

Zoeal Stages and Megalopa of *Hemigrapsus penicillatus* (De Haan, 1835) (Decapoda, Brachyura, Grapsidae) Reared in the Laboratory

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ABSTRACT

The complete larval development of *Hemigrapsus penicillatus* (De Haan, 1835) from hatching to first crab stage was obtained by culture in the laboratory. Under culture conditions with salinity 33.3‰, temperature 25°C, and photophase 14/10 h light/dark, the megalopa and the first crab instar were attained in minimum of 18 and 29 days after hatching respectively. Five zoeal stages and a megalopal stage are described and illustrated in detail.

Morphological characters of *H. penicillatus* larvae were compared with those of other members within the subfamily Varuninae. Morphological differences among *H. penicillatus*, *H. sanguineus* and *H. sinensis* in megalopal stage are tabulated.

Key words: zoea, megalopa, *Hemigrapsus penicillatus*, Brachyura, Korea.

INTRODUCTION

Hemigrapsus penicillatus (De Haan, 1835) is very commonly found in entire coasts of Korea and inhabits under the stones, pebbles, and rocks of intertidal region (Kim, 1973). This species also occurs in Japan, China, and Hawaii (Sakai, 1976).

Some or complete larval stages have been described for about 75 grapsid species belonging to 24 genera and 4 subfamilies. Of them, Varuninae larvae are known for 16 species, including 8 species of *Hemigrapsus* (Table 1). Aikawa (1929) and Kim (1979) described the first zoeal stage and all larval stages of *H. penicillatus*, respectively. Aikawa's description, however, is very brief and questionable in the accuracy and Kim made an error in identification of adult crab and thus described characteristics of the larvae of other species.

In this paper we redescribe and illustrate the five zoeal stages and a megalopa of *H. penicillatus* in

Table 1. Published descriptions of larvae of the subfamily Varuninae. * = crabs found in Korea; @ = plankton materials; PZ, Z, M and C= prezoal, zoal, megalopal and crab stages.

Species	Described stages	Authors	Date
<i>Acmaeopleura parvula</i> *	Z1-5, M	Kurata	1968a
	Z1-5, M	Kim and Jang	1987
<i>Brachynotus sexdentatus</i>	Z2	Paula	1987
<i>Eriocheir japonicus</i> *	Z1	Aikawa	1929
	Z1-5, M, C1-5	Morita	1974
	Z1-5, M	Kim and Hwang	1990
<i>Eriocheir leptognathus</i> *	Z1-5, M	Lee	1988
<i>Eriocheir sinensis</i> *	@ Z1, M	Peters and Panning	1933
	Z1-5, M	Kim and Hwang	1995
<i>Eriocheir rectus</i>	Z1-5, M	Shy and Yu	1992
<i>Euchirograpsus americanus</i>	Z1-6, M	Wilson	1980
<i>Gaetice depressus</i> *	Z1	Aikaw	1929
	Z1	Kim	1980
	Z1-5	Kim and Lee	1983
<i>Hemigrapsus crenulatus</i>	PZ, Z1	Wear	1970
<i>Hemigrapsus edwardsi</i>	PZ, Z1	Wear	1970
<i>Hemigrapsus longitarsis</i> *	Z1	Aikawa	1929
<i>Hemigrapsus nudus</i>	Z1-5, M, C1	Hart	1935
<i>Hemigrapsus oregonensis</i>	Z1-5, M, C1	Hart	1935
<i>Hemigrapsus sanguineus</i> *	Z1	Aikawa	1929
	Z1-5, M	Kurata	1968b
	Z1-5, M	Hwang <i>et al.</i>	1993
<i>Hemigrapsus sinensis</i> *	Z1-5, M	Kim and Moon	1987
<i>Hemigrapsus penicillatus</i> *	Z1	Aikawa	1929
	Z1-5, M	Kim	1979
	Z1-5, M	present study	1995

detail. We compare the larvae of this species with those of known species of the subfamily Varuninae, particularly those of *Hemigrapsus*.

MATERIALS AND METHODS

Ovigerous females of *H. penicillatus* were captured from Kadok Island, Pusan, on 24 June 1993. They were transported to the laboratory in plastic boxes and the females were placed individually in glass containers (300 mm diameter × 200 mm depth) with filtered seawater (33.3‰ salinity) until hatching occurred on 6 July 1993.

Positively phototactic active larvae were separated into 20 groups of 10 larvae per glass bowl

(containing 80 ml filtered seawater of 33.3‰) and kept in a culture chamber with a light regime of 14:10 hr L:D and 25°C. *Brachionus* sp. for the early stages and newly hatched *Artemia* nauplii for the later stages were provided as food daily. Filtered seawater was changed every day. The larvae were examined each day before changing the water for the presence of live or dead larvae and exuviae.

Specimens, dead larvae and exuviae of each developmental stage were preserved in 7% neutral formalin. Larval descriptions were made based on at least 15 individuals of each stage. Drawings and measurements were based on freshly killed larvae and made with the aid of a camera lucida and an ocular micrometer. The chromatophore patterns were determined from the observation of living larvae. The terminology of setal types follows the nomenclature named by Bookhout and Costlow (1974).

RESULTS

Five zoeal stages and a megalopal stage were obtained. The megalopa and first stage crab appeared in a minimum of 18 and 29 days from hatching, respectively. Survival and developmental time from hatching to each larval stage are given in Table 2. Measurements of various features of the larvae are presented in Table 3.

First Zoea (Fig. 1)

Carapace (Figs. 1A, B). With rostral, dorsal, and lateral spines; all spines smooth. Rostral spine straight, uniformly tapered and shorter than dorsal spine. Dorsal spine slightly curved posteriorly. Lateral spines small and slightly curved downward. Postero-ventral margin of carapace round and finely serrate. Minute simple seta flanking each side of dorsal spine base. Eyes sessile.

Abdomen and telson (Fig. 1C). Composed of 5 somites and a telson. Somites 2-3 with distinct dorso-lateral knobs. Somites 2-5 each with paired simple setae on postero-dorsal margin and

Table 2. Time required for each larval stage and survival percentage of *Hemigrapsus penicillatus* (De Haan) at 25°C, salinity 33.3‰ and photophase 14/10 h light/dark. (Initial number of larvae = 200, mean values based only on larvae attaining next stage).

Stage	Number of larvae	Survival percentage	Survival of each stage (%)	Day reached		
				Minimum	Mean/S.D.	Maximum
Hatch to						
Zoea II	188	94.0	94.0	3	3.98/0.78	6
Zoea III	174	87.0	92.6	6	8.12/1.36	12
Zoea IV	160	80.0	92.0	9	12.29/2.17	16
Zoea V	142	71.0	88.8	13	16.01/2.25	20
Megalopa	118	59.0	83.1	18	20.90/2.41	26
Crab I	90	45.0	76.3	29	32.42/2.67	37

Table 3. Measurements of various features of the zoeae and megalopa of *Hemigrapsus penicillatus* (De Haan). All measurements are in mm; mean values, for 15 individuals of each larval stage, are given with standard deviation in brackets.

