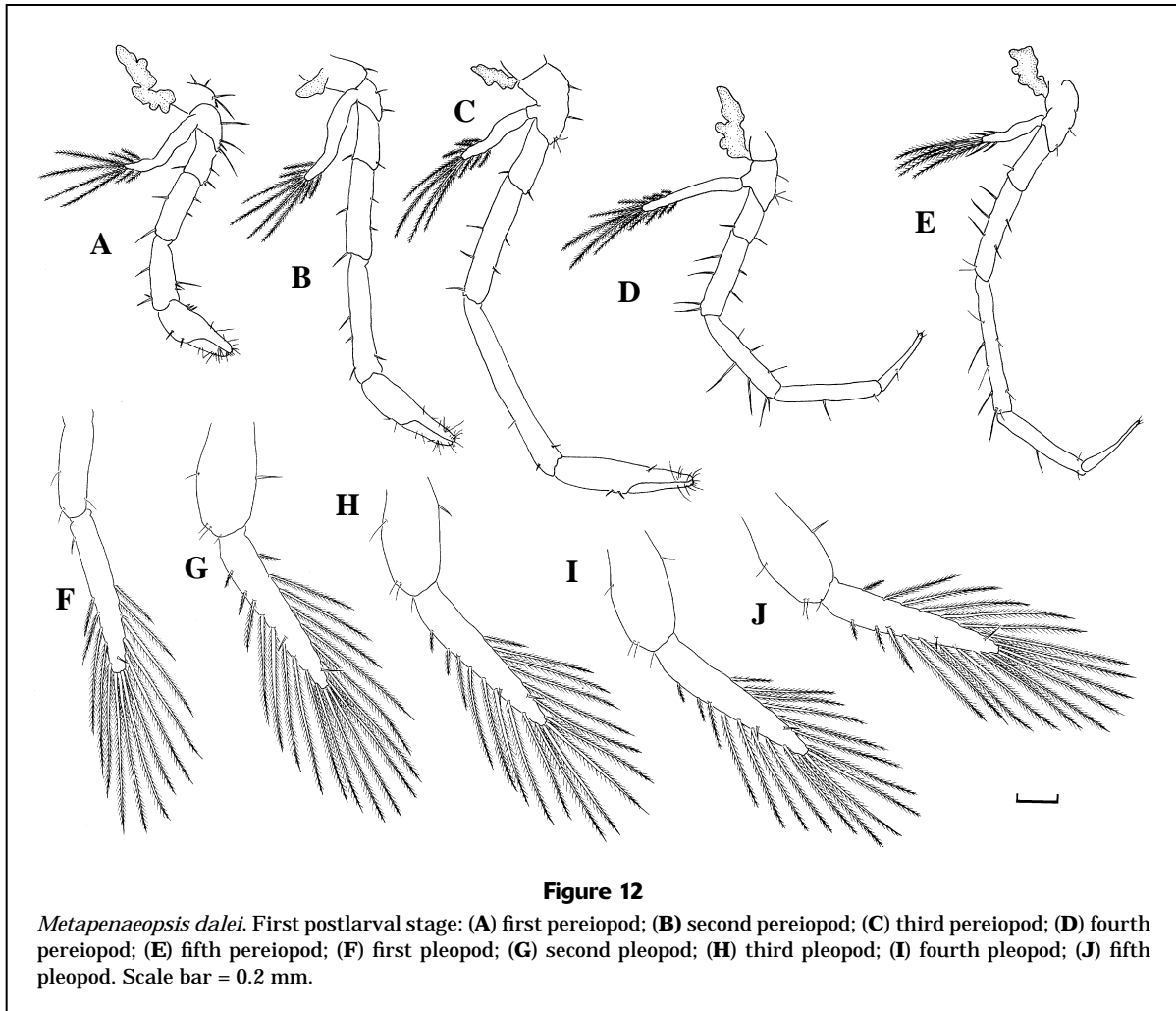
Third pleopod (Fig. 12H): Similar to 1st pleopod, with 19 setae.

Fourth pleopod (Fig. 12I): Similar to 1st pleopod, with 18 setae.

Fifth pleopod (Fig. 12J): Similar to 1st pleopod, with 19 setae.