Feature	Zoea I	Zoea II	Zoea III	Zoea IV	Zoea V	Megalopa
TSL	0.90(0.02)	1.08(0.06)	1.64(0.04)	1.67(0.07)	2.26(0.13)	
Range	0.88-0.93	1.04-1.15	1.56-1.68	1.63-1.73	2.14-2.45	
DL	0.31(0.01)	0.37(0.02)	0.54(0.04)	0.56(0.04)	0.79(0.04)	
Range	0.28-0.33	0.35-0.42	0.49-0.58	0.54-0.60	0.73-0.86	
RL	0.22(0.01)	0.28(0.02)	0.36(0.02)	0.49(0.03)	0.76(0.07)	
Range	0.20-0.23	0.25-0.32	0.33-0.41	0.44-0.55	0.69-0.84	
LL	0.08(0.01)	0.10(0.01)	0.12(0.01)	0.13(0.01)	0.15(0.02)	
Range	0.07-0.10	0.09-0.11	0.10-0.13	0.12-0.14	0.13-0.17	
AL	0.17(0.01)	0.27(0.01)	0.34(0.02)	0.35(0.03)	0.56(0.03)	
Range	0.15-0.19	0.24-0.30	0.31-0.36	0.33-0.41	0.51-0.60	
CL	0.49(0.01)	0.53(0.02)	0.76(0.02)	0.82(0.04)	1.18(0.02)	1.67(0.06)
Range	0.46-0.51	0.50-0.55	0.70-0.79	0.80-0.85	1.11-1.23	1.62-1.72
CW						1.24(0.06)
Range						1.20-1.29

AL, second antenna length; CL, carapace length; CW, carapace width; DL, dorsal spine length; LL, lateral spine length; RL, rostral spine length; TSL, total spine length (= length from rostral to dorsal spine tips)

terminating in postero-lateral spines. Telson bifurcated. Each furca with a row of minute spinules on inner region. Three serrate spines on inner margin of each furca.

Antennule (Fig. 1D). Smooth and conical, with 2 long aesthetascs and a short simple seta.

Antenna (Fig. 1E). Protropod tapered, with 2 rows of spinules on distal half. Exopod with 2 small simple setae at the base of terminal spine.

Mandibles (Fig. 1F). Asymmetrical. Molar and incisor processes irregularly dentated. Junction of molar and incisor processes with 5 teeth on right mandible.

Maxillule (Fig. 1G). Endopod 2-segmented, proximal segment with a plumose seta, distal segment with 4 terminal and 1 subterminal plumodenticulate setae. Basal and coxal endites each with 5 plumodenticulate setae.

Maxilla (Fig. 1H). Endopod unsegmented, slightly bilobed, with 4 plumodenticulate setae terminally. Basal endite bilobed, distal and proximal lobes each with 4 and 5 plumodenticulate setae. Coxal endite bilobed, distal and proximal lobes each with 2 and 4 plumose setae. Scaphognathite with 4 densely plumose setae and terminal process with dense microtrichia.

First maxilliped (Fig. 1I). Coxa naked. Basis with 10 plumodenticulate setae. Endopod 5-segmented, with proximal to distal setation pattern of 2, 2, 1, 2 and 4+1 plumodenticulate setae. Exopod with 4 natatory plumose setae.

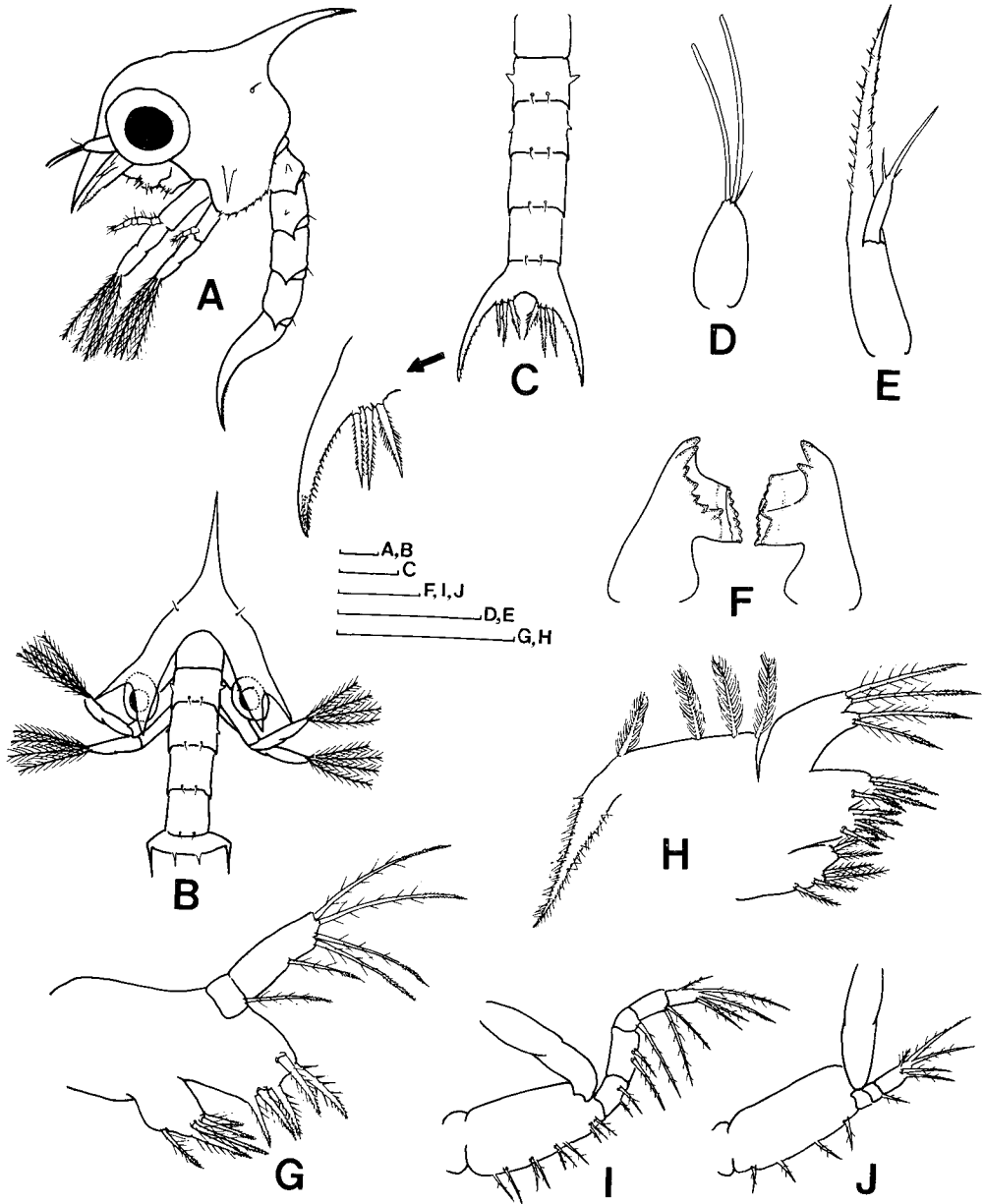


Fig. 1. First zoea of *Hemigrapsus penicillatus* (De Haan): A, lateral view; B, posterior view; C, dorsal view of abdomen; D, antennule; E, antenna; F, mandibles; G, maxillule; H, maxilla; I, first maxilliped; J, second maxilliped. Scale bars = 0.1 mm.

Second maxilliped (Fig. 1J). Basis with 4 plumodenticulate setae. Endopod 3-segmented, with proximal to distal setation pattern of 0, 1 and 6 plumodenticulate setae. Exopod with 4 natatory plumose setae.

Chromatophores. The pattern of chromatophores fairly consistent throughout zoeal development. Dark brown chromatophores present between the eyes, on the base of rostrum and antennule, on labrum and mandibles, on the base of the first maxilliped, on cardiac and postero-lateral regions of carapace, and along ventral region of abdominal somites 2-5 and telson.

Second Zoea (Fig. 2)

Carapace (Fig. 2A). Postero-ventral margin with 2 pairs of plumose setae. Two pairs of simple setae added on antero-medial margin. Eyes stalked.

Abdomen and telson (Figs. 2A,B). Somite 1 with a dorso-medial plumose seta.

Antennule (Fig. 2C). With 4 aesthetascs and a simple seta.

Antenna (Fig. 2D) and Mandibles (Fig. 2E). As in the first stage.

Maxillule (Fig. 2F). Basal and coxal endites each with 7 and 5 plumodenticulate setae. A plumose seta added on dorsal margin.

Maxilla (Fig. 2G). Distal and proximal lobes of coxal endite each with 3 and 4 plumose seta. Scaphognathite with 8 densely plumose setae.

First maxilliped (Fig. 2H) and Second maxilliped (Fig. 2I). Exopod with 6 natatory plumose setae.

Third Zoea (Fig. 3)

Carapace (Fig. 3A). Postero-ventral margin with 5 or 6 pairs of plumose setae. Paired simple setae added on base of the rostral spine and dorsal spine.

Abdomen and telson (Figs. 3A, B). Somite 6 present. Telson with 4 pairs of serrate spines on inner margin.

Antennule (Fig. 3C). With 3 aesthetascs and a simple seta.

Antenna (Fig. 3D). Endopod present as a small bud.

Mandibles (Fig. 3E). Left mandible with an additional tooth on junction of incisor and molar process.

Maxillule (Fig. 3F). Basal endite with 7 terminal and 1 lateral plumodenticulate setae. A plumodenticulate seta added on proximal margin.

Maxilla (Fig. 3G). Scaphognathite bearing 13 densely plumose setae.

First maxilliped (Fig. 3H). Coxa with a plumodenticulate seta. A plumose seta added on the third segment of endopod, setation now 2, 2, 2, 2 and 5. Exopod with 8 natatory plumose setae.

Second maxilliped (Fig. 3I). Exopod with 8 natatory plumose setae.

Fourth Zoea (Fig. 4)

Carapace (Fig. 4A). Postero-ventral margin with 8 or 9 pairs of plumose setae. Paired simple setae added on anterior margin and dorsal spine. Buds of thoracic appendages visible through the carapace.

Abdomen and telson (Figs. 4A, B). Somite 1 with 3 dorso-medial plumose setae. Pleopod buds present on postero-ventral margin of somites 2-6. Telson with 2 small serrate spines on central arch.

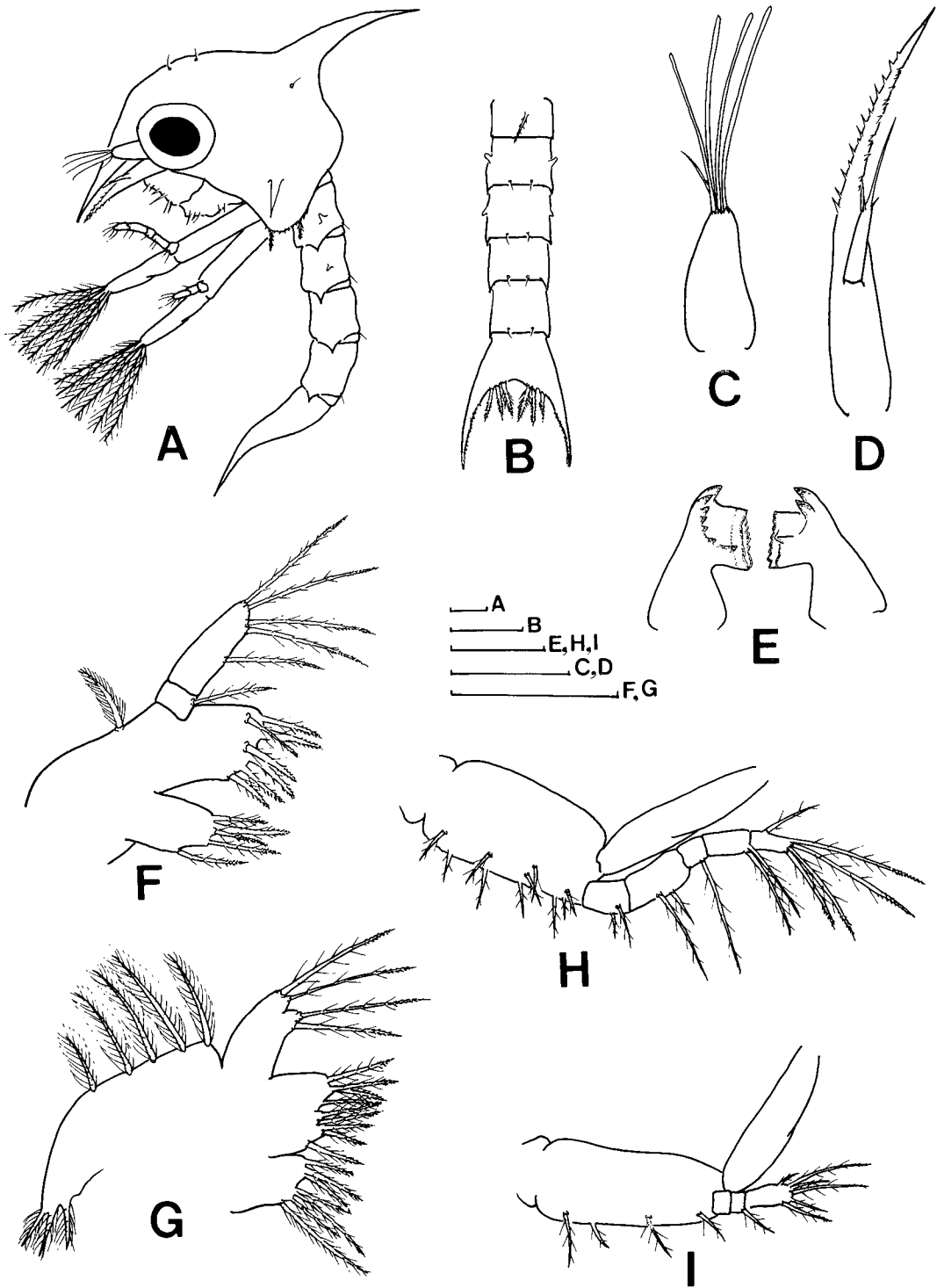


Fig. 2. Second zoea of *Hemigrapsus penicillatus* (De Haan): A, lateral view; B, dorsal view of abdomen; C, antennule; D, antenna; E, mandibles; F, maxillule; G, maxilla; H, first maxilliped; I, second maxilliped. Scale bars = 0.1 mm.