Abdomen (Fig. 6, G and H): One lateral spine on 5th and 6th abdominal somites, one dorsomedian spine and one pair of lateroventral spines on 6th abdominal somite.

Uropod (Fig. 11J): Protodop with two spines; endopod with 23 plumose setae; exopod one fused spine and 21 plumose setae; numerous fine setae on dorsal and ventral surface of both rami.



Telson (Fig. 11J): Pointed, with seven pairs of setae, one posteromedian spine, and numerous fine setae on surface.

Discussion

Jackson et al. (1989) and Dall et al. (1990) used laboratory-reared and field-caught larvae, respectively, for their keys to the larvae and postlarvae of the penaeid genera. The protozoal stages of the genus *Metapenaeopsis* can be distinguished easily from those of other genera by the 2nd antennal formula, mobile eyes, presence of strong spines above the frontal organ, and the body length. The mysis and postlarval stages are easily separated from those of other genera by the serrated anteroventral margins of the carapace and unique thoracic sternal plate spines (2, 2, 0, 0, 0).

The first naupliar stage of *M. dalei* bears a chitinous conical protuberance on the posterodorsal aspect of the body. The cephalic knobs described for *M. stridulans* and *M. barbata* are also present from 3rd naupliar to 6th nauplius stages (Chong and Sasekumar, 1994; Ronquillo and

Saisho, 1997). The protozoal stages of *M. mogiensis*, *M. andamanensis*, *M. palmensis*, *M. stridulans*, *M. barbata*, and *M. dalei* have similar orbital or supraorbital spines, a telson setal formula of 7+7 and antennal setation of 0, 1; 5, 5 or 0, 1; 4, 5. However, five dorsomedian abdominal spines are found on the abdomen of the 3rd protozoal stage of *M. dalei*, but three in *M. stridulans* and *M. barbata*. The mysis and postlarval stages of *M. palmensis*, *M. stridulans*, *M. barbata*, and *M. dalei* are similar in general appearance, but some differences are found in the posterior ventral serrations of the carapace, in the number of setae on the scaphognathite and scaphocerite, and the thoracic sternal plate spines. Comparative morphological characteristics of *M. palmensis*, *M. stridulans*, *M. barbata*, and *M. dalei* are listed in Table 3.

The important morphological characters of the first postlarva of *M. dalei* that distinguish it from the rest are

- 1 43 scaphognathite setae on maxilla;
- 2 three scaphocerite spines on outer margin of antenna; and
- 3 sternal plate spines: 2, 2, 0, 1, 1.

Table 3Comparison of larval morphological characteristics of *Metapenaeopsis palmensis*, *M. stridulans*, *M. barbata*, and *M. dalei*.

Developmental stage	Characters	<i>M. palmensis</i> (Jackson et al., 1989)	<i>M. stridulans</i> (Chong and Sasekumar, 1994)	<i>M. barbata</i> (Ronquillo and Saisho, 1997)	<i>M. dalei</i> (the present study)
Egg	diameter (mm)	—	0.697–0.729	0.220–0.570	0.325–0.375
Nauplius	shape	—	pandulate	oval	oval
Third stage protozoaea	dorsomedian abdominal spines	5	3	3	5
First stage mysis	posterior ventral serrations on the carapace	absent	absent	absent	present
Third stage mysis	statocyst	present	absent	present	present
First stage postlarva	scaphognathite setae in maxilla	20	21	30–31	43
	scaphocerite spines on outer margin of antenna	1	2	2, 2, 0, 0, 0	3
	thoracic sternal plate spines	2, 2, 0, 0, 0	—	2, 2, 0, 1, 1	2

Acknowledgments

We are grateful to D. I. Williamson (Port Erin Marine Biological Station, Isle of Man, U.K.) and C. Sankarankutty (Universidade Federal do Rio Grande do Norte, Natal, Brazil) for critical reading of the manuscript. We thank H. K. Cha for collecting the gravid females of *Metapenaeopsis dalei*. We express our gratitude to the head of Taean Fish Hatchery, NFRDI, for providing us with experimental facilities. The authors wish to acknowledge the financial support of the Korea Research Foundation made in program year of (1998).

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