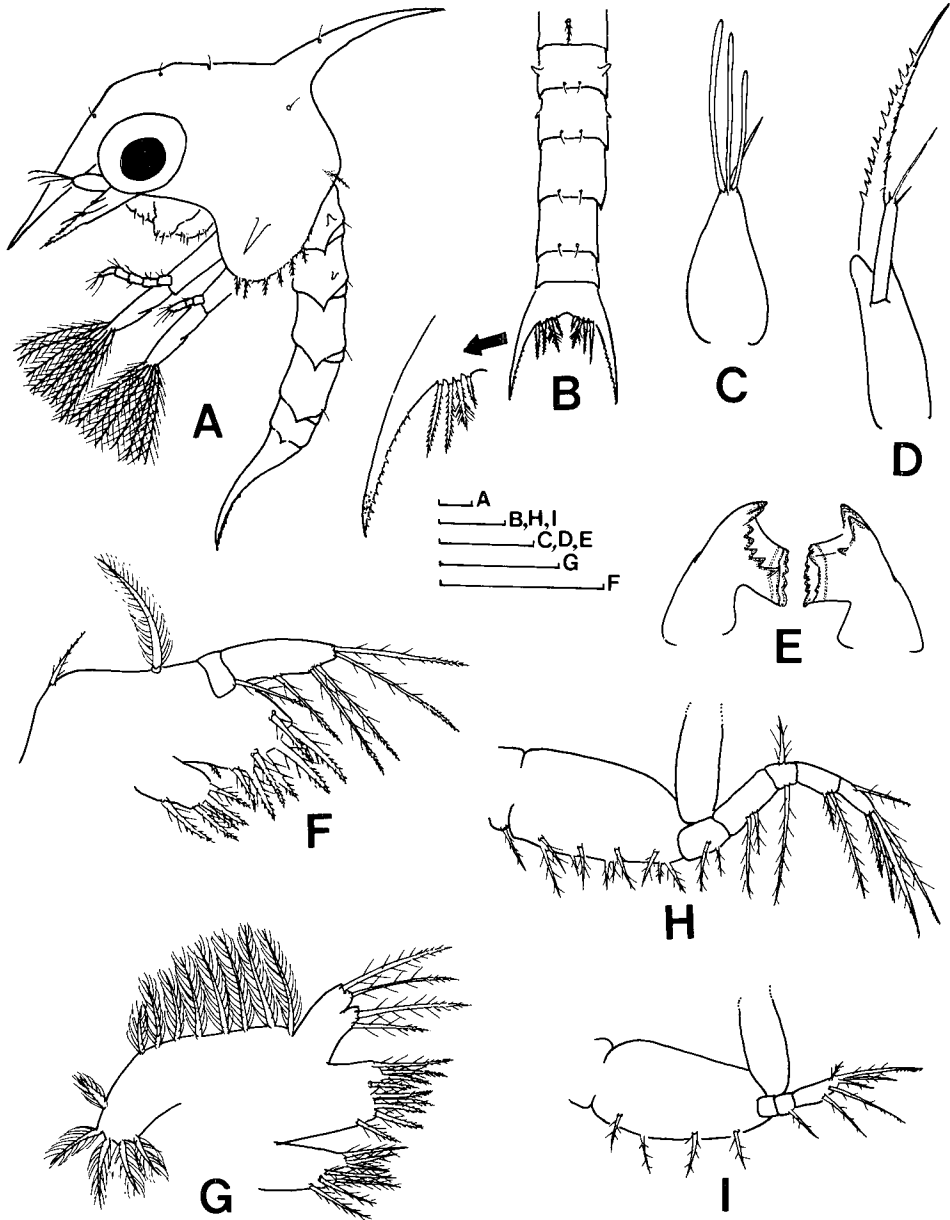


Fig. 3. Third zoea of *Hemigrapsus penicillatus* (De Haan): A, lateral view; B, dorsal view of abdomen; C, antennule; D, antenna; E, mandibles; F, maxillule; G, maxilla; H, first maxilliped; I, second maxilliped. Scale bars = 0.1 mm.

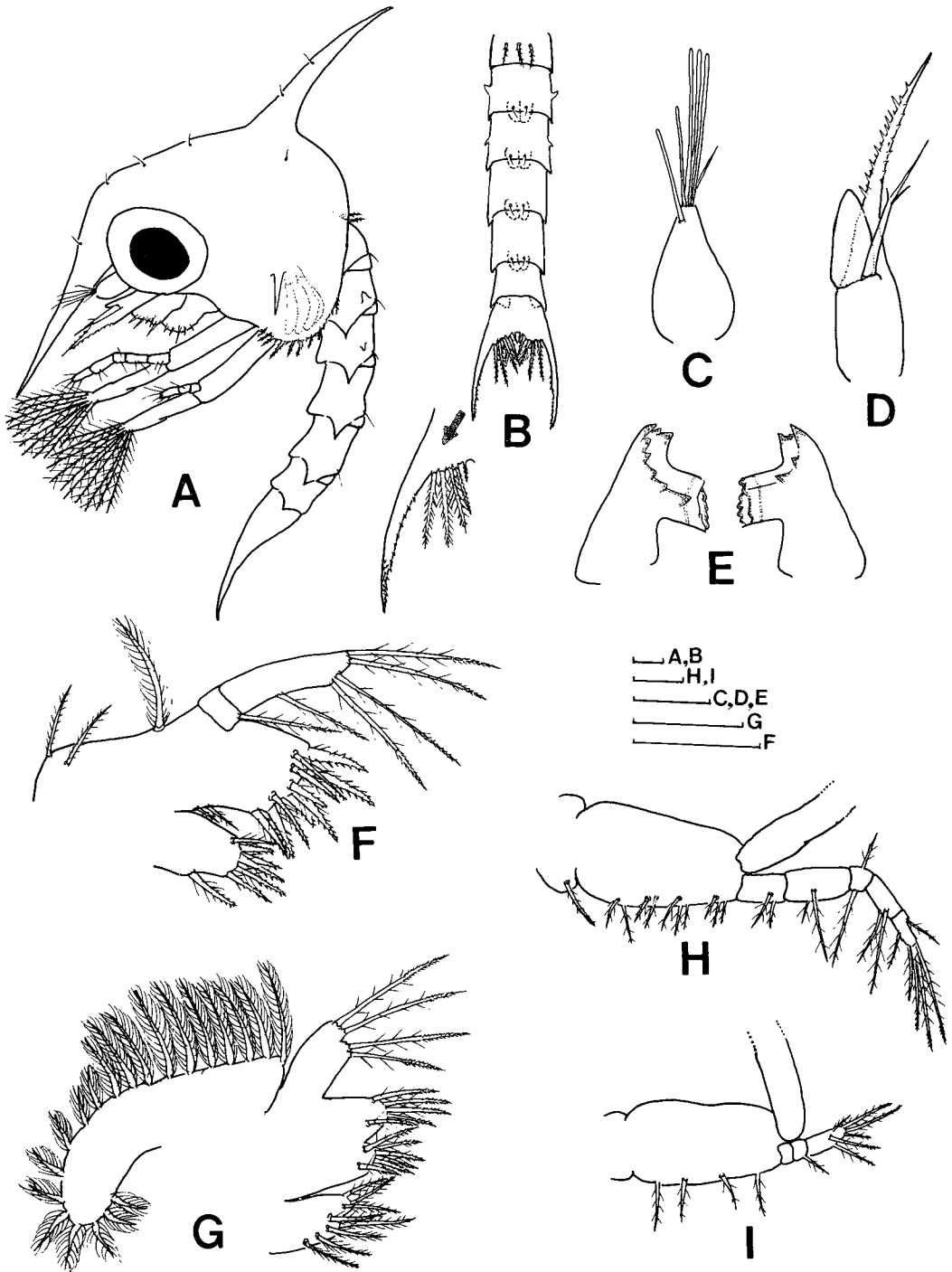


Fig. 4. Fourth zoea of *Hemigrapsus penicillatus* (De Haan): A, lateral view; B, dorsal view of abdomen; C, antennule; D, antenna; E, mandibles; F, maxillule; G, maxilla; H, first maxilliped; I, second maxilliped. Scale bars = 0.1 mm.

Antennule (Fig. 4C). With 4 terminal, a subterminal aesthetascs and a simple seta.

Antenna (Fig. 4D). Endopod bud much larger.

Mandibles (Fig. 4E). Left mandible with an additional tooth on junction of incisor and molar processes.

Maxillule (Fig. 4F). Basal endite with 10 terminal and 2 lateral plumodenticulate setae. Coxal endite with 7 plumodenticulate setae. A plumose seta added on proximo-lateral margin.

Maxilla (Fig. 4G). Distal and proximal lobes of basal endite each with 5 and 6 plumodenticulate setae. Distal and proximal lobes of coxal endite each with 3 and 5 plumose setae. Scaphognathite with 19-20 densely plumose setae.

First maxilliped (Fig. 4H). A plumose seta added on distal segment of endopod, setation now 2, 2, 2, 2 and 6. Exopod with 10 natatory plumose setae.

Second maxilliped (Fig. 4I). Exopod with 10 natatory plumose setae.

Fifth Zoea (Fig. 5)

Carapace (Fig. 5A). Postero-ventral margin with 10-12 pairs of plumose setae. Dorsal spine with 4 pairs of simple setae. Thoracic appendages enlarged and chela prominent.

Abdomen and telson (Figs. 5A, B). Somite 1 with 5 dorso-median plumose setae. Pleopod buds much elongated. Telson with paired simple setae on medio-dorsal region.

Antennule (Fig. 5C). With 5 aesthetascs plus a simple seta terminally and 4 aesthetascs subterminally. Basal region swollen. Endopod bud small, round.

Antenna (Fig. 5D). Endopod incompletely 2-segmented, extending 3/5 length of protopod.

Mandibles (Fig. 5E). Mandibular palps present as small buds.

Maxillule (Fig. 5F). Basal endite with 13 terminal and 3 lateral plumodenticulate setae. Coxal endite with 10 plumodenticulate setae.

Maxilla (Fig. 5G). Distal and proximal lobes of basal endite each with 7 and 8 plumodenticulate setae. Distal and proximal lobes of coxal endite each with 4 and 8 plumose setae. Scaphognathite with 34-37 densely plumose setae marginally.

First maxilliped (Fig. 5H). Coxa with 2 plumodenticulate setae. A plumose seta added on second segment of endopod, setation now 2, 3, 2, 2 and 6. Exopod with 12 natatory plumose setae.

Second maxilliped (Fig. 5I). Exopod with 12 natatory plumose setae.

Megalopa (Figs. 6,7)

Carapace (Fig. 6A). Subquadrate in dorsal view. Rostrum ending in a pointed tip, deflected ventrally. Plumose setae fringed along lateral and posterior margin. Simple setae scattered on dorsal surface as illustrated. Smooth undulation present on lateral region.

Abdomen and telson (Fig. 6A). With 6 somites and a telson. All somites with simple setae as illustrated. Telson semicircular in dorsal view, with 3 plumose setae on posterior margin and 2 dorsal simple setae.

Antennule (Fig. 6B). Peduncle 3-segmented: first segment with 4 plumose and 6 simple setae, second segment with 3 plumose setae, third segment naked. Lower ramus with 3 terminal and 1 lateral simple setae. Upper ramus 4-segmented: first segment unarmed, second segment with 5 aesthetascs, third segment with 6 aesthetascs plus a plumose seta, fourth segment with 5 aesthetascs

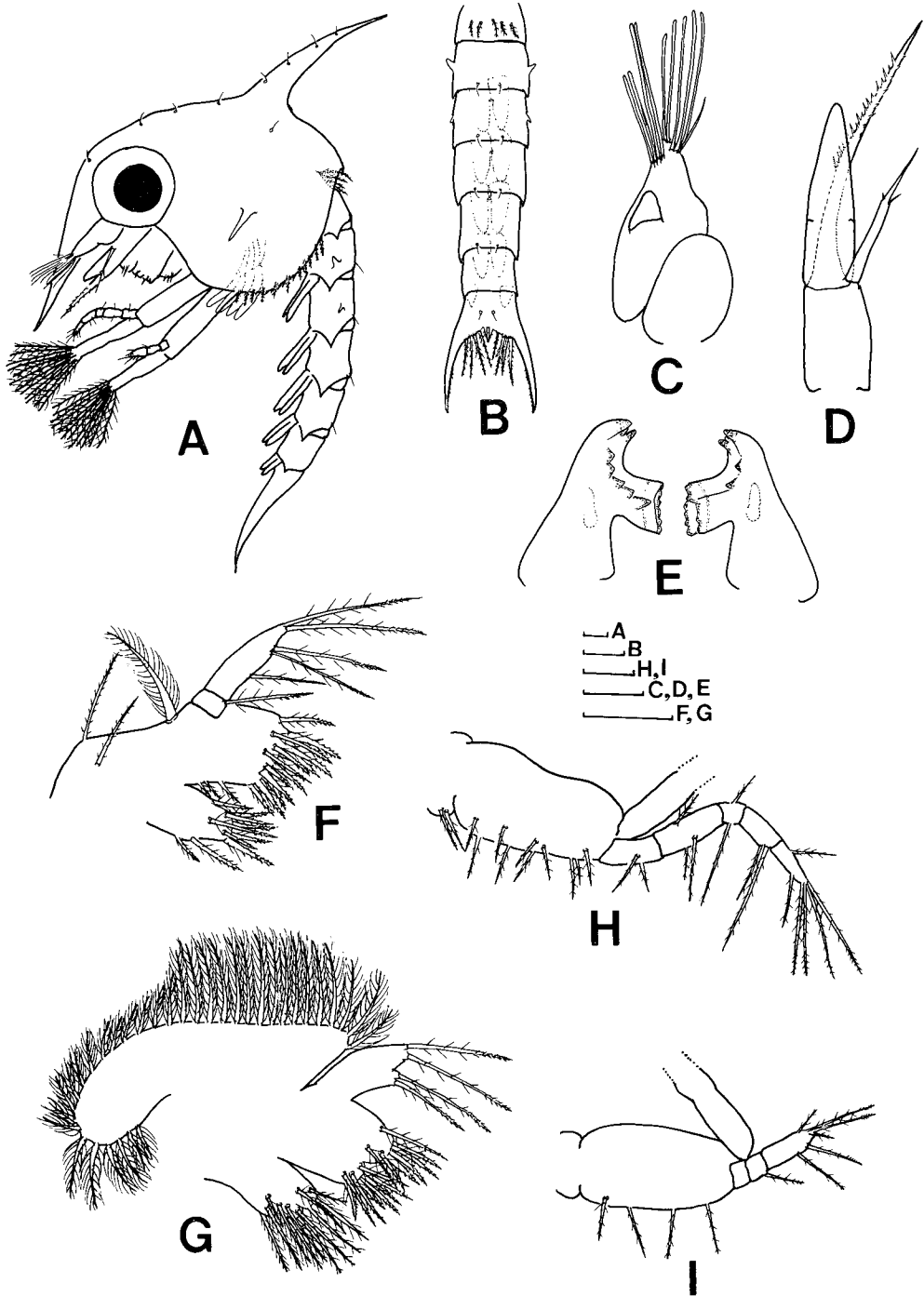


Fig. 5. Fifth zoea of *Hemigrapsus penicillatus* (De Haan): A, lateral view; B, dorsal view of abdomen; C, antennule; D, antenna; E, mandibles; F, maxillule; G, maxilla; H, first maxilliped; I, second maxilliped. Scale bars = 0.1 mm.

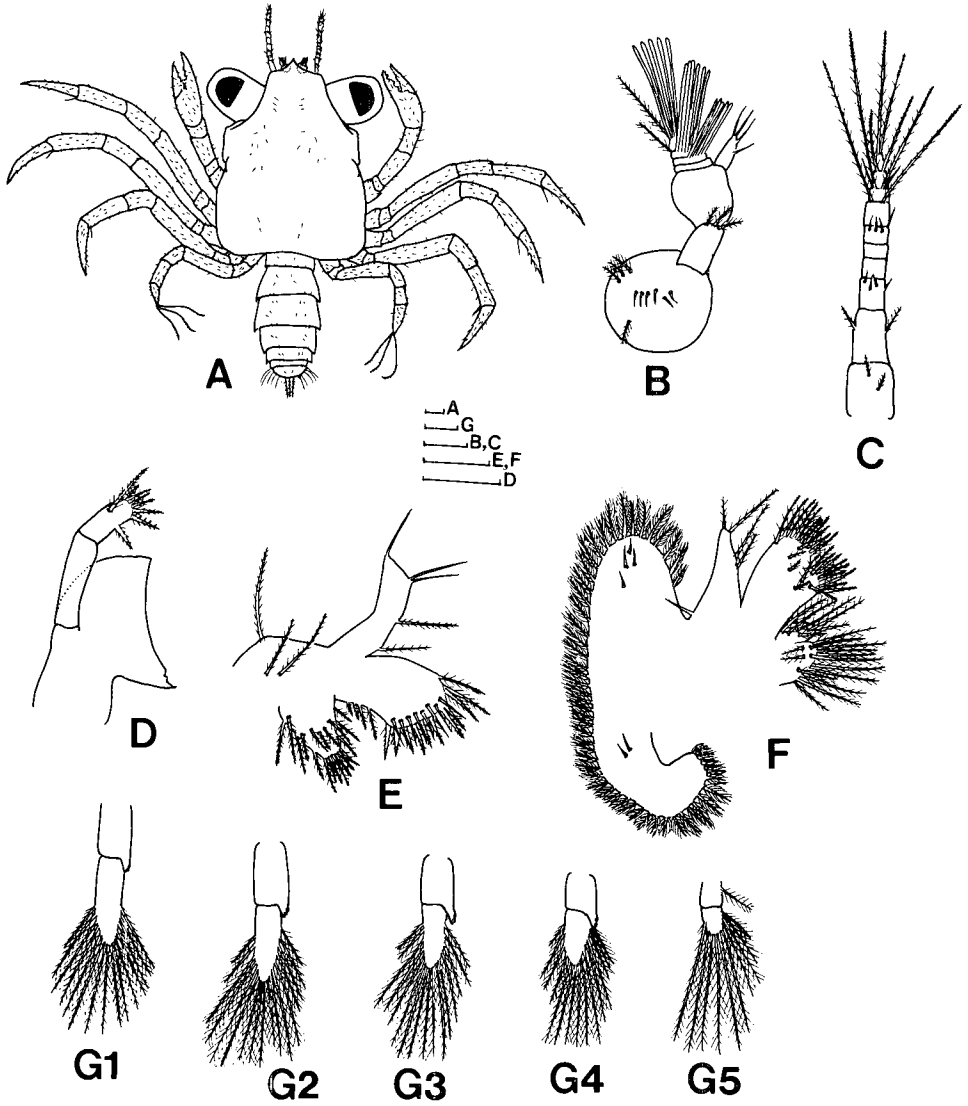


Fig. 6. Megalopa of *Hemigrapsus penicillatus* (De Haan): A, dorsal view; B, antennule; C, antenna; D, mandible; E, maxillule; F, maxilla; G1-5, pleopods 1-5. Scale bars = 0.1 mm.

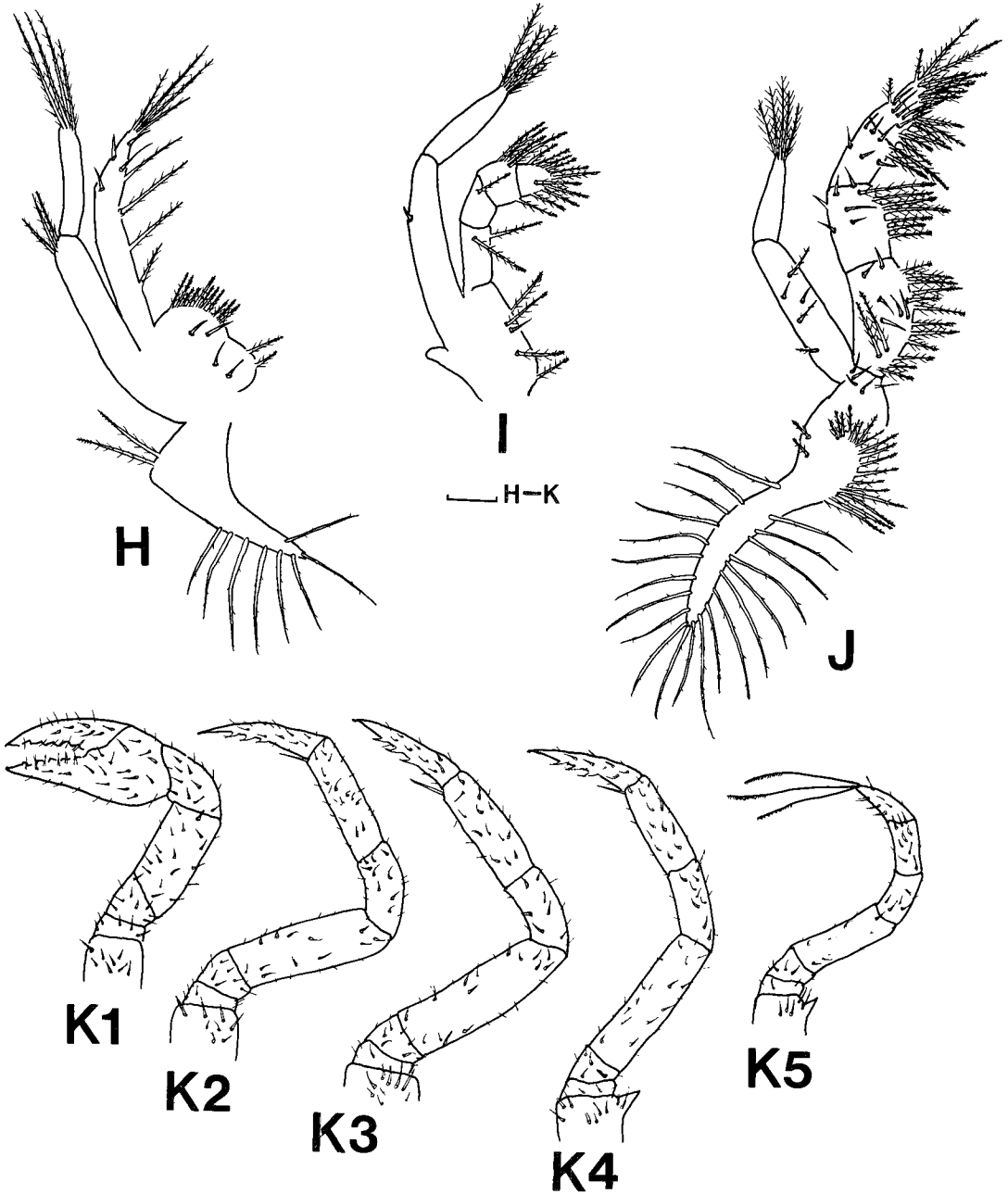


Fig. 7. Megalopa of *Hemigrapsus penicillatus* (De Haan): H, first maxilliped; I, second maxilliped; J, third maxilliped; K1-5, pereopods 1-5. Scale bars = 0.1 mm

plus a plumose seta.

Antenna (Fig. 6C). Ten-segmented, with proximal to distal setation pattern of 2, 2, 4, 0, 0, 4, 2, 4, 2 and 2 simple or plumodenticulate setae.

Mandible (Fig. 6D). Symmetrical. Palp 2-segmented: proximal segment naked, distal segment with 8 plumodenticulate setae.

Maxillule (Fig. 6E). Endopod with 3 terminal simple setae and 2 lateral plumose setae. Basal endite with 15 plumodenticulate plus 8 simple setae. Coxal endite with 19 plumodenticulate setae. Dorsal region with 3 plumose setae.

Maxilla (Fig. 6F). Endopod unsegmented, with 4 plumose and a simple setae. Distal and proximal lobes of basal endite each with 13 and 12 plumodenticulate setae. Distal and proximal lobes of coxal endite each with 6 and 14 plumose setae. Scaphognathite with 54-57 plumose setae on margin and 6 simple setae on blade.

Pleopods (Figs. 6G 1-5). Well developed on somites 2-6. Exopods of pleopods 1-5 each with 14-16, 17-18, 16-17, 15 and 10 natatory plumose setae. Endopods of pleopods 1-4 with 3 hooked spines. Pleopod 5 lacking endopod and with a plumose seta on basal segment.

First maxilliped (Fig. 7H). Unsegmented endopod with 8 plumose and 4 simple setae. Exopod 2-segmented: proximal segment with 3 small plumose setae, distal segment with 4 long plumose setae terminally. Basal and coxal endites each with 13 and 4 plumodenticulate or simple setae on or near margin. Epipod triangular in shape, with 8 sparsely plumose setae terminally and 2 plumodenticulate setae proximally.

Second maxilliped (Fig. 7I). Endopod 4-segmented, with proximal to distal setation pattern of 2, 1, 5 and 10 plumodenticulate setae. Exopod 2-segmented: proximal segment with a stout spine, distal segment with 5 plumose setae. Basis with 4 plumodenticulate and a simple setae.

Third maxilliped (Fig. 7J). Endopod 5-segmented, with proximal to distal setation pattern of 20, 13, 8, 13 and 8 plumodenticulate or simple setae. Exopod 2-segmented: proximal segment with 3 plumose and 2 simple setae, distal segment with 5 plumose setae. Epipod with 21 sparsely plumose setae and 20 plumodenticulate setae. Basis with 5 plumodenticulate setae.

Pereiopods (Figs. 7K 1-5). Cheliped covered with short simple setae: fingers with a few teeth on each cutting margin. Pereiopods 2-4 similar in shape, each with a disto-ventral tooth on propodus and 3 ventral teeth on dactylus. Pereiopod 5 with 3 long hooked serrate setae on dactylus.

Chromatophores. Spidery dark brown and yellowish-red chromatophores present on eyestalks, on medio-lateral, postero-lateral, posterior and gastric regions of carapace, on all segment of pereiopods 1-5, and on each abdominal somite.

DISCUSSION

Aikawa (1929) described very briefly only the first zoea of *H. penicillatus* from Japan. There are, however, some discrepancies between the present description and that given by Aikawa. He reported two terminal aesthetascs and two hairs on the first antenna, compared with our two aesthetascs and a simple seta. He also described a setation of 0,1,5 on endopod of the second maxilliped, but the setation of our specimen is 0,1,6 throughout the zoeal stages. In addition, Aikawa described that

each of abdominal somites has a hair on dorsal margin; exopod of the second antenna has a seta at middle. Whereas our specimen showed that abdominal somites 2-5 have two simple setae on postero-dorsal margin; exopod of the second antenna has two short simple setae at the base of terminal spine. These differences probably relate to the low magnification of his microscope and therefore we have need for re-observation of larvae hatched from Japan species.

Kim (1979) reported the complete larval development of *H. penicillatus*, but morphological features which can be discerned from his descriptions and figures make positive identification of those specimens uncertain. For example, in his description lateral carapace spines are absent in all zoeal stages, but appear in our specimens and Aikawa's. This feature is very useful in identifying crab larvae. Because of *H. penicillatus* and *Gaetice depressus* (De Haan, 1835) are very similar as adults, Kim made a mistake in identification of crab and may be described morphological characteristics of the larvae of *G. depressus*. Comparisons between the present study of the first zoea of *H. penicillatus* and those of Aikawa (1929) and Kim (1979) are given in Table 4.

Within the subfamily Varuninae, the first zoea of *Euchirograpsus americanus* A Milne Edwards, 1880 from the western North Atlantic waters is significantly unlike to the zoeae of other species (Table 4). Wilson (1980) suggested that the zoea larvae of this species are more allied to Plagusiinae and Grapsinae larvae than to those of Varuninae by antenna and telson types. The other species may be separated into two major groups by carapace spines. One of them is a group of lacking lateral carapace spines as the genera *Acmaeopleura* and *Gaetice*. The other group has lateral carapace spines as the genera *Eriocheir* and *Hemigrapsus*. The first zoeae in these two groups can be identified by using several of the listed characters (Table 4). The type of antenna has been always considered an important classification feature in brachyuran larvae. Most varunine larvae have a type B2 [= exopod about 1/2-3/4 length of the protopod with a short seta at base of terminal spine] or B3 antenna [= exopod with two short setae at base of terminal spine]. This type is found predominantly in *Eriocheir* and *Hemigrapsus*, but only *E. leptognathus* Rathbun, 1914 and *E. rectus* Stimpson, 1858 have a type B7 [= exopod substantially reduced in size to protopod] and B1 antenna [= exopod lacking seta at base of terminal spine] respectively. As to other features for distinguishing among the larvae of the Varuninae, armature of abdominal somites can be useful. For instance, abdominal somite with dorso-lateral knobs is second somite in *H. oregonensis*, *H. crenulatus* (H. Milne Edwards, 1837) and *H. edwardsi* (Hilgendorf, 1882), second and third somites in *A. parvula* Stimpson, 1858, *E. leptognathus*, *G. depressus*, *H. longitarsis* (Miers, 1879), *H. nudus*, *H. penicillatus* and *H. sanguineus* (De Haan, 1835), second through fourth somites in *E. japonicus* De Haan, 1835, *E. sinensis* H. Milne Edwards, 1853, *E. rectus* and *H. sinensis* Rathbun, 1929. Also, significant differences in the first zoeae among the Varuninae species are apparent in mouthparts setations. Basis (2,2,3,3) and endopod (2,2,1,2,5) setations of the first maxilliped are consistent in most known species. However, those of *H. crenulatus* by Wear (1970) are considerably different as 3,3,3,3 and 1,1,1,2,5. Endopod of the second maxilliped is 0,1,6 in most species, but 1, 1,6 in *H. edwardsi* and 0,1,5 in *H. nudus* and *H. oregonensis*. In addition, comparisons of these features in the first zoeae are given in Table 4.

The complete larval development is known for eleven species of the Varuninae, eight of which are known in Korean waters. *H. nudus* and *H. oregonensis* from British Columbia have been described previously by Hart (1935), but both descriptions and illustrations are too brief to be used in

Table 4. Comparisons of morphological features of the first zoea larvae in 15 species of the subfamily Varuninae.

	TSL	CL	LCS	AS	Tel- son type	Ant- enna type	Ante- rnule form	Maxillule			Maxilla			Maxilliped 1			Maxilliped 2		
								End.	BE	CE	End.	BE	CE	Sca.	End.	Basis	End.	Basis	End.
<i>Acmaeopleura parvula</i> (Kim and Jang, 1987)	?	0.56	-	2-3	B	B3	2A+1S	1,5	5	5	4,5	3,4	4+1	2,2,1,2,5	2,2,3,3	0,1,6	4		
<i>Eriocheir japonicus</i> (Kim and Hwang, 1990)	1.18	0.50	+	2-4	B	B3	2A+2S	1,5	5	5	4,5	2,4	4+1	2,2,1,2,5	2,2,3,3	0,1,6	4		
<i>Eriocheir leptognathus</i> (Lee, 1988)	1.25	0.50	+	2-3	B	B7	2A+1S	1,5	5	6	4,5	3,3	4+1	2,2,1,2,5	2,2,3,3	0,1,6	4		
<i>Eriocheir sinensis</i> (Kim and Hwang, 1995)	1.02	0.43	+	2-4	B	B3	2A+2S	1,5	5	5	4,5	2,4	4+1	2,2,1,2,5	2,2,3,3	0,1,6	4		
<i>Eriocheir rectus</i> (Shy and Yu, 1992)	1.01	0.28	+	2-4	B	B1	2A+1S	5	5	4	?	?	?	1,1,1,1,4*	?	5*	?		
<i>Euchirograpsus americanus</i> (Wilson, 1980)	?	0.70	+	2-5	A	C	3A+1S	1,5	5	6(5)	4,5	3,5	3+1	2,2,1,2,5	2,2,2,2	1,1,6	4		
<i>Gaeftice depressus</i> (Kim and Lee, 1983)	0.83	0.50	-	2-3	B	B3	2A+1S	1,5	5	5	4,5	3,3	4+1	2,2,1,2,5	2,2,3,3	0,1,6	4		
<i>Hemigrapsus crenulatus</i> (Wear, 1970)	1.05	?	+	2	B	B3	2A+1S	1,5	5	4	3,3	2,4	3+1	1,1,1,2,5	3,3,3,3	1,1,6	4		
<i>Hemigrapsus edwardsi</i> (Wear, 1970)	1.20	?	+	2	B	B3	2A+1S	1,5	6	4	4,4	2,4	5+1	2,2,2,2,6	?	1,1,6	4		
<i>Hemigrapsus longitarsus</i> (Aikawa, 1929)	0.76	0.44	+	2-3	B	B2	2A+1S	1,5	5	5	4	8	4+1	2,2,1,2,5	2,2,3,3	?	4		
<i>Hemigrapsus nudus</i> (Hart, 1935)	1.20	?	+	2-3	B	B3	2A+1S	1,5	6	5	4	7	4+1	2,2,1,2,5	2,1,3,3	0,1,5	4		

Table 4. (Continued).

	TSL	CL	LCS	AS	Tel- son type	Ant- enna type	Ante- nnule form	Maxillule			Maxilla			Maxilliped 1			Maxilliped 2		
								End.	BE	CE	End.	BE	CE	Sca.	End.	Basis	End.	Basis	End.
<i>Hemigrapsus oregonensis</i> (Hart, 1935)	1.10	?	+	2	B	B3	2A+1S	1,5	6	5	4	7	6	4+1	2,2,1,2,5	2,1,3,3	0,1,5		
<i>Hemigrapsus penicillatus</i> (Aikawa, 1929)	0.90	0.44	+	?	?	B2	2A+2S	1,5	5	5	4	9	6	4+1	2,2,1,2,5	2,2,3,3	0,1,5		
<i>Hemigrapsus penicillatus</i> (Kim, 1979)	0.75	?	-	2-3	B	B2	3A+1S	1,5	5	5	4	5,4	2,4	4+1	2,2,1,2,5	?	0,1,5		
<i>Hemigrapsus penicillatus</i> (present study)	0.90	0.49	+	2-3	B	B3	2A+1S	1,5	5	5	4	4,5	2,4	4+1	2,2,1,2,5	2,2,3,3	0,1,6		
<i>Hemigrapsus sanguineus</i> (Hwang et al. 1993)	0.93	0.49	+	2-3	B	B3	2A+1S	1,5	5	5	4	4,5	2,4	4+1	2,2,1,2,5	2,2,3,3	0,1,6		
<i>Hemigrapsus sinensis</i> (Kim and Moon, 1987)	0.85	0.46	+	2-4	B	B3	2A+2S	1,5	5	5	4	4,5	3,4	4+1	2,2,1,2,5	2,2,3,3	0,1,6		

A, aesthetascs; AS, abdominal somites with lateral knobs; BE, basal endite; CE, coxal endite; CL, carapace length; End., endopod; LCS, lateral carapace spines; S, simple seta; Sca., scaphognathite; TSL, total spine length (= length from rostral to dorsal tips); +, presence; -, absence; ?, no description; telson and antenna types following Aikawa's scheme (1929, 1933); *data from figures.

Table 5. Comparison of morphological features of the megalopa in three species of *Hemigrapsus*.

	<i>H. penicillatus</i> (present study)	<i>H. sanguineus</i> (Hwang <i>et al.</i> , 1993)	<i>H. sinensis</i> (Kim and Moon, 1987)
Carapace			
Length/Width	1.67/1.24 mm	1.74/1.54 mm	1.14/0.92 mm
Antennule			
Peduncle	3-segmented;4P+6S,3P,0	3-segmented;3P+6S,3P,1S	3-segmented;3P+2S,3S,1S
Lower ramus	4S	4S	4S
Upper ramus	0;5A;6A+1P;5A+1P	0;7A;7A+1P;5A+1P	0;6A;5A+1S+1P;5A+1S
Antenna			
Flagellum	10-segmented; 2,2,4,0,0,4,2,4,2,2	10-segmented; 3,2,3,0,0,4,2,4,3,3	10-segmented; 1-3,1-2,1-2,0,0,0-3, 1,5,3,3
Mandible			
Palp	2-segmented;0,8PD	2-segmented;0,7MD+1P	2-segmented;0,7
Maxillule			
Endopod	unsegmented;3S+2P	unsegmented;4S+2P	2-segmented;2,4
Basal endite	15PD+8S	18PD+11S	20-23
Coxal endite	19PD	26P	13-16
Maxilla			
Endopod	4P+1S	0	2S
Basal endite	13PD dis.;12PD prox.	12-14PD dis.;11-12PD prox.	10-11 dis.;8-9 prox.
Coxal endite	6P dis.;14P prox.	27-28P	6 dis.;12-14 prox.
Scaphognathite	54-57P;6S on face	56-58P;6S on face	31-41P;4-5S on face
Maxilliped I			
Endopod	8P+4S	2S	2S
Basal endite	11PD+2S	11PD+6S	11-12
Coxal endite	2PD+2S	11PD+7S	11-13
Exopod	3P;4P	2P;4P	2P;4P
Epipod	8SP+2PD	8PD+9-10A	7
Maxilliped II			
Endopod	2PD;1PD;5PD;10PD	2S+1P;1P;7PD;8PD	0;1;4-5;8
Exopod	1S;5P	1S,5	1;5
Epipod	0	1PD+7A	4
Basis	4PD+1S	5S	1
Maxilliped III			
Endopod	20;13;8;13;8 PD or S	13P+7S;7P+5S;2P+5S; 6P+6S;10PD	14;10;7;9-11;7-8
Exopod	3P+2S;5P	3P+3S;5P	2S;5P
Epipod	21SP+20PD	12PD+33A	8P+14
Basis	5PD	24PD or S	14-19
Pleopod			
Exopod	14-16;17-18;16-17;15;10	20-21;19-20;17-18;16-17; 12-13	14;14;13;11-12;7

A, aesthetascs; dis., distal lobe; MD, multidenticulate; P, plumose; PD, plumodenticulate; prox., proximal lobe; S, simple seta; SP, sparsely plumose.

comparison with those of other known species. The postero-lateral projections of the fifth abdominal somite of *E. sinensis* megalopa are large, but those of other species are small. Particularly, differences among the megalopae of the four *Eriocheir* species were discussed and tabulated by Kim and Hwang (1995). The megalopa of *H. sinensis* can be separated from the other described Varuninae megalopae by the absence of rostrum on carapace, whereas they are curved ventrally in megalopae of other species. Currently, the megalopal descriptions of *Hemigrapsus* are available for *H. penicillatus* (the present study), *H. sanguineus* and *H. sinensis*. Comparison of morphological features separating megalopa of *H. penicillatus* from those of *H. sanguineus* and *H. sinensis* is given in Table 5.

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풀게 *Hemigrapsus penicillatus*(게아목, 바위게과)의 zoea 및 megalopa 유생기

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적 요

풀게의 유생을 수온 25°C, 염분농도 33.3‰, 광주기 14:10 h light:dark의 실험실 조건하에서 사육하였다. 사육 결과 본 종은 5 zoea와 1 megalopa 유생기를 가지며, 부화 후 megalopa와 제1기 crab까지는 최소 18일과 29일이 걸렸다. 전체 유생기의 형태적인 특징을 상세히 기술 및 도시하였다. 풀게 유생과 참게아과 내의 이미 보고된 유생 상호간에 구별될 수 있는 형태적인 특징들에 대하여 토의하였다. 특히, 풀게속의 megalopa 유생 상호간 형태적 특징을 도표화하였다